# Paradox Valley Unit of the Colorado River Basin Salinity Control Program

# Final Environmental Impact Statement Volume 3 – Appendices E-J

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Western Colorado Area Office**
**Interior Region 7: Upper Colorado Basin**
**Grand Junction, Colorado**

**December 2020**

# MISSION STATEMENTS

The mission of the Department of the Interior is to protect and manage the nation's natural resources and cultural heritage; provide scientific and other information about those resources; and honor its trust responsibilities or special commitments to American Indians, Alaska natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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# Appendix E

## Final Air Quality Technical Report

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# PARADOX VALLEY UNIT ENVIRONMENTAL IMPACT STATEMENT: AIR QUALITY TECHNICAL REPORT – FINAL

## August 2019

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# ENVIRONMENTAL IMPACT STATEMENT:
# AIR QUALITY TECHNICAL REPORT – FINAL

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# LIST OF ACRONYMS

| | |
|---|---|
| BIF | Brine Injection Facility |
| BLM | Bureau of Land Management |
| BSFC | brake specific fuel consumption |
| $CaCO_3$ | calcium carbonate |
| CAT | Caterpillar |
| CDOT | Colorado Department of Transportation |
| CDPHE | Colorado Department of Public Health and Environment |
| $CH_4$ | Methane |
| CWA | Clean Water Act |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalents |
| EPA | U.S. Environmental Protection Agency |
| FLPMA | Federal Land Policy and Management Act of 1976, as amended |
| GCWR | gross combined weight rating |
| GHG | greenhouse gas |
| GVW | gross vehicle weight |
| GWP | Global Warming Potential |
| Gpm | gallons per minute |
| $H_2S$ | Hydrogen sulfide |
| HDPE | high-density polyethylene |
| hp | horsepower |
| MOVES | Motor Vehicle Emissions Simulator |
| MERPS | Modeled Emission Rates for Precursors |
| mg/L | milligrams per liter |
| $N_2O$ | nitrous oxide |
| NAAQS | National Ambient Air Quality Standards |
| NEPA | National Environmental Policy Act |
| NOx | nitrogen oxides |
| O&M | operations and maintenance |
| PM | particulate matter |
| $PM_{10}$ | particulate matter less than 10 microns |
| $PM_{2.5}$ | particulate matter less than 2.5 microns |
| PSD | Prevention of Significant Deterioration |

| | |
|---|---|
| PVU | Paradox Valley Unit |
| Reclamation | U.S. Bureau of Reclamation |
| ROW | right of way |
| $SO_2$ | sulfur dioxide |
| STF | Surface Treatment Facility |
| TDS | total dissolved solids |
| TSP | total suspended particulates |
| tpy | (short) tons per year |
| ULSD | ultra-low sulfur diesel |
| UST | underground storage tank |
| VMT | vehicle miles travelled |
| VOC | volatile organic compounds |

# 1.0 INTRODUCTION

## 1.1 Overview

The United States Bureau of Reclamation (Reclamation) currently operates the Paradox Valley Unit (PVU) in southwestern Colorado near Bedrock in accordance with Title II of the Colorado River Basin Salinity Control Act. Operating since 1996, the PVU disposes of naturally occurring brine from the Paradox Valley via deep-well injection. The existing PVU is the largest single contributor to the Colorado River Basin Salinity Control Program, annually controlling approximately 95,000 tons of salt (10% of the Basin's total) that would otherwise enter the Dolores river and, ultimately, the Colorado River. Existing PVU brine control and disposal facilities include:

- a brine production well field (9 wells)
- a surface treatment facility (STF) with a 25,000-gallon underground storage tank (UST)
- a ~5-acre brine injection facility (BIF), including two 25,000-gallon USTs, an injection pump building, fresh water treatment plant, injection well, well annulus monitoring system building, and additional ancillary facilities
- pipelines (3- to 4-inch diameter pipelines connecting each well to the STF and a 3.5-mile, 10-inch diameter brine transfer pipeline connecting the STF to the BIF)
- a headquarters facility, and
- a seismic monitoring system, consisting of 20 stations within a 20-mile radius around the BIF.

The PVU injection well at the BIF may be nearing the end of its useful life. As the injection pressure increases and brine disposal rates are further reduced, a new brine control and disposal facility (proposed action) is needed to continue to enhance and protect the quality of water available in the Colorado River for use in the United States and the Republic of Mexico.

Reclamation, as lead federal agency, is preparing the Paradox Valley Unit Environmental Impact Statement (PVU EIS) pursuant to the National Environmental Policy Act (NEPA) to evaluate alternatives to continue to construct, operate, and maintain facilities for collection and disposal of saline ground water of the Paradox Valley. The Bureau of Land Management (BLM) is a cooperating agency with a connected action, processing Reclamation's right-of-way (ROW) application and potentially an action for withdrawal with transfer of jurisdiction. Four alternatives are analyzed in the PVU EIS:

- Alternative A – No Action
- Alternative B – New Injection Well
- Alternative C – Evaporation Ponds
- Alternative D – Zero-Liquid Discharge Technology

Ramboll and ERO Resources Corporation have been contracted by Reclamation to provide a quantitative basis for identifying and comparing the potential differences among air emissions for the four alternatives and to determine compliance with the Clean Air Act's National Ambient Air Quality Standards (NAAQS) and/or Prevention of Significant Deterioration (PSD) requirements, the Colorado Department of Public Health and Environment (CDPHE) regulations, and other applicable regulations. The results are disclosed in this Air Quality Report, which is organized into four primary sections:

- 1.0 Introduction: Includes summary of the purpose and need for the proposed action, summaries of the No Action Alternative and the three action alternatives, and an overview of the air quality analysis approach, including applicable benchmarks.
- 2.0 Sources of Air Emissions and Emission Calculation Methods: Includes descriptions of sources by type and associated activity levels applicable to each alternative, and descriptions of calculation methods for each source type, sources of emission factors, and models/data used.
- 3.0 Results: Includes summary tables of emissions by source type (and totals) for each alternative and comparisons to applicable benchmarks, also includes detailed tables in an appendix. Potential effects on ambient air quality are discussed.
- 4.0 References: Includes all documents and sources cited in the analysis

## 1.2 Project Description and Alternatives

Reclamation's proposed action is to continue to construct, operate, and maintain facilities for the collection and disposal of saline groundwater of Paradox Valley to comply with Title II, Section 202(a)(1), of the Colorado River Basin Salinity Control Act and the U.S. Environmental Protection Agency's (EPA) numeric standards in accordance with the Clean Water Act (CWA). The need for the proposed action is to control salinity in the Colorado River contributed by upstream water from the Dolores River within the Paradox Valley.

Reclamation has submitted a ROW application for the Proposed Action (COC-78766) to the BLM pursuant to Title V of the Federal Land Policy and Management Act of 1976, as amended (FLPMA), and implementing regulations (43 CFR 2800). This ROW application considers the need for Reclamation to replace the existing PVU injection well. Reclamation may also file a petition/application with the BLM for a withdrawal of lands. If the petition/application is filed, the BLM would process the petition/application in accordance with the FLPMA (Section 204) and according to the provisions in 43 CFR 2300. The purpose of the BLM's action is to respond to Reclamation's application for a ROW or withdrawal to construct, operate, maintain, and decommission a salinity control facility on public lands. The need for this action is to fulfill BLM's responsibility under the FLPMA and BLM ROW regulations to manage the public lands for multiple uses (43 CFR 2801).

The four PVU EIS alternatives (No Action and three action alternatives) are summarized in the following sections. The location of facilities under each alternative are shown on Figure 1; more detailed location figures are provided in the PVU EIS and referenced below.

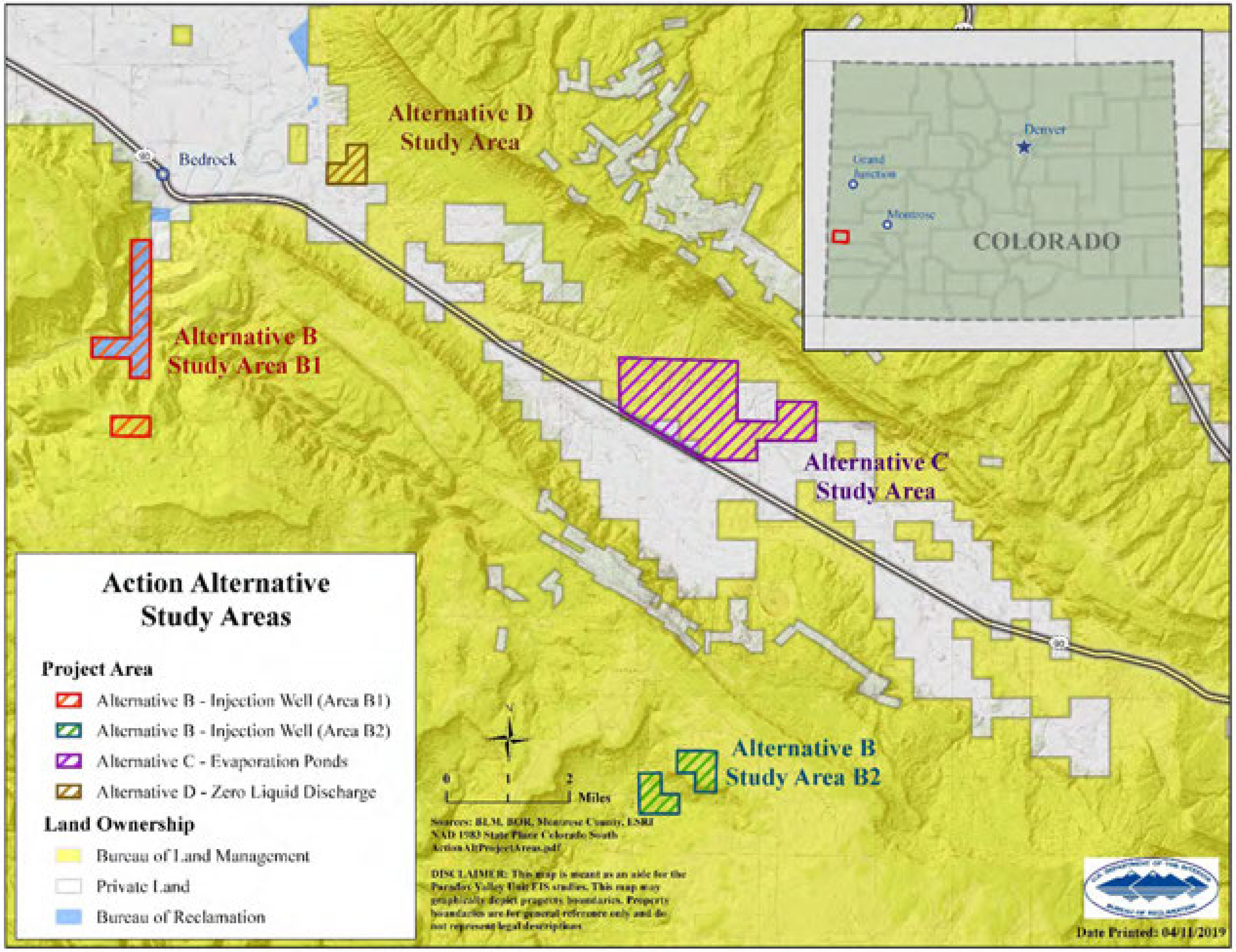



**Figure 1. Project Location Map and Action Alternative Study Areas (source: Reclamation)**

### 1.2.1 Alternative A (No Action)

Under Alternative A (no action), the existing deep injection well would not be replaced. Brine injection would continue until the well becomes inoperable or uneconomical to operate. For purposes of this analysis, it is assumed that economical operation of the existing injection well would no longer be viable after 2026.

After a cessation for 2 years, the injection well would be plugged and abandoned as described in Reclamation's Plugging and Abandonment Plan. In the event Reclamation chooses not to permanently abandon the well at that time, Reclamation would be required to notify the EPA, demonstrate that the well would be used in the future, and describe actions or procedures that would be taken to ensure the well does not endanger underground sources of drinking water during the period of temporary abandonment.

The pipelines and brine production wells would be capped or plugged and abandoned in place. The brine USTs, fresh water treatment plant, well annulus monitoring system, and additional ancillary facilities would be removed and disposed of in an approved location. All injection well equipment would be removed from the buildings. The buildings, foundations, and electrical transformers would remain in place, and the buildings would be assessed for possible future use. Appropriate safety and security measures would be installed, such as fencing across access roads, to prevent trespass on Reclamation property. Reclamation would continue to own land associated with the PVU until a future date when the land would be reevaluated for other uses. Any abandoned facilities on BLM public lands would be reclaimed as per a BLM-approved reclamation plan.

### 1.2.2 Alternative B (New Deep Injection Well)

Under Alternative B, brine would be collected from the existing brine production well field and piped from the STF to a new deep injection well (Figure 1). Brine would be injected into a currently unpressurized block of the Leadville Formation, which should have sufficient permeability and porosity to accept the injected brine at a continuous rate of 200 gallons per minute (gpm), while keeping wellhead pressures below 5,000 pounds per square inch over a 50-year period.

Two areas (B1 and B2) are analyzed in the EIS as potential locations for a new injection well. The final location of the injection well would be determined after additional geologic studies are performed.

Area B1:

- 440-acre study area; 360 acres is Reclamation-owned land and 80 acres is BLM-administered land on Skein Mesa.
- Facilities would include a new injection well, BIF, an access road, bridges, and a buried brine pipeline, and above ground electric distribution lines. Surface facilities would cover ~5 acres and a new road corridor with subsurface pipelines would be constructed on ~11 acres.
- Requires a ROW and/or land withdrawal from BLM.

Area B2:

- 810-acre study area of BLM-administered land on Monogram Mesa
- Facilities would include a new injection well, BIF, and a pipeline with multiple pumping stations to lift the brine from the STF either to the top of Monogram Mesa (Monogram Mesa Well Option) or to Fawn Springs Bench (Fawn Springs Bench Well Option), depending on the findings of additional geologic investigations, and new access roads. The surface facilities would cover ~7 acres and subsurface pipelines and pumping stations would be constructed within ~85 acres.
- Requires a ROW and/or land withdrawal from BLM, an easement from the Colorado Department of Transportation (CDOT), and/or easements on private land.

Alternative B would prevent ~114,000 tons of salt from entering the Dolores River annually, if the brine is continually diverted. Construction of a new deep injection well would take place over an approximate 2- to 3-year period.

Operation and maintenance requirements would be similar to those at the existing well; however, greater automation would be included which would result in less manual operation. At the end of the injection well's useful life, closure of the well would be subject to the provisions of the EPA under the Underground Injection Control Program.

### 1.2.3 Alternative C (Evaporation Ponds)

Under Alternative C, brine would be collected from the existing brine production well field and piped from the STF to a series of evaporation ponds, which would be located ~7 miles southeast of the production well field (Figure 1). Hydrogen sulfide ($H_2S$) treatment would occur at the evaporation pond site to remove $H_2S$ prior to brine discharge into the evaporation ponds. The facility would be operated to evaporate water from the brine, thereby allowing the solid salt to be harvested for disposal in an onsite salt landfill or to be used as a commodity. Additional NEPA analyses would be completed if, in the future, marketing the bittern or other salt produced at the evaporation ponds was determined to be beneficial to consumers.

The Alternative C study area is 1,520 acres on land primarily administered by the BLM, although there is some private land at the perimeter. Facilities would include a brine pipeline, fresh water pipeline, electric line extension, series of evaporation ponds, $H_2S$ treatment system, ~60-acre salt landfill, perimeter wildlife fencing, and access roads, pipelines and ditches connecting the facilities. The total permanent footprint of the evaporation pond facilities would be ~600 acres.

Alternative C would prevent ~171,000 tons of salt from entering the Dolores River annually, if the brine would be continually diverted. Construction of the evaporation pond facilities would take place over an approximate 2- to 5-year period.

Operations would include $H_2S$ treatment, evaporation in a concentrator pond and later in crystallizer ponds (to precipitate sodium chloride from the brine), salt harvest, and salt transfer to the landfill. Brine water would be sprayed on the landfilled salt to form a crust and prevent wind erosion. If necessary, a thin layer of soil would be placed to cover the salt layer. Remaining liquid (bittern) would be transferred from the crystallizer ponds to a bittern pond, where the bittern would continue to concentrate. When the bittern reaches a marketable concentration (about 30 percent magnesium chloride), it would be pumped to the bittern product storage pond. Any remaining bittern solids would be removed to the landfill.

Closure of the evaporation ponds would follow the applicable requirements of the State of Colorado, which could include removing pumping and piping systems, removing the geomembrane liners, site grading to restore the ground to a natural appearance, and reseeding disturbed areas. Closure of the landfill would include constructing an earthen cover system, grading, and establishing surface water management structures to control erosion. All other features of Alternative C would be evaluated for removal, abandonment in place, or other uses by Reclamation.

### 1.2.4 Alternative D (Zero Liquid Discharge Facility)

Under Alternative D, brine would be collected from the existing brine production well field and piped to a centralized treatment plant consisting of a series of thermally driven crystallizers. The facility would be operated to evaporate (and later condense) water from the brine, resulting in a solid salt and freshwater stream. The solid salt would be disposed of in an onsite landfill. Additional NEPA analyses would be completed in the future if marketing the salt produced at the zero-liquid discharge (ZLD) facility was determined to be beneficial to consumers.

The Alternative D study area is 480 acres and is primarily administered by the BLM, although the pipelines may cross private lands and/or be located within county and State road easements (Figure 1). Facilities would include a brine pipeline, freshwater pipelines, access road, ~150,000-square foot ZLD facility building, $H_2S$ treatment system, and a ~60-acre salt landfill. In addition, it would require installation of a buried interconnect and ~14 miles of buried distribution line from the main gas transmission line located in the southeast Paradox Valley to the project area, upgrades to electrical lines and substation protection, and construction of new regulators near the substation. The permanent footprint of the ZLD facility would be ~80 acres.

Alternative D would prevent ~171,000 tons of salt from entering the Dolores River annually, if brine is continually diverted. Construction of the ZLD facilities would take place over an approximate 2- to 3-year period.

The ZLD facility would be designed to accommodate a continual flow of up to 300 gpm of brine (484 acre-feet per year). The conceptual design includes the use of multiple crystallizers operating in parallel that would reduce the brine to a solid product (salt) suitable for landfill disposal. The crystallizers would use natural gas as a heat source to drive the evaporation process, and additional heat may be required in the building to prevent equipment from freezing in winter.

Brine would be pumped from the production wells to the $H_2S$ treatment system, acid would be used to adjust the pH and minimize carbonate scaling, and the brine would be stored in a crystallizer feed tank. From there, brine would be pumped into thermally driven crystallizers. As water evaporated, the brine would become saturated and salts would begin to precipitate out of solution. Salt would be transferred from the drain bins to the landfill over the 50-year life of the project. Brine would be sprayed on the landfilled salt to form a crust and prevent wind erosion. If necessary, a thin layer of soil would be placed to cover the salt layer.

Along with the solid product, the crystallizers would produce ~250 gpm (~80 percent of brine flow rate) of high temperature (~50 degrees Celsius), low to neutral pH (4.5 to 7.5), and low alkalinity (< 20 milligrams per liter [mg/L] as calcium carbonate [$CaCO_3$]) freshwater, with estimated total dissolved solids (TDS) of 500 mg/L. The freshwater stream would be released back into the Dolores River, pending a discharge permit from CDPHE. It may be necessary to adjust the temperature and/or pH before the produced water can be discharged.

### 1.3 Overview of Air Quality Impact Analysis Approach

Annual emissions from construction and operations and maintenance activities under each proposed action alternative were estimated as described in Section 2; results are summarized in Section 3. Emission sources associated with the proposed action are subject to regulation by the U.S. Environmental Protection Agency (EPA) under the federal Clean Air Act and by the Colorado Department of Public Health and Environment (CDPHE). The EPA has set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants – carbon monoxide (CO), particulate matter (including particulate matter smaller than 10 microns [$PM_{10}$] and particulate matter smaller than 2.5 microns [$PM_{2.5}$]), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), ozone ($O_3$), and lead (Pb). Ozone is not directly emitted from sources but is formed via photochemical reactions in the atmosphere from the precursor gases – nitrogen oxides (NOx) and volatile organic compounds (VOCs). Total Suspended Particulates (TSP) could also result from the PVU. These refer to particulate material collected from ambient air by a high volume filter sampler and includes particles up to a nominal size of 25 – 45 µm; TSP is not a NAAQS pollutant but is often used to characterize dust emissions. Particulate matter can be both directly emitted from sources as primary PM and formed via chemical reactions in the atmosphere as a secondary pollutant from gaseous precursors (VOC, $SO_2$, NOx, and ammonia ($NH_3$)). Secondary formation can account for a significant fraction of fine particulate matter ($PM_{2.5}$) but is typically only a small contributor to the total mass concentration of $PM_{10}$.

Air quality in the Paradox Valley area is currently classified by EPA as being in attainment of all criteria pollutants. EPA's New Source Review (NSR) regulations require that new or modified stationary sources located in areas designated as attainment with respect to the NAAQS must comply with the Prevention of Significant Deterioration (PSD) program elements which are designed to limit the degradation of air quality in these relatively "clean" locations. Under the Clean Air Act, certain parks and wilderness areas are designated as Mandatory Class I areas within which more stringent air quality protections apply under the PSD regulations. The closest Class I area to Paradox Valley is Arches National Park which is located approximately 63 km northwest of Bedrock. Canyonlands National Park, also a Class I area, is located approximately 74 km to the west of Bedrock. PSD permits are required for major sources, defined as certain types of stationary sources such as large fossil fuel fired boilers with criteria pollutant emissions in excess of 100 tons per year; the major source threshold for other types of sources is 250 tons/year. EPA's air permitting programs use significant emission rate levels to determine when NSR requirements apply to existing facilities. Significant emission rates (SERs) are used to evaluate whether a proposed project at an existing facility is considered a major modification and therefore requires the facility to obtain permits. EPA's $PM_{2.5}$ NSR rule sets SERs of 10 tons per year (tpy) for directly emitted $PM_{2.5}$, 40 tpy for $SO_2$ and NOx, and 40 tpy for VOCs.

CDPHE regulates $H_2S$ and other hazardous pollutants listed in Colorado Regulation 3, Appendix B which include 1,2-dichloroethane, carbon disulfide, and toluene, among others. The EPA also regulates hazardous air pollutants via limits on emissions from certain types of sources and via permitting requirements for larger sources.

Authority for permitting sources as required under the Clean Air Act has been delegated by EPA to the CDPHE. CDPHE has set emission thresholds as shown in Table 1-1 for (a) the requirement to obtain an Air Pollutant Emissions Notice (APEN) and (b) the requirement to obtain an operating permit. Sources with emissions exceeding the APEN threshold must report emissions via an APEN; sources exceeding the permitting threshold must also obtain an air quality permit. Sources with emissions exceeding CDPHE's permitting threshold but below EPA's major source thresholds must obtain a minor source permit; larger sources must obtain a major source permit. Note that construction emissions are not subject to CDPHE air permitting requirements but "land development" projects that include clearing a land area "greater than or equal to 25 contiguous acres and/or 6 months in duration" typically require an APEN including a fugitive dust control program unless estimated emissions do not exceed those listed in Table 1-1. Mobile tailpipe exhaust emissions are not included in the emissions used for comparison.

**Table 1-1. CDPHE Emission Thresholds for Permitting**

| Pollutant | APEN (tons/year) | Minor Source Permit (tons/year) |
|---|---|---|
| CO | 2 | 10 |
| $PM_{10}$ | 2 | 5 |
| $PM_{2.5}$ | 2 | 5 |
| TSP | 2 | 10 |
| $NO_x$ | 2 | 10 |
| VOC | 2 | 5 |
| SOx | 2 | 10 |
| Other Criteria Pollutants (includes $H_2S$) | 2 | 2 |
| Hazardous Air Pollutants[a] | 250 lb/year | -- |

[a]As listed in Regulation 3, Appendix B

CDPHE's modeling guidelines[1] include emission thresholds intended to alleviate the need to perform air dispersion modeling analyses for smaller sources that are unlikely to result in downwind concentrations that exceed applicable ambient standards (Table 1-2). For NOx, $SO_2$, and $PM_{2.5}$, separate long-term and short-term thresholds are defined to protect against possible exceedances of short-term standards as compared to long-term ambient standards.

[1] https://www.colorado.gov/airquality/permits/guide.pdf

**Table 1-2. CDPHE Modeling Guideline for Air Quality Permit modeling emission thresholds.**

| Pollutant | Modeling Threshold (tons/year) | |
|---|---|---|
| | **Long Term (tons/year)** | **Short Term (equivalent annual rate)** |
| CO | 100.7[a] (23 lb/hour) | 23 lb/hour (100.7 tpy [a]) |
| $NO_x$ | 40 | 0.46 lb/hour (2.01 tpy [a]) |
| $SO_2$ | 40 | 0.46 lb/hour (2.01 tpy [a]) |
| $PM_{10}$ | 14.97 [a] (82 lb/day) | 82 lb/day (359.2 tpy [a]) |
| $PM_{2.5}$ | 5 | 11 lb/day (48.2 tpy [a]) |
| Pb | 0.05 [a] (25 lb per 3 months) | 25 lb per 3 months (0.050 tpy [a]) |

[a]Equivalent annual emissions based on continuous release at specified short-term rate.

# 2.0 AIR EMISSION SOURCES AND EMISSION CALCULATION METHODS

## 2.1 Emissions Sources and Species

Construction and operation of Alternatives B, C, or D as well as the decommissioning activities under the No Action Alternative (Alternative A) described in Section 1.2 involve the use of off-road construction equipment and on-road vehicles. Sources of emissions included in this analysis include tailpipe emissions from all vehicles and equipment, tire wear and brake dust from on-road vehicles, re-entrained road dust from on-road vehicles traveling on dirt roads, and fugitive dust from off-road vehicles and equipment travel. Also included are fugitive dust emissions from earth moving activities and windblown dust from disturbed surfaces. Operation of the evaporation ponds which would be constructed under Alternative C would result in the release via evaporation of small amounts of volatile compounds contained in the brine, including carbon disulfide, toluene, and 1,2-dichloroethane. Operation of the Zero Liquid Discharge facility under Alternative D would involve natural gas combustion in the thermally driven crystallizers. Propane would be used for space heating and domestic hot water in the Brine Injection Facility building under Alternatives B1 or B2 or the $H_2S$ building under Alternative C.

Emission estimates were prepared for criteria pollutants (CO, VOC, NOx, $PM_{10}$, $PM_{2.5}$, $SO_2$) and greenhouse gases ($CO_2$, $CH_4$, $N_2O$). The varying radiative forcing of the different greenhouse gases (GHGs) at a 100-year timescale are accounted for by also reporting GHGs on a $CO_2$-equivalent ($CO_2e$) basis based on widely accepted global warming potentials (GWPs) of 25 for $CH_4$ and 298 for $N_2O$ (IPCC, 2014). Emissions of lead (Pb) from sources associated with the proposed action alternatives are negligible due to the use of unleaded fuels and are not quantified.

Emission calculation methods are described in Section 2.2. Hydrogen sulfide ($H_2S$) emissions associated with brine treatment and disposal are described in Section 3.3.1.

## 2.2 Emission Calculation Methods

Emission calculation methods are briefly summarized in this section. Detailed compilations of emission factors, activity levels, and resulting emissions are provided in the Appendix and associated EXCEL spreadsheets. In general, wherever data was unavailable or limited, assumptions were made that were typically conservative, i.e., protective of the environment.

On-road vehicle exhaust, tire, and brake wear emissions were calculated by combining vehicle type, vehicle miles travelled (VMT), and average speeds provided by Reclamation with emission factors in grams per mile obtained from EPA's Motor Vehicle Emission Simulator (MOVES2014b)[2].

Off-road equipment emissions were calculated consistent with MOVES2014b methodology based on standard reference emission rates and project equipment activity and rated power estimates. The emissions were estimated using equipment type – which in most cases included specific model numbers – and estimated hours of use provided by Reclamation. All equipment types provided by Reclamation were diesel powered. Engine horsepower ratings were obtained by

[2] https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

referencing equipment model numbers in the manufacturer's literature. Engine emission control tier levels were specified by Reclamation for most pieces of equipment and was conservatively set to Tier 2 in those few cases where it was not available. MOVES2014b default load factors were used in all cases and MOVES2014b transient adjustment factors were applied to all engines below Tier 4. Emission factors for NOx, CO, VOC, $PM_{10}$ and $PM_{2.5}$ were set to the appropriate engine tier standards based on rated horsepower. $SO_2$ emission factors were obtained from MOVES-NONROAD equation, each engine's brake-specific fuel consumption (BSFC) and 15 ppm ultra-low sulfur diesel (ULSD) fuel content. Emission factors of two of the GHGs ($CO_2$ and $CH_4$) were based on MOVES2014b values; emission factors for the third GHG ($N_2O$) were based on values used in EPA's national GHG emission inventory (EPA, 2018; Annex Part 3A, Table A-112).

Re-entrained road dust emissions from travel on paved roads was based on EPA's *AP-42:Compilation of Air Emissions Factors* (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors), Sec. 13.2.1 Equation 2. Vehicle class and average speeds were obtained from information provided by Reclamation. Precipitation data were obtained from the Western Regional Climate Center (https://wrcc.dri.edu/summary/Climsmco.html). Silt loading was based on the Ubiquitous Baseline value presented in AP-42, Table 13.2.1-2.

Re-entrained road dust emissions from travel on unpaved industrial (i.e., non-public use) roads was based on AP-42, Sec. 13.2.2. Vehicle class and average speeds were obtained from information provided by Reclamation and precipitation data from the Western Regional Climate Center (https://wrcc.dri.edu/summary/Climsmco.html). A representative silt loading factor of 8.2% (Amec Foster Wheeler, 2017) was used along with a representative surface moisture content from the 2014 National Emission Inventory Supporting Documentation for unpaved roads.[3] A 50% default control efficiency factor for watering was assumed (Countess Environmental, 2006).

Fugitive dust emissions from earthmoving operations were calculated using emission factors based on cubic yards of earth disturbed from Table 3-2 of the Western Regional Air Partnership (WRAP) Fugitive Dust Handbook (Countess Environmental, 2006). A default 50% control efficiency for watering was assumed for the dust emissions (Countess Environmental, 2006).

Windblown dust emissions from disturbed surfaces were estimated based on AP-42 Sec. 11.9, Table 11.9-4 emission factor for wind erosion of exposed areas (0.38 tons TSP per acre-year). TSP emissions from both windblown and fugitive dust from earthmoving activities were assumed to consist of 50% $PM_{10}$[4] of which 10% is $PM_{2.5}$ (Amec Foster Wheeler, 2017).

[3] ftp://newftp.epa.gov/air/nei/2014/doc/2014v2_supportingdata/nonpoint/Unpaved%20Roads%20for%202014v2.zip

[4] https://www3.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf

# 3.0 RESULTS

## 3.1 Overview

Summaries of annual emissions from construction and operational phases of each of the proposed action alternatives are presented in this section. Construction emissions are reported assuming all construction activities will occur within a single year even though some of the inventoried activities are projected to extend beyond a 12-month period. Thus, actual annual construction emissions may be lower than the annual totals reported here in some cases. Operation and maintenance emissions represent annual operation and maintenance activities which are expected to remain constant over the life of the project.

Criteria pollutant (NOx, $SO_2$, CO, VOC, $PM_{10}$, $PM_{2.5}$) emissions are reported in U.S. (short) tons: 1 ton equals 2,000 lb or 0.9072 metric tonnes. GHG emissions are reported as $CO_2e$ emissions in short tons/year. All GHG emissions from the proposed action are from internal combustion engines and include $CO_2$, $CH_4$, and $N_2O$, with $CO_2$ being the dominant contributor (~99%). Detailed tables of emissions of each pollutant – including the three GHG pollutants – under each alternative by equipment type are presented in the Appendix.

Total emissions for the construction and operation and maintenance (O&M) under each alternative are summarized in Table 3-1. Mobile sources include on-road and off-road vehicles and portable equipment (including drill rigs). Dust emissions include re-entrained road dust from travel on paved and unpaved roads, dust from earthmoving operations, and windblown dust from disturbed surfaces. More detailed breakdowns of construction emissions for each alternative are provided in Section 3.2 below. More detailed breakdowns of O&M emissions are presented in Section 3.3. On-road and fugitive dust emissions from existing vehicle use through 2026 are presented under O&M emissions in the No Action Alternative (Alternative A).

**Table 3-1. Emissions (Tons/Year) for Each Alternative.**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$[c] |
|---|---|---|---|---|---|---|---|
| **Alternative A** | | | | | | | |
| Construction: Mobile Sources[a] | 3.01 | 0.006 | 1.85 | 0.17 | 0.10 | 0.10 | 381.61 |
| Construction: Fugitive Dust[b] | -- | -- | -- | -- | 1.21 | 0.15 | -- |
| Windblown Dust | -- | -- | -- | -- | -- | -- | -- |
| O&M: Mobile Sources | 0.04 | 0.0002 | 0.07 | 0.005 | 0.003 | 0.002 | 24.96 |
| O&M: Fugitive Dust | -- | -- | -- | -- | 2.98 | 0.32 | -- |
| O&M: Stationary Sources | -- | -- | -- | -- | -- | -- | -- |
| **Alternative B1** | | | | | | | |
| Construction: Mobile Sources | 69.59 | 0.1492 | 41.31 | 3.97 | 2.37 | 2.28 | 8,626.51 |
| Construction: Fugitive Dust[a] | -- | -- | -- | -- | 26.90 | 2.84 | -- |
| Windblown Dust | -- | -- | -- | -- | 1.62 | 0.162 | -- |
| O&M: Mobile Sources | 0.02 | 0.0001 | 0.03 | 0.002 | 0.001 | 0.001 | 14.4 |
| O&M: Fugitive Dust | -- | -- | -- | -- | 1.30 | 0.14 | -- |
| O&M: Stationary Sources | 0.01 | 0.00003 | 0.01 | 0.001 | 0.001 | 0.001 | 12.8 |
| **Alternative B2** | | | | | | | |
| Construction: Mobile Sources | 69.95 | 0.1495 | 41.47 | 3.97 | 2.37 | 2.29 | 8,664.2 |
| Construction: Fugitive Dust[a] | -- | -- | -- | -- | 13.78 | 1.55 | -- |
| Windblown Dust | -- | -- | -- | -- | 8.46 | 0.846 | -- |
| O&M: Mobile Sources | 0.07 | 0.0004 | 0.12 | 0.01 | 0.004 | 0.002 | 48.5 |

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$[c] |
|---|---|---|---|---|---|---|---|
| O&M: Fugitive Dust | -- | -- | -- | -- | 2.88 | 0.33 | -- |
| O&M: Stationary Sources | 0.02 | 0.00003 | 0.009 | 0.001 | 0.001 | 0.001 | 16.0 |
| **Alternative C** | | | | | | | |
| Construction: Mobile Sources | 53.07 | 0.078 | 68.32 | 3.56 | 3.45 | 3.33 | 8,636.0 |
| Construction: Fugitive Dust[a] | -- | -- | -- | -- | 78.77 | 8.64 | -- |
| Windblown Dust | -- | -- | -- | -- | 59.38 | 5.938 | -- |
| O&M: Mobile Sources | 3.85 | 0.0044 | 4.68 | 0.301 | 0.22 | 0.21 | 487.2 |
| O&M: Fugitive Dust | -- | -- | -- | -- | 10.82 | 1.32 | -- |
| O&M: Stationary Sources | 0.05 | 0.0001 | 0.03 | 0.003 | 0.003 | 0.003 | 51.1 |
| **Alternative D** | | | | | | | |
| Construction: Mobile Sources | 5.45 | 0.0072 | 6.60 | 0.36 | 0.34 | 0.32 | 797.4 |
| Construction: Fugitive Dust[a] | -- | -- | -- | -- | 15.85 | 1.60 | -- |
| Windblown Dust | -- | -- | -- | -- | 11.02 | 1.102 | -- |
| O&M: Mobile Sources | 1.25 | 0.0010 | 2.35 | 0.197 | 0.09 | 0.09 | 117.1 |
| O&M: Fugitive Dust | -- | -- | -- | -- | 1.32 | 0.35 | -- |
| O&M: Stationary Sources | 21.00 | 0.1260 | 17.64 | 1.155 | 1.60 | 1.60 | 25,349.8 |

[a]Exhaust, tire, and brake wear.

[b]Fugitive dust (re-entrained road dust and dust from earthmoving operations)

[c]Based on 100-year GWPs (25 for $CH_4$ and 298 for $N_2O$) from the IPCC Fourth Assessment Report (IPCC, 2007) as used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017* (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017).

A detailed breakdown of construction emissions for each alternative is provided in Section 3.2 below. Detailed breakdowns of O&M emissions are presented in Section 3.3.

## 3.2 Construction Emissions

### 3.2.1 Alternative A (No Action)

Emissions from the well shut-in and abandonment activities which would occur under Alternative A are provided in Table 3-2. Note that well shut-in and abandonment would also likely occur under Alternative B at the end of the useful life of the new injection well but emissions from this activity are minor relative to construction and operation and maintenance activities.

**Table 3-2. a) Mobile Source Emissions from Construction Activities under Alternative A (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| Existing Injection Well Closure | 2.72 | 0.0059 | 1.57 | 0.153 | 0.090 | 0.087 | 335.2 |
| Injection Facility Closure | 0.12 | 0.0002 | 0.12 | 0.007 | 0.005 | 0.005 | 21.9 |
| Surface Treatment Facility Closure – STF | 0.04 | 0.0001 | 0.04 | 0.003 | 0.002 | 0.001 | 7.5 |
| Surface Treatment Facility Closure - Production Wells | 0.13 | 0.0002 | 0.13 | 0.008 | 0.006 | 0.006 | 17.1 |
| TOTAL: | 3.01 | 0.0063 | 1.85 | 0.171 | 0.103 | 0.099 | 381.6 |

**Table 3-2. b) Dust Emissions from Construction Activities under Alternative A (tons/year)**

| Phase | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Re-Entrained Road Dust | 0.90 | 0.18 | 0.04 |
| Earthmoving | 2.1 | 1.0 | 0.1 |

### 3.2.2 Alternative B1 (New Deep Injection Well in Area B1)

Emissions for construction activities which would occur under Alternative B1 are provided in Table 3-3.

**Table 3-3. a) Mobile Source Emissions from Construction Activities under Alternative B1 (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| Injection Facility | 0.50 | 0.0005 | 0.58 | 0.031 | 0.028 | 0.028 | 60.0 |
| Ancillary Facility - Site Prep and Access | 1.02 | 0.0010 | 1.59 | 0.113 | 0.071 | 0.068 | 116.4 |
| Ancillary Facility - Pipeline | 0.16 | 0.0002 | 0.19 | 0.011 | 0.009 | 0.009 | 19.0 |
| Injection Well | 67.90 | 0.1474 | 38.95 | 3.818 | 2.263 | 2.173 | 8,431.2 |
| TOTAL: | 69.59 | 0.1492 | 41.31 | 3.974 | 2.371 | 2.277 | 8,626.5 |

**Table 3-3. b) Dust Emissions from Construction Activities under Alternative B1 (tons/year)**

| Phase | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Re-Entrained Road Dust | 85.13 | 23.95 | 2.55 |
| Earthmoving | 5.9 | 3.0 | 0.30 |
| Windblown Dust | 3.23 | 1.62 | 0.16 |

### 3.2.3 Alternative B2 (New Deep Injection Well in Area B2)

Emissions for construction activities which would occur under Alternative B2 are provided in Table 3-4. While mobile source emissions are generally comparable with Alternative B1, much more windblown dust is generated in Alternative B2 because more surface area is disturbed (89 acres versus 17).

**Table 3-4. a) Mobile Source Emissions from Construction Activities under Alternative B2 (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| Injection Facility | 0.50 | 0.0005 | 0.58 | 0.031 | 0.03 | 0.03 | 59.94 |
| Ancillary Facility - Site Prep and Access | 0.29 | 0.0003 | 0.42 | 0.030 | 0.02 | 0.02 | 32.37 |
| Ancillary Facility - Pipeline | 1.29 | 0.0014 | 1.53 | 0.090 | 0.07 | 0.07 | 151.85 |
| Injection Well | 67.87 | 0.1473 | 38.93 | 3.815 | 2.25 | 2.17 | 8,420.06 |
| TOTAL: | 69.95 | 0.1495 | 41.47 | 3.966 | 2.37 | 2.29 | 8,664.22 |

**Table 3-4. b) Dust Emissions from Construction Activities under Alternative B2 (tons/year)**

| Phase | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Re-Entrained Road Dust | 40.88 | 11.28 | 1.30 |
| Earthmoving | 5.0 | 2.5 | 0.3 |
| Windblown Dust | 16.9 | 8.5 | 0.8 |

### 3.2.4 Alternative C (Evaporation Ponds)

Emissions for construction activities which would occur under Alternative C are provided in Table 3-5. Fugitive dust emissions are the highest in Alternative C across all alternatives due to the large area disturbed.

**Table 3-5. a) Mobile Source Emissions from Construction Activities under Alternative C (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| Evaporation Pond Complex | 47.88 | 0.0710 | 62.00 | 3.21 | 3.14 | 3.03 | 7,880.23 |
| $H_2S$ Building | 0.43 | 0.0005 | 0.53 | 0.03 | 0.03 | 0.03 | 52.85 |
| Landfill | 4.11 | 0.0057 | 5.02 | 0.27 | 0.25 | 0.24 | 627.05 |
| Pipeline | 0.65 | 0.0007 | 0.77 | 0.04 | 0.04 | 0.04 | 75.92 |
| TOTAL: | 53.07 | 0.0778 | 68.32 | 3.56 | 3.45 | 3.33 | 8,636.05 |

**Table 3-5. b) Dust Emissions from Construction Activities under Alternative C (tons/year)**

| Phase | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Re-Entrained Road Dust | 72.21 | 18.29 | 2.59 |
| Earthmoving | 121.0 | 60.5 | 6.0 |
| Windblown Dust | 118.8 | 59.4 | 5.94 |

### 3.2.5 Alternative D (Zero Liquid Discharge Facility)

Emissions for construction activities which would occur under Alternative D are provided in Table 3-6.

**Table 3-6. a) Mobile Source Emissions from Construction Activities under Alternative D (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| ZLD Building | 1.09 | 0.0012 | 1.32 | 0.072 | 0.072 | 0.069 | 129.8 |
| ZLD Tech Trucks | 0.04 | 0.0001 | 0.009 | 0.002 | 0.002 | 0.001 | 15.6 |
| Landfill | 4.16 | 0.0057 | 5.09 | 0.277 | 0.254 | 0.245 | 633.1 |
| Pipeline | 0.16 | 0.0002 | 0.19 | 0.011 | 0.009 | 0.009 | 19.0 |
| TOTAL: | 5.45 | 0.01 | 6.60 | 0.36 | 0.34 | 0.32 | 797.4 |

**Table 3-6. b) Dust Emissions from Construction Activities under Alternative D (tons/year)**

| Phase | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Re-Entrained Road Dust | 4.0 | 1.1 | 0.12 |
| Earthmoving | 29.5 | 14.8 | 1.48 |
| Windblown Dust | 22.0 | 11.0 | 1.1 |

### 3.3 Operation and Maintenance Emissions

Onroad and entrained fugitive dust emissions due to use of existing vehicles (four pickup trucks) at the PVU are calculated and reported for operation and maintenance emissions in the No Action Alternative (Alternative A). These emissions would occur through 2026. The main onroad pollutant emissions are NOx (0.039 tpy), CO (0.074 tpy), and CO2 (24.923 tpy). Re-entrained vehicle fugitive dust results in 2.98 tpy of PM10 and 0.32 tpy of PM2.5. Additional information is provided in Table 3-1 and the emissions inventory spreadsheets attached with this report.

Operation and maintenance emissions under each action alternative are summarized in Table 3-7 to Table 3-11 below. Note that there are no O&M activities under Alternative A. Details of the emissions sources are provided in the enclosed EXCEL spreadsheets. Criteria air pollutant and GHG emissions are highest in Alternative D (except for fugitive $PM_{10}$ dust that is highest in Alternative C) and are driven by the natural gas combustion to meet energy needs of the zero-liquid discharge technology option. Potential emissions of hazardous air pollutants from the evaporation ponds in Alternative C are shown in Table 3-10.[5] These were estimated using the methodology and analyte concentration data of Amec Foster Wheeler (2017). The flowrate is assumed to be 300 gpm.

The ZLD technologies process in Alternative D also has the potential to release a similar amount of HAP and VOC emissions from the brine as identified in Alternative C. Further analysis should be conducted during future pilot testing of these systems to define the quantity and location of these emissions.

**Table 3-7. O&M Emissions under Alternative B1 (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| B1 – Injection Well | 0.02 | 0.0001 | 0.03 | 0.002 | 0.001 | 0.001 | 14.4 |
| Energy Consumption | 0.013 | 0.00003 | 0.008 | 0.001 | 0.0007 | 0.0007 | 12.77 |
| Fugitive Dust | -- | -- | -- | -- | 1.30 | 0.14 | -- |
| Total: | 0.04 | 0.00 | 0.04 | 0.00 | 1.30 | 0.14 | 30.37 |

[5] Evaporation ponds would only be used under Alternative C; thus, these emissions only apply to this alternative.

### Table 3-8. O&M Emissions under Alternative B2 (tons/year)

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| B2 – Injection Well | 0.07 | 0.0004 | 0.12 | 0.007 | 0.004 | 0.002 | 48.5 |
| Energy Consumption | 0.016 | 0.00003 | 0.001 | 0.001 | 0.001 | 0.001 | 15.97 |
| Fugitive Dust | -- | -- | -- | -- | 2.88 | 0.33 | -- |
| Total: | 0.08 | 0.00 | 0.13 | 0.01 | 2.88 | 0.33 | 64.50 |

### Table 3-9. O&M Emissions under Alternative C (tons/year)

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| Evaporation Pond Complex | 0.24 | 0.0003 | 0.22 | 0.02 | 0.01 | 0.01 | 41.0 |
| Salt Harvest | 3.14 | 0.0037 | 3.57 | 0.21 | 0.17 | 0.17 | 408.9 |
| Landfill | 0.47 | 0.0003 | 0.89 | 0.07 | 0.03 | 0.03 | 37.1 |
| $H_2S$ Building | 0.0003 | 0.000001 | 0.0001 | 0.00003 | 0.00002 | 0.00001 | 0.2 |
| Energy Consumption | 0.052 | 0.0001 | 0.03 | 0.003 | 0.003 | 0.003 | 51.09 |
| Fugitive Dust | -- | -- | -- | -- | 10.82 | 1.32 | -- |
| Total: | 3.90 | 0.00 | 4.71 | 0.30 | 11.04 | 1.53 | 538.30 |

### Table 3-10. Hazardous Air Pollutant Water Concentrations and Air Emissions due to Evaporation under Alternative C (source: Amec Foster Wheeler (2017))

| Analyte | Average concentration (µg/L) | Maximum concentration (µg/L) | Average Emissions (lb/yr) | Maximum Emissions (lb/yr) |
|---|---|---|---|---|
| a,a,a-Trifluorotoluene | 29.8 | 32 | 39.21 | 42.11 |
| Acetone [1] | 8.15 | 10 | 10.72 | 13.16 |
| 2- Butanone (MEK) | 5.66 | 6 | 7.45 | 7.9 |
| Carbon disulfide | 1.19 | 2 | 1.57 | 2.63 |
| 1,2-Dichloroethane-d4 (Surr) | 16.2 | 17 | 21.32 | 22.37 |
| Toluene-d8 (Surr) | 9.38 | 9.8 | 12.34 | 12.9 |
| 4-Bromofluorobenzene (Surr) | 9.51 | 9.7 | 12.51 | 12.76 |
| Dibromofluoromethane (Surr) | 12.9 | 13 | 16.98 | 17.11 |
| Total: | -- | -- | 122.1 | 130.9 |

* These emissions are unique to Alternative C because they represent the volatilization of HAPs from the evaporation ponds.

**Table 3-11. O&M Emissions under Alternative D (tons/year)**

| Phase | NOx | $SO_2$ | CO | VOC | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| ZLD Facility O&M | 0.02 | 0.0001 | 0.03 | 0.002 | 0.001 | 0.001 | 13.4 |
| Salt Hauling | 0.01 | 0.0001 | 0.01 | 0.001 | 0.001 | 0.001 | 7.1 |
| Landfill | 1.22 | 0.0009 | 2.31 | 0.193 | 0.088 | 0.085 | 96.6 |
| Energy Consumption | 21.00 | 0.13 | 17.64 | 1.16 | 1.60 | 1.60 | 25,349.8 |
| Fugitive Dust | -- | -- | -- | -- | 1.32 | 0.35 | -- |
| Total: | 22.25 | 0.13 | 19.99 | 1.35 | 3.00 | 2.03 | 25,466.8 |

### 3.3.1 Hydrogen Sulfide ($H_2S$) Emissions and Odor

Significant amounts of $H_2S$ are present as a naturally occurring dissolved gas in the produced brine. Emissions of $H_2S$ to the atmosphere may occur at the Surface Treatment Facility or at the Brine Injection Facility. Reclamation has conducted prior analyses over the years to identify the $H_2S$ releases. Upon review of these analyses, and considering updated operating procedures, Reclamation has concluded that additional evaluations need to be performed to adequately identify the releases (F. Busch, Reclamation, personal communication, May 22, 2019). Therefore, for the purposes of this EIS, it is assumed that all facilities will be designed and operated such that $H_2S$ releases will always stay below the CDPHE Permit level of 2 tons per year. Reclamation's theoretical evaluation of possible chemical processes show that maintaining emissions below 2 tons/year is reasonably possible to accomplish based on existing bench tests performed to date (*ibid*).

Potential $H_2S$ releases under each of the proposed action Alternatives B, C, and D are assumed to be evenly split between the STF vent stack and the proposed project site and thus a maximum of 1 ton per year at each location. Note that the existing STF facility is not part of the proposed action analyzed in this EIS. After implementation of an action alternative, if the emissions are greater than 1 ton/year of hydrogen sulfide at either the STF or at the project site, an adaptive management strategy will be implemented to reduce the emissions. This could include things such as altering the treatment technique; closing the raw brine systems with items such as floating tank roofs, tank vent weights, filling the head-space with a noble gas, mechanical systems such as hydrogen sulfide scrubbers, or other measures.

The aforementioned limits on $H_2S$ emissions, and additional mitigation measures to be implemented if required, are expected to minimize or avoid any odor issues due to the Project.

## 3.4 Summary of Emissions and Air Quality Impacts

### 3.4.1 Construction and/or Closure Impacts

#### 3.4.1.1 Alternative A (No Action)

In Alternative A, there would be a small and temporary effect on air quality (primarily on dust and $NO_2$ air concentrations) over a period of approximately a month due to emissions exhaust emissions of NOx, VOCs, $SO_2$, $PM_{2.5}$, and $PM_{10}$ as well as dust emissions of $PM_{2.5}$ and $PM_{10}$ from re-entrained road dust and earthmoving from the on-road and off-road vehicles and portable equipment used for plugging and abandoning of the existing injection well, and closure of the injection facility and surface treatment facility. Note that some of these emissions would also occur under the action alternatives because the existing well would have to be plugged and abandoned, albeit at a potentially different time. The No Action Alternative construction emissions are comparable to or up to ten times lower than the action alternative emissions depending on the alternative.

Greenhouse gas emissions of $CO_2$, $CH_4$ and $N_2O$ would be released during closure in the No Action Alternative but are very small (over an order of magnitude smaller than the action alternatives).

#### 3.4.1.2 Alternatives B1 and B2

Construction activities in Alternatives B1 and B2 would result in on-road and off-road engine exhaust emissions of NOx, VOCs, $SO_2$, $PM_{2.5}$, and $PM_{10}$ as well as dust emissions of $PM_{2.5}$ and $PM_{10}$ from re-entrained road dust, earthmoving and wind erosion. These releases would affect air quality temporarily during the construction period by impacting concentrations of $NO_2$, $SO_2$, ozone, $PM_{2.5}$ and $PM_{10}$. Construction emissions (except for particulate emissions that peak in Alternative C) are highest in Alternative B2 across all action alternatives. Emissions and air quality impacts would also occur during the closure activities in all action alternatives at end of useful life (for example, the plugging and abandonment of the well in Alternative B) but these impacts would likely be small relative to the operation and maintenance activities.

Greenhouse gas emissions of $CO_2$, $CH_4$ and $N_2O$ would be released during construction in Alternatives B1 and B2. Emissions of GHGs during construction are approximately ten times higher than in Alternative D and approximately twenty times higher than in Alternative A, primarily because of the vehicles and equipment used in the construction of the new injection well in Alternatives B1 and B2. Emissions of $CO_2$ constitute most of the GHG emissions. Alternative B2 has the maximum annual GHG emissions released in construction under any alternative (8,664 tons/year $CO_2e$); these emissions represent a very small fraction (approximately 0.006%) of the total projected GHG emissions of 147.7 million tons/year in Colorado in 2020 (Arnold et al., 2014). As in the case of criteria pollutants, the construction-related GHG emissions reported for all action alternatives represent an upper bound because all construction is assumed to happen within the same one-year period.

#### 3.4.1.3 Alternative C

As in other action alternatives, construction activities in Alternative C would result in on-road and off-road mobile source exhaust emissions of NOx, VOCs, $SO_2$, $PM_{2.5}$, and $PM_{10}$ as well as dust emissions of $PM_{2.5}$ and $PM_{10}$ from re-entrained road dust, earthmoving and wind erosion. These releases would affect air quality temporarily during the construction period by impacting concentrations of $NO_2$, $SO_2$, ozone, $PM_{2.5}$ and $PM_{10}$. Dust contributions to construction emissions are highest in Alternative C across alternatives due to the relatively large surface area disturbed. The calculations of construction emissions in all action alternatives conservatively assume that the emissions are emitted in the same year (except for earthmoving dust emissions under Alternative C which have been annualized) whereas, in reality, the emissions would typically occur over a 2-3 year period depending on Alternative. Thus, the construction emissions reported for the action alternatives represent an upper bound.

Greenhouse gas emissions of $CO_2$, $CH_4$ and $N_2O$ would be released during construction in Alternative C. Emissions are comparable to Alternative B and ten times higher than in Alternative D and approximately twenty times higher than in Alternative A, primarily because of the heavy construction equipment used to build the evaporation ponds. Emissions of $CO_2$ constitute most of the GHG emissions. The annual GHG emissions released in construction under Alternative C (8,636 tons/year $CO_2e$) represent a very small fraction (approximately 0.006%) of the total projected GHG emissions of 147.7 million tons/year in Colorado in 2020 (Arnold et al., 2014). This is an upper bound as discussed above.

#### 3.4.1.4 Alternative D

In Alternative D as well, construction activities would result in on-road and off-road mobile source exhaust emissions of NOx, VOCs, $SO_2$, $PM_{2.5}$, and $PM_{10}$ as well as dust emissions of $PM_{2.5}$ and $PM_{10}$ from re-entrained road dust, earthmoving and wind erosion. These releases would affect air quality temporarily during the construction period by impacting concentrations of $NO_2$, $SO_2$, ozone, $PM_{2.5}$ and $PM_{10}$.

Greenhouse gas emissions of $CO_2$, $CH_4$ and $N_2O$ would be released during construction are twice that in Alternative A but are approximately ten times lower than the other action alternatives due to the reasons stated above. Emissions of $CO_2$ constitute most of the GHG emissions. The annual GHG emissions released in construction under Alternative D (797.4 tons/year $CO_2e$) represent a very small fraction (approximately 0.0005%) of the total projected GHG emissions of 147.7 million tons/year in Colorado in 2020 (Arnold et al., 2014). This is an upper bound as discussed above.

### 3.4.2 Operations and Maintenance Impacts

#### 3.4.2.1 Existing vehicle use

Due to the current use of four pickup trucks at the PVU, there would be small levels of O&M emissions under Alternative A (the No Action) as outlined in Table 3-1 (and consequently air quality impacts) of the criteria pollutants due to exhaust emissions and fugitive dust through 2026.

#### 3.4.2.2 Comparison with Reporting and Permit Thresholds

Operations and maintenance impacts in the Action Alternatives are compared with reporting and permit thresholds below.

<u>Alternatives B1 and B2</u>

The operation and maintenance stationary sources of emissions do not exceed the EPA SER thresholds described in Section 1.3 and therefore EPA's major source PSD requirements would not be triggered.

This air quality impact analysis is not a permitting exercise. However, the CDPHE permit emission thresholds in Table 1-1 offer a guideline for comparison with PVU Project emissions. Table 3-12 presents a comparison of operational Project emissions excluding mobile source exhaust (as specified by CDPHE) against the APEN and minor source permit thresholds.

Emissions of all pollutants except TSP in Alternative B1 are below the APEN reporting thresholds. All pollutants in Alternative B1 are below the minor source permit thresholds. Emissions of all pollutants except $PM_{10}$ and TSP in Alternative B2 are below the APEN reporting thresholds.

Emissions of all pollutants except TSP in Alternative B2 are below the minor source permit thresholds. Emissions of $PM_{10}$ and TSP emissions are primarily due to fugitive dust.

**Table 3-12. Comparison of PVU operational* source emissions in each action alternative with reporting and permit thresholds.**

| Pollutant | PVU Emissions for Alt B1 (tons/ year) | PVU Emissions for Alt B2 (tons/ year) | PVU Emissions for Alt C (tons/ year) | PVU Emissions for Alt D (tons/ year) | APEN Reporting Threshold (tons/ year) | Minor Source Air Permit threshold (tons/ year) |
|---|---|---|---|---|---|---|
| $NO_x$ | 0.01 | 0.02 | 0.05 | 21.00 | 2 | 10 |
| $SO_2$ | 0.00003 | 0.00003 | 0.00011 | 0.12600 | 2 | 10 |
| CO | 0.01 | 0.01 | 0.03 | 17.64 | 2 | 10 |
| VOC | 0.001 | 0.001 | 0.003 | 1.155 | 2 | 5 |
| $PM_{10}$ | 1.30 | 2.88 | 10.82 | 2.91 | 2 | 5 |
| $PM_{2.5}$ | 0.14 | 0.33 | 1.32 | 1.94 | 2 | 5 |
| TSP | 4.64 | 10.43 | 39.04 | 7.11 | 2 | 10 |
| $H_2S$ [a] | < 2 | < 2 | < 2 | < 2 | 2 | 2 |
| Hazardous Air Pollutants | --[b] | --[b] | 0.019[c] | 0.016[d] | 0.125 | --[e] |

*Includes all operational emissions except tailpipe emissions

[a]Conservatively assumed to be at most 2 tons/year (see Section 3.3.1)

[b]Emissions of hazardous air pollutants (air toxics) from vehicles and mobile equipment were not explicitly quantified. These air toxic emissions include benzene and other hydrocarbons such as 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, and naphthalene, and would slightly increase the air concentrations of these pollutants.

[c]The emissions of the individual hazardous air pollutant with the highest emissions (i.e., a,a,a-Trifluorotoluene) is listed here. Details are found in the attached emission spreadsheets.

[d]This value represents formaldehyde emissions from the natural gas burner.

[e]Minor source permits are not required for sources of HAPs. The <u>major</u> source permitting threshold for HAPs is 10 tons/year for any individual HAP or 25 tons/year for total HAP emissions. As per Table 3-10, maximum total HAP emissions under Alternative C are 131 lb/year or 0.07 tons/year.

<u>Alternative C</u>

The operation and maintenance stationary sources of emissions do not exceed the EPA SER thresholds described in Section 1.3 and therefore EPA's major source PSD requirements would not be triggered.

Emissions of all criteria pollutants except $PM_{10}$ and TSP in Alternative C are below the APEN and minor source permit thresholds. The estimated hazardous air pollutant emissions due to volatilization from the evaporation ponds under Alternative C are well below the APEN reporting threshold. The values shown in Table 3-12 for Alternative C is the maximum across all HAPs (a,a,a-Trifluorotoluene) and was calculated following the methodology and data for analyte concentrations provided by Amec Foster Wheeler (2017). The value represents the potential maximum emissions resulting from the complete volatilization of the HAP from the evaporation ponds and thus is an upper bound. This value is well below the APEN reporting threshold.

Alternative D

The operation and maintenance stationary sources of emissions do not exceed the EPA SER thresholds described in Section 1.3 and therefore EPA's major source PSD requirements would not be triggered.

Alternative D has the highest O&M NOx and CO emissions across all action alternatives. These are due to the energy consumption associated with natural gas combustion for the zero-liquid discharge technology option. Emissions of NOx and CO emissions exceed the CDPHE minor source permitting thresholds. Emissions of all other pollutants are below these thresholds. A separate permitting study would be needed to determine if the implementation of Alternative D requires a minor source air quality permit. Emissions of NOx, CO, PM10 and TSP exceed the APEN reporting threshold. $PM_{10}$ and TSP emissions are primarily due to fugitive dust.

The estimated hazardous air pollutant emissions of formaldehyde from natural gas combustion under Alternative D are well below the APEN reporting threshold. As noted in Section 3.3, there is a potential for release of HAP and VOC emissions from the brine in Alternative D (similar to Alternative C) and further pilot testing analysis should be performed to identify the quantity and location of these emissions.

#### 3.4.2.3 Comparison with Modeling Thresholds

Table 3-13 presents a comparison of operational stationary source emissions in each action alternative with the long-term modeling thresholds recommended by CDPHE.

Alternatives B1 and B2

Operational stationary source emissions of all pollutants in Alternatives B1 and B2 are well below the CDPHE long-term modeling thresholds and therefore air quality impacts are expected to be small.

Alternative C

Operational stationary source emissions of all pollutants in Alternative C are well below the CDPHE long-term modeling thresholds and therefore air quality impacts are expected to be small.

Alternative D

Operational stationary source emissions of all pollutants in Alternative D are well below the CDPHE long-term modeling thresholds and therefore air quality impacts are expected to be small. However, the emissions of NOx and CO are highest across all alternatives due to the combustion of natural gas for energy and therefore air quality impacts due to these pollutants are expected to be highest across the action alternatives.

**Table 3-13. Comparison of operational stationary source emissions with modeling thresholds.**

| Pollutant | Alternative A (tons/year) | Alternative B1 (tons/year) | Alternative B2 (tons/year) | Alternative C (tons/year) | Alternative D (tons/year) | CDPHE long term modeling threshold (tons/year) |
|---|---|---|---|---|---|---|
| $NO_x$ | 0 | 0.01 | 0.02 | 0.05 | 21.00 | 40 |
| $SO_2$ | 0 | 0.00003 | 0.00003 | 0.00011 | 0.12600 | 40 |
| CO | 0 | 0.01 | 0.01 | 0.03 | 17.64 | 100.7 (23 lb/hr) |
| $PM_{10}$ | 0 | 0.001 | 0.001 | 0.003 | 1.60 | 14.97 (82 lb/day) |
| $PM_{2.5}$ | 0 | 0.001 | 0.001 | 0.003 | 1.60 | 5 |

#### 3.4.2.4 Impact of Reclamation Restricted Access Road East of Dolores River in Alternative B1

Reclamation intends to use a restricted access road east of the Dolores River to access the Alternative B project area from the north. There is an occupied residence near this dirt road and thus there is potential concern about air quality impacts if Alternative B - Area B1 is implemented. The dirt road to be utilized during construction and it is across the river from the PVU office approximately 150 meters away.

Fugitive dust emissions associated with this road were estimated by assuming that 5% of all VMT for the Project occurred on restricted access roads (i.e., this road) (F. Busch, Reclamation, personal communication, June 20, 2019). Total annual $PM_{2.5}$, $PM_{10}$ and TSP emissions associated with this road during construction are 0.91 tons/year, 9.10 tons/year and 32.09 tons/year, respectively. These constitute approximately a third of the fugitive dust emissions from all construction sources in Alternative B1. The emissions would be distributed over the length of the restricted access road and vehicle speeds would be restricted to 25 miles per hour. Also, as noted in the EIS, dust suppression measures would be employed to reduce daily PM emissions and fugitive dust during construction

There would be no impacts under the other action alternatives as there no occupied houses nearby (within 350 meters) of any dirt road that will be used during construction of the alternatives.

#### 3.4.2.5 Impact at Class I Areas

The Project's potential impacts on federally-protected Class I areas was evaluated by performing a Q/D (emissions divided by distance) screening analysis following the Federal Land Manager's Air Quality Related Value (AQRV) Work Group (FLAG) 2010 guidance, which compares the ratio of the sum of pollutant emissions of $SO_2$, $NO_x$, $PM_{10}$, and sulfuric acid mist ($H_2SO_4$) to the distance of the source from the Class I area (FLAG, 2010). The analysis was performed for the two closest Class I areas, the Arches National Park which is approximately 63 km from Bedrock and Canyonlands National Park which is approximately 74 km from Bedrock. The analysis was based on total annual O&M Project emissions in tons per year for each Alternative. Sulfuric acid emissions were assumed to be negligible. For comparison, the analysis was also performed for existing emissions due to current vehicle use (i.e., Alternative A through 2026) at the PVU. The results of the analysis are shown in Table 3-14 and Table 3-15. Given that Q/D value is well below the threshold of 10 at the two closest Class I areas for all Alternatives, the Project would have no presumptive adverse impacts to any air quality related values such as visibility or deposition at Arches, Canyonlands or any other Class I area in any of the alternatives and no further analysis is required.

**Table 3-14. Class I Q/d Screening Analysis for Arches National Park**

| Alternative | Operational Emissions (Q) (tons/year) | Emissions/Distance (Q/d) | Additional analysis required (Y/N)? |
|---|---|---|---|
| A | 3.0 | 0.05 | N |
| B1 | 1.3 | 0.02 | N |
| B2 | 3.0 | 0.05 | N |
| C | 14.9 | 0.24 | N |
| D | 25.4 | 0.40 | N |

**Table 3-15. Class I Q/d Screening Analysis for Canyonlands National Park**

| Alternative | Operational Emissions (Q) (tons/year) | Emissions/Distance (Q/d) | Additional analysis required (Y/N)? |
|---|---|---|---|
| A | 3.0 | 0.05 | N |
| B1 | 1.3 | 0.02 | N |
| B2 | 3.0 | 0.04 | N |
| C | 14.9 | 0.20 | N |
| D | 25.4 | 0.34 | N |

#### 3.4.2.6 Ozone

Ozone will be formed in the atmosphere from NOx and VOCs released from the Project. Impacts on ozone air concentrations due to the proposed action are expected to be very low because of the relatively low magnitude of NOx and VOC emissions in all alternatives. Alternative D has the highest NOx emissions across all alternatives. An ozone ambient impact analysis was conducted for Alternative D using Modeled Emission Rates for Precursors (MERPs), consistent with EPA's Guidance on the Development of MERPs as a Tier I Demonstration Tool for Ozone and $PM_{2.5}$ Under the PSD Permitting Program (EPA, 2019). The MERP is the emission rate (tpy) of a precursor pollutant below which the impact from the precursor pollutant emissions on the formation of ambient ozone would not be expected to cause or contribute to a violation of the NAAQS for ozone. The MERP value is derived by EPA from the ratio of the precursor pollutant emissions from a hypothetical source to the maximum modeled impacts from that source, which is multiplied by the air quality concentration threshold that is used to determine if such an impact causes or contributes to a violation of the NAAQS, referred to as the critical air quality threshold, here, the 8-hour ozone Significant Impact Level (SIL).

For this analysis, operational annual NOX and VOC emissions from the Alternative D stationary source (i.e., natural gas combustion in the zero-liquid discharge technology) were compared with the lowest, most conservative MERPs for the Rockies/Plains zone, consistent with EPA's Guidance (EPA, 2019). These values are extremely conservative for this Project because they represent the lowest values from the Western U.S. Since both NOX and VOC contribute to ozone formation, the contribution from both pollutants was considered together. Per the guidance, the proposed emissions increase was expressed as a percentage of the individual MERP for that precursor and then summed.

The estimated percentage of the 8-hr ozone SIL (of 1 ppb) resulting from operational NOx and VOC emissions from the Alternative D stationary source = (21 tpy NOx from Project/184 tpy NOx 8-hr daily maximum $O_3$ MERP) + (1.16 tpy VOC from Project/1,067 tpy VOC 8-hr daily maximum $O_3$ MERP) = .114 + .001 = .115 * 100 = 11.5%.

Thus, the ozone impacts associated with both NOx and VOC precursor emissions from Alternative D are expected to be well below the EPA recommended 8-hour ozone SIL. Impacts for the other Alternatives would be even lower. Using less conservative MERP values from the EPA (2019) guidance would result in estimated ozone impacts that are up to 10 times lower. Therefore, it is highly unlikely that any of the action alternatives would push the area out of attainment for ozone.

#### 3.4.2.7 Greenhouse Gas Emissions during Operations and Maintenance

Greenhouse gas emissions of $CO_2$, $CH_4$ and $N_2O$ would be released during O&M in all action alternatives. Alternative D has the highest operational GHG emissions across the alternatives due to the energy consumption from natural gas usage for the ZLD. The total annual O&M emissions of 25,467 tons/year $CO_2e$ would represent approximately a very small fraction (0.02%) of the total Colorado GHG emissions in 2020 (Arnold et al., 2014). Emissions of GHGs during O&M are 538 tons/year in Alternative C, and 27 tons/year and 65 tons/year in Alternatives B1 and B2, respectively, and thus are relatively negligible.

# 4.0 REFERENCES

AMEC Foster Wheeler, 2017. Air Quality Technical Report Salinity Control Investigations Paradox Valley Unit, Colorado. AMEC Foster Wheeler Environment & Infrastructure, Inc. Phoenix, AZ, March 13, 2017.

Arnold, S., J. Dileo, T. Takushi, 2014. Colorado Greenhouse Gas Inventory—2014 Update Including Projections to 2020 & 2030. Colorado Department of Public Health and Environment. October. Internet website (accessed June 2019): https://www.colorado.gov/pacific/sites/default/files/AP-COGHGInventory2014Update.pdf

Countess Environmental, 2006. WRAP Fugitive Dust Handbook. Western Governors' Association. September. Internet website (accessed July 2019): https://www.wrapair.org/forums/dejf/fdh/content/FDHandbook_Rev_06.pdf

EPA, 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. EPA430-R-18-003. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016. April.

EPA, 2019. Air Quality Assessment Division. Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier I Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program. Memorandum. April 30.

Federal Land Managers' Air Quality Related Values Work Group (FLAG) U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service. 2010. FLAG Phase I Report—Revised. Natural Resource Report NPS/NRPC/NRR— 2010/232. National Park Service, Denver, Colorado.

IPCC, 2007. Climate Change – The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press. Cambridge, United Kingdom 996 pp

IPCC (Intergovernmental Panel on Climate Change), 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

# APPENDIX

# EMISSIONS CALCULATIONS

**Provided under separate cover in Excel spreadsheet format**

**Calculations available from Reclamation upon request**

# Appendix F

## Geomechanical and Flow Modeling Summary Report

***Geomechanical and Flow Modeling***

***for Paradox Valley Unit***

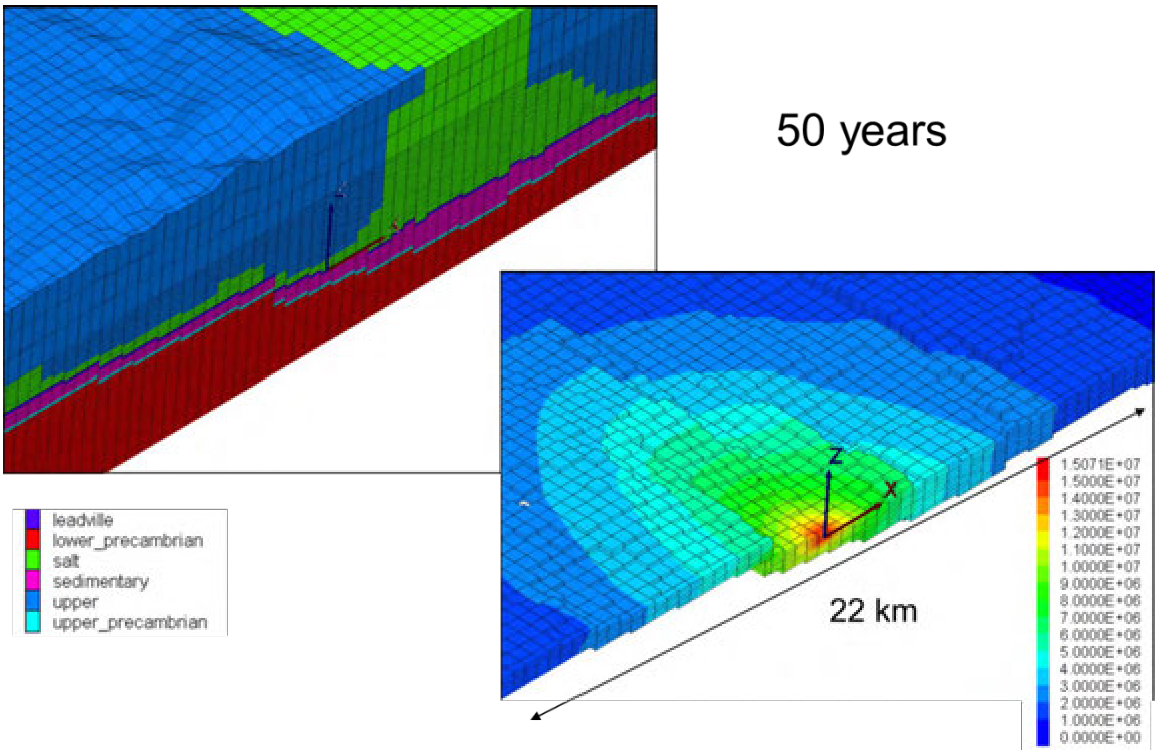
***Study for USBR: Summary Report***

ITASCA

Consulting Group, Inc.

*Geomechanical and Flow Modeling for Paradox Valley Unit*

*Study for USBR: Summary Report*




March 27, 2017
2-5792-01:17R11

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***Summary***

A coupled 3D geo-mechanical and flow model of the Paradox Valley Unit was set up with the commercial code *FLAC3D* using USBR data. The modeling region includes the existing brine injection well site (PVU-1) and five potential sites (BIF-1, BIF-2, Mesa-1, Mesa-2, and Pinion Ridge) that Reclamation is interested in appraising and ranking. The criteria for appraisal set by USBR include: 1) the potential for simulated wellhead pressure to reach a critical target pressure; 2) the risk of induced seismicity in the injection layer based on elastic stress state in the model; and 3) the potential for surface heave.

The *FLAC3D* model is a six-layer model that includes, from top to bottom, the Upper, the Salt, the Leadville, the Sedimentary, the Upper Precambrian, and the Lower Precambrian. Brine is injected in the Leadville in the model. Also, the Salt and Lower Precambrian are considered impermeable to the flow.

The model is calibrated by matching the wellhead pressure data, available for about 25 years of injection at PVU-1 with the model wellhead predictions at the site. The calibration parameters include: 1) the permeability of major Faults in the model; and 2) the coefficient of the well pressure correction (based on radial flow theory), used to account for the relatively small well diameter, compared to model discretization size.

The *increasing trend* in wellhead pressure data was captured in the model by specifying that fault sections with offset larger than a reference value of 500 ft be impermeable. On the other hand, a good match in the wellhead pressure *level* was obtained by reducing the coefficient of well pressure correction to account for the deviation from radial flow in the Leadville, near the injection location (the Sedimentary layer below the Leadville has a low level of permeability).

The calibrated model was used to model up to 50 years of brine injection at PVU-1 and at the additional potential well sites. The risk of induced seismicity in the Leadville, based on the elastic stress state in the model, was quantified using Factor of Safety on fluid pressure and a frictional Coulomb criterion. The numerical analysis shows that, with the model and properties adopted for the work, there is not a single well site that minimizes all three criteria.

In particular, according to the model predictions, Pinion Ridge and Mesa-1 have a low potential for slip but also have the highest potential for heave induced by injection. Pinion Ridge and Mesa-1 would be good candidates for brine reinjection if the primary concern is to minimize the potential for slip. However, they would be the worst candidates of the six if a change in surface elevation was a concern for the stability of existing surface structures. Also, BIF-1 has the highest predicted wellhead pressure and the lowest value of heave associated with injection. Interestingly, the

modeled PVU-1 (existing well) is estimated to have the highest potential for slip according to the FoS measure based on elastic stresses.

The results reported in this document are intended to serve as guidance for comparing potential second injection well sites only. The accuracy of modeling predictions is restricted by the limited formation property and other data. One way to improve the quality of the model predictions would be to use an elasto-plastic mechanical framework, with representative strength data for the prediction of potential slip induced by injection. Also, a model with finer discretization around the well location will likely be able to capture aspects of the physics more accurately.

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# 1.0 INTRODUCTION

## 1.1 Background

Reclamation's Paradox Valley Unit (PVU) is a critical component of the Colorado River Basin Salinity Control Program, which is a multi-works program to control the salinity of water delivered to users in the United States and Mexico. PVU is located in western Colorado, approximately 90 km southwest of Grand Junction. Using a field of shallow brine extraction wells located in Paradox Valley, PVU diverts highly saline groundwater that would otherwise flow into the Dolores River, a tributary of the Colorado River. The diverted brine is piped several miles and then injected into a 16,000-foot deep waste-disposal well located on the margin of Paradox Valley. The disposal well was completed in 1988.

The PVU injection rate is currently about 7,000 barrels of brine per day, resulting in the disposal of about 100,000 tons of salt per year. Because of the relatively low permeability of the target injection formation (<20 md), brine injection at these rates results in surface pressures of about 5,000 psi and downhole pressures of about 12,000 psi, which is above the injection formation fracture closure pressure. The target injection formation is a Mississippian-age limestone. Reclamation is conducting technical studies to appraise drilling a second deep disposal well in the vicinity of Paradox valley and is considering multiple sites for that well. A second well is just one of several alternatives that will be considered for an Environmental Impact Study.

Reclamation has selected specific comparison sites that are expected to have suitable reservoir and operational properties based on results from separate studies, including reprocessing and interpreting 500+ miles of 2D seismic reflection data, analysis of available well log and core data, aeromagnetic data survey and interpretation, gravity data interpretation, geologic structure interpretation, induced seismicity analysis, assessment of environmental impacts, drilling feasibility studies, and assessing the feasibility of constructing and operating surface infrastructure.

## 1.2 Objectives

The objective of this project is to conduct an appraisal-level analysis of multiple potential disposal well sites, describing the evolution of various physical properties within the numerical models given an assumed injection history and initial stress state.

The analysis includes five potential new injection sites in the Paradox Valley area identified by Reclamation, as well as the existing PVU injection well.

The work includes:

- Setup of a 3D numerical model and performing preliminary injection simulation for the existing PVU injection well located in a low permeability fractured formation in the

Paradox Valley Region. The data provided by the Bureau of Reclamation for this task includes: interpreted faults; formation horizons; and initial formation properties.

- Performing a coupled fluid-mechanical simulation of fluid injection at a specified rate for up to 50 years. This includes monitoring pore pressure, stress, and displacements at specified locations in the model, including the ground surface.
- Model calibration with the existing PVU injection well using the actual daily flow rates and wellhead injection pressures provided by Reclamation.
- Modeling injection at five new additional potential injection sites specified by Reclamation based on separate studies, such as the interpretation of seismic reflection data, well log data, formation properties, aeromagnetic data, geologic structure, induced seismicity, environmental impacts, drilling feasibility, and the feasibility of constructing and operating surface infrastructure.

### 1.3 Work Flow

The work summarized in this report was guided by regular meeting interactions with the USBR. Seven progress reports (in the form of PowerPoint presentations) documenting the work in progress were presented at those meetings: PR1 on December 5, 2016, PR2 on December 19, 2016, PR3 on December 11, 2016, PR4 on January 23, 2017, PR5 on February 3, 2017, PR6 on February 21, 2017, and PR7 on March 6, 2017. The progress reports (PR) form an integral part of this report; they are included in the Appendices.

## 2.0 GEOMECHANICAL MODEL

Fluid injection, fluid flow, pore pressure dissipation, and rock mass deformation are simulated using Itasca's commercial numerical code, *FLAC3D* (Itasca, 2013).

*FLAC3D* has the capability to conduct fully coupled hydro-mechanical simulations. Depending on the nature of the problem, the type and "tightness" of coupling can be optimized to ensure numerical stability and accuracy, but also to provide reasonable simulation times. The problem is solved as a single-phase, porous medium flow. The hydro-mechanical (HM) component of coupling allows prediction of the effect of the pore pressure change on elastic deformation and also potential inelastic deformation, particularly along the specified faults (as controlled by their shear strength).

*FLAC3D* contains an embedded language, *FISH*, that gives the user access to all internal variables and allows custom-written functions.

We consider the case of a saturated porous medium with isotropic permeability in small-strain mode. Changes in saturation are not considered for this project. Also, only elastic deformations induced by the brine injection are considered.

## 2.1 Data for the Simulations

The data provided by the Bureau of Reclamation for the model setup include: interpreted faults; formation horizons; and initial formation properties. Initially, the depth grids for the ground surface, the top of the Paradox Salt, the top of the Leadville, and the top of the Precambrian were provided in the form of depth grids. The depth grids (*x*-, *y*-, *z*-coordinates of formation surfaces) were converted into surface meshes. The thickness of the Leadville was specified at 90 m, and the thickness of the top of the Precambrian at 58 m. The Welds footprint (the Welds cut through the Salt) was also provided at a later stage in the project.

The trace of major vertical Faults were provided; see Figure 1.

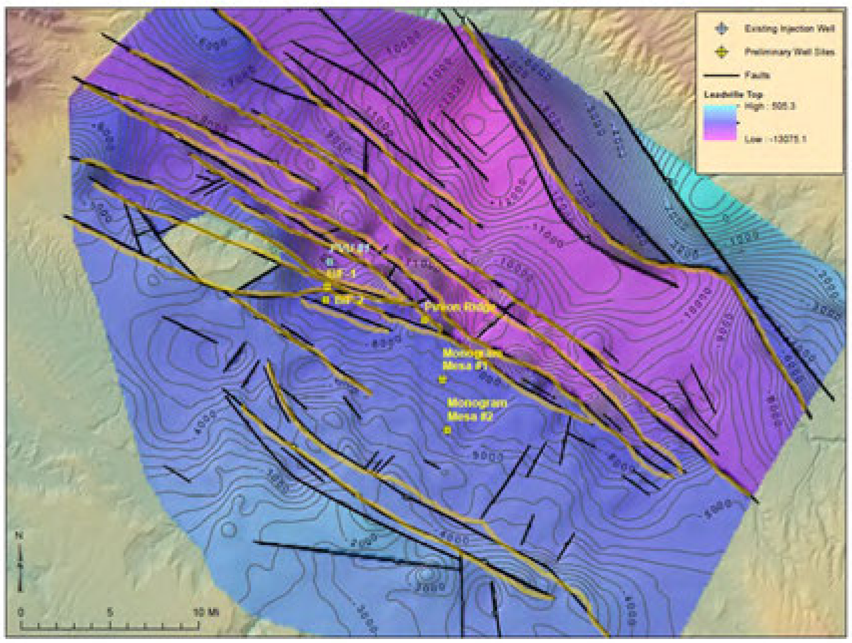



***Figure 1 Major Fault traces in the Leadville, marked in yellow (USBR).***

The formation properties are listed in Table 1.

***Table 1 Formation Properties (USBR)***

| Layer | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Layer description | Formations above salt | Salt | Leadville | Sedimentary layers below Leadville | Precambrian | Lower Precambrian |
| Density | 2.53 g/cm$^3$ | 2.16 g/cm$^3$ | 2.69 g/cm$^3$ | 2.56 g/cm$^3$ | 2.65 g/cm$^3$ | 2.65 g/cm$^3$ |
| Bulk modulus | 29.8 GPa | 25.3 GPa* | 64.8 GPa | 50.6 GPa | 50.1 GPa | 50.1 GPa |
| Young's modulus | 43.1 GPa | 35.8 GPa* | 76.2 GPa | 66.8 GPa | 83.0 GPa | 83.0 GPa |
| Shear modulus | 17.1 GPa | 14.2 Gpa* | 29.2 GPa | 26.1 GPa | 33.9 GPa | 33.9 GPa |
| Poisson's ratio | 0.260 | 0.264* | 0.304 | 0.280 | 0.224 | 0.224 |
| Permeability | 0.1 mD | 0 mD | 6 mD | 0.1 mD | 1.5 mD | 0 mD |
| Porosity | 0.06 | 0 | 0.05 | 0.01 | 0.03 | 0 |
| Diffusivity (before 1/8/02) | 0.0019 m$^2$/s | 0 m$^2$/s | 0.20 m$^2$/s | 0.0043 m$^2$/s | 0.051 m$^2$/s | 0 m$^2$/s |
| Diffusivity (after 1/8/02) | 0.0020 m$^2$/s | 0 m$^2$/s | 0.21 m$^2$/s | 0.0044 m$^2$/s | 0.053 m$^2$/s | 0 m$^2$/s |

The brine density was 1173 kg/m$^3$, initially (PR1). The revised value (PR2 to PR7) is 1153 kg/m$^3$ (USBR data). The brine viscosity is 0.001348 Pa·sec.

The daily injection rate covering 25.24 years of data for the existing PVU-1 well is presented in Figure 2.

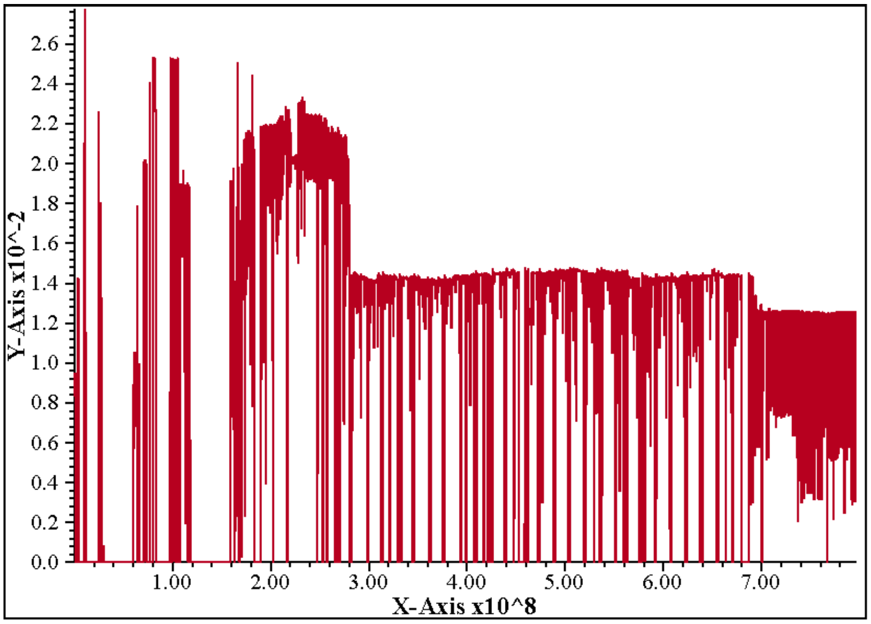



***Figure 2 Injection rate [m³/sec] versus time [sec] (interpreted from USBR data).***

The wellhead pressure data for PVU-1 is plotted in Figure 3.

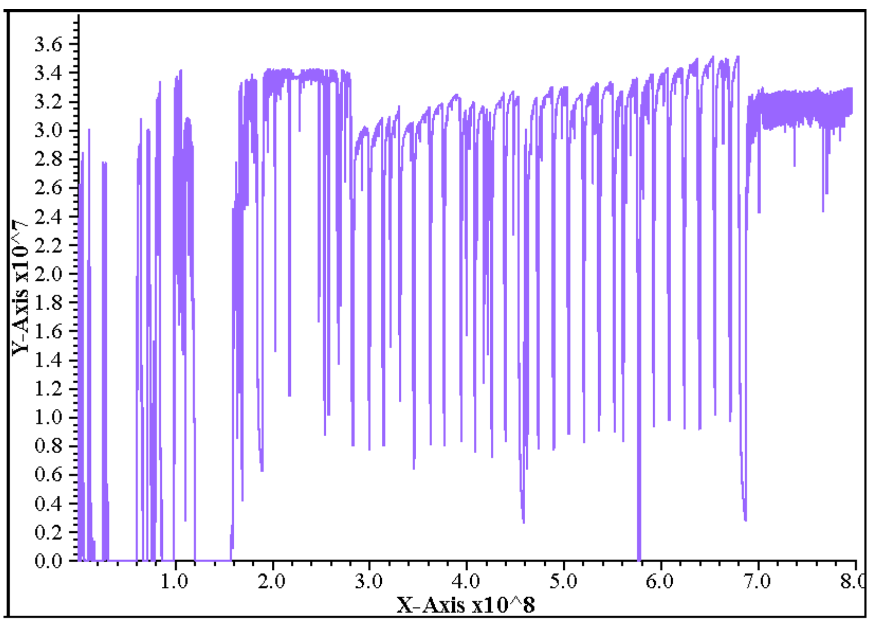



***Figure 3 Wellhead pressure data [Pa] versus time [sec] for PVU-1 (from USBR data).***

USBR is interested in studying the response at the well locations shown in Figure 4.

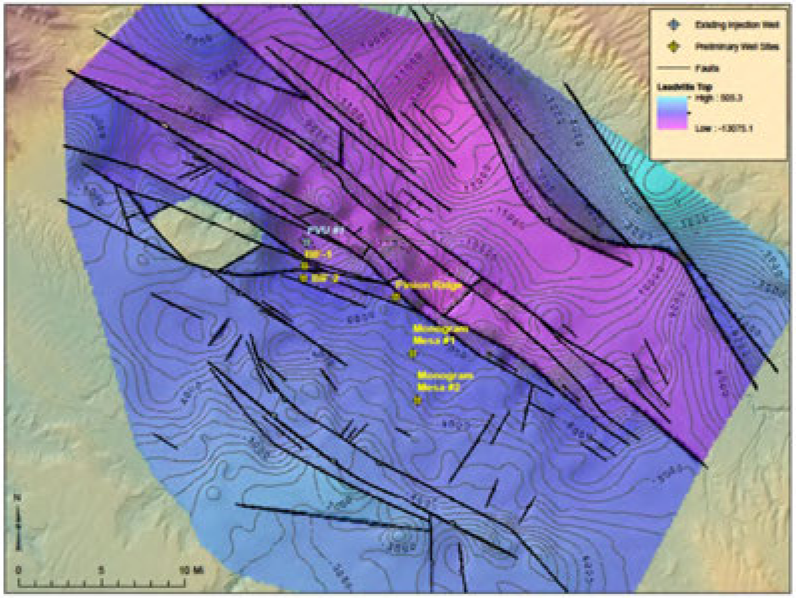


***Figure 4 Well locations (USBR).***

The value of in-situ fluid pressure at the injection location in the Leadville is 42.3 MPa (USBR data).

The faults with offset larger than 500 ft are considered as impermeable in the model. These impermeable barriers to the flow are sketched, in yellow, in Figure 5.

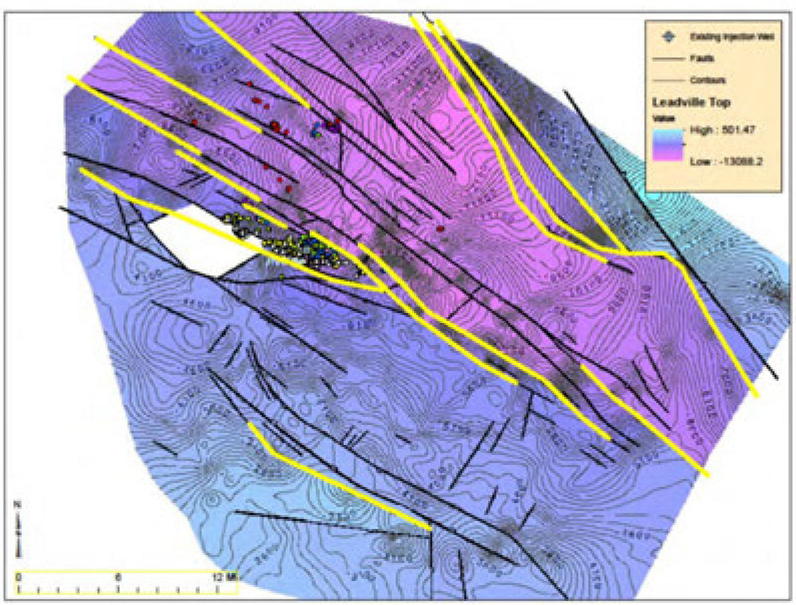


***Figure 5 Impermeable Fault traces (USBR).***

## 2.2 *FLAC3D* Model

Four different model meshes were produced during the evolution of the project.

The initial '6 layers' model (used in PR1) contained six stratigraphic units: the Upper; the Salt; the Leadville; the Sedimentary; the Upper Precambrian; and the Lower Precambrian.

The surface elevations were updated (USBR data) for the second model realization (PR2).

Welds were introduced in the stratigraphy sequence in the third model (PR3).

The model footprint was adjusted to accommodate the six well locations in the same model, while limiting possible boundary effects (PR4 to PR7).

The latest model realization is 56 km long (along the valley *y*-direction in the model), 40 km wide (across the valley *x*-direction), and the maximum height is 7.5 km. The lateral size of the model was selected large enough to minimize boundary effects. To evaluate the 'radius of influence' of the well, we used the estimate:

$$L = \sqrt{ct} \tag{1.1}$$

With the Leadville diffusivity c=0.20 $m^2$ /sec and the maximum injection time t= 50 years, the 'safe' distance estimate from the injection point is about 18 km.

The *FLAC3D* mesh contains a total of 616,000 zones and 640,845 gridpoints.

The zone size is 400 m x 400 m in the horizontal plane and 100 m high in the Leadville.

A view of the model stratigraphy cut by two vertical planes through the location of PVU-1 is shown in Figure 6. The same view with the Upper removed is shown in Figure 7.

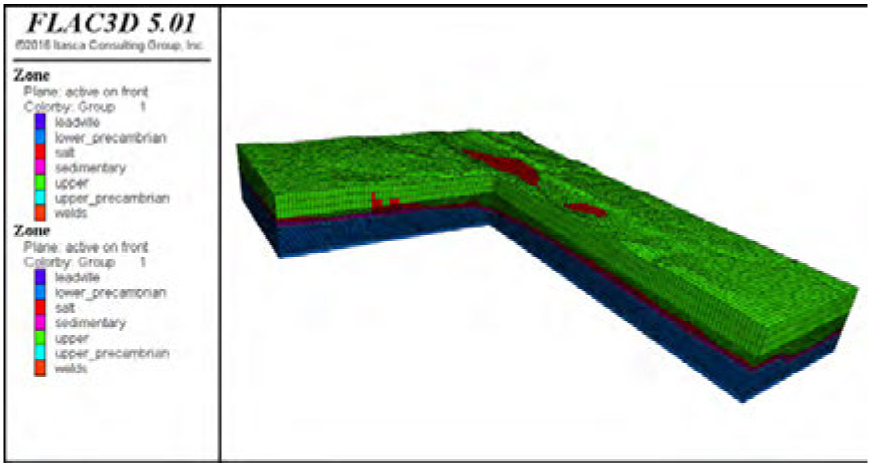



***Figure 6 View of model stratigraphy in a portion of the model.***

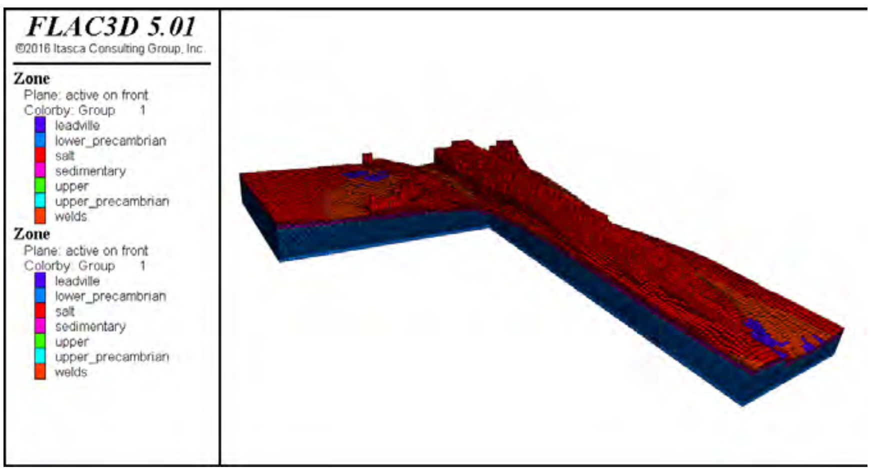



***Figure 7 View of model stratigraphy in a portion of the model, Upper removed.***

Additional model views are included in the progress reports included in appendices.

Note that the Leadville and the Upper Precambrian layers each have a thickness of 100 m in the model. This is different from the thickness values (of 90 m for the Leadville and 58 m for the Upper Precambrian) provided by USBR. The larger thickness value was adopted in the interest of model size and run time management to allow for the performance of a relatively large number of trial and verification runs for the project. However, this is not a limitation in the model, and values could potentially be adjusted.

Faults are assumed to be vertical and to follow the major traces specified in the Leadville (USBR data). There are two different fault representations in the model: 'transparent' faults and 'impermeable' faults. Transparent faults have zero thickness; they are characterized by offsets in adjacent layers, but have no preferential permeability. Impermeable faults are fault segments that have more than 500 ft offset; they are assigned a one zone thickness and zero permeability. Note that impermeable faults are not present in all model representations considered in this work.

### 2.3 Injection Modeling

Injection at a specified rate in the Leadville is modeled by specifying a unit volumetric source at the injection location. The in-situ fluid pressure is assumed to be at steady-state (i.e., fluid pressures stay constant if no injection is made). The injection location is taken as the zone closest to the well location in the Leadville. The code solves the diffusion equation, with true diffusivity, and calculates the fluid pressures induced by the injection, for a period of up to 50 years of injection.

The total fluid pressure in the model is calculated by adding the in-situ pressure to the excess pore pressure (induced by the injection). For the in-situ pressure, a constant potentiometric surface is assumed, consistent with the value of in-situ fluid pressure at the injection location in the Leadville (USBR data).

*FLAC3D* considers the flow of one single fluid. The fluid is considered to have the density of water for the simulation of fluid flow. The decision to use the water density for the simulations was made considering the radius of brine ‘extension’ in the model after 50 years of injection at a representative rate of 0.0151 $m^3$/s in the Leadville. The estimate is:

$$r = \sqrt{\frac{Qt}{n\pi h}} \tag{1.2}$$

With the height of the Leadville, h=100m, and the porosity of the Leadville, n=0.05, the estimate is about 1.2 km, a size relatively small compared to the estimate of ‘radius of influence’ of the well of about 18 km after 50 years of injection (see Equation (1.1)).

At the injection location, a well correction is applied to the excess zone pore pressure value evaluated by the code to account for the relatively large zone size compared to well diameter in the model. The total corrected fluid pressure at the injection location is obtained by superposition of corrected fluid pressure and in-situ pressure.

The well pressure correction, $\Delta p_w$, is evaluated using the formula:

$$\Delta p_w = \beta \frac{Q}{2\pi kh} \ln \frac{r_0}{r} \tag{1.3}$$

where $Q$ ($m^3$/sec) is the flow rate, $k = 4.45 \cdot 10^{-12}$ $m^2$/Pa·sec is the Leadville mobility coefficient, $h = 100$ m is the injection interval, $r = 0.5$ m is the assumed well radius, $r_0 = 200$ m is half the zone lateral size in the Leadville, and $\beta$ is a dimensionless calibration parameter, chosen to fit the PVU-1 model wellhead pressure prediction to the available USBR data (see Section 7).

A comparison of fluid pressure predictions using this approach and Theis' analytic well solution is included in Appendix B.

The head loss in the well is assumed to be negligible, and the wellhead pressure is estimated by subtracting the static brine pressure in the well from the total corrected fluid pressure at the injection location.

## 2.4 Coupled Flow-Mechanical Simulation

The modeling approach for the coupled fluid-mechanical simulations follows the recommendations outlined in the *FLAC3D* ***Fluid-Mechanical Interaction*** manual. Indeed, in most practical cases of pore pressure-driven systems, experience shows that the coupling between pore pressure and mechanical fields is weak. In particular, if the medium is elastic, the numerical simulation can be performed with the flow calculation in the flow-only mode and then in mechanical-only mode to bring the model to equilibrium. (The Biot modulus is set to zero during the mechanical cycling to prevent additional generation of pore pressure.) However, when conducting the flow calculation, it is important to preserve the true diffusivity of the system (and hence the characteristic time scale).

If the true diffusivity, $c$, is known, then an apparent Biot modulus, $M^a$, should be used in the simulations, with

$$M^a = \frac{c}{k} \tag{1.4}$$

and $k$ is the mobility coefficient. (The Biot modulus is an input property in the *FLAC3D* model; the apparent Biot modulus is the inverse of the storage coefficient, with the storage coefficient defined in units [$M^{-1}T^2$ L].)

In Appendix A, Terzaghi's assumption is used to support this partial uncoupling approach (the uncoupling is 'partial' because the fluid diffusion equation uses a storage coefficient that takes into account the contribution of both the fluid and the solid matrix).

### *2.4.1 Biot Parameters*

For the simulations, it is assumed that the diffusivity is a (measured) field quantity: the same value is used, independent of the assumed value of Biot coefficient, $\alpha$. This implies that the storage coefficient ($1/M^a$) remains unchanged. Thus, the numerical fluid pressure predictions will be the same, independent of the assumed value of Biot coefficient.

However, a reduction in Biot coefficient is expected to produce a reduction in maximum surface heave in the elastic simulations. Also, an increase in the $\alpha$ value is expected to produce an increase in stress confinement in the model.

## 2.5 Calibration Scenarios

The initial modeling work, documented in PR1, considered injection in the Leadville at the PVU-1 location at a continuous rate of 0.01198 $m^3$/sec for a period of up to 50 years. Three permeable layers were considered in the 6-layer model: the Leadville; the Sedimentary; and the Upper Precambrian. The calculation of wellhead pressure was made based on induced fluid pressure in the injection zone, as described in Section 2.3. However, in these early runs, the calibration coefficient $\beta$ was taken equal to one, the brine density (used to evaluate the static brine pressure in the well) was 1173 kg/$m^3$, and the in-situ fluid pressure was taken as 43.1 MPa (based on injection depth and water density). The numerical simulations predicted a wellhead pressure of 31.2 MPa after 20 years, and of 33.0 MPa after 50 years. The predicted value after 20 years of injection was in the same ballpark as the recorded value.

The PVU-1 injection and wellhead pressure data was made available for the continuation of the project. The calibration of the *FLAC3D* Paradox Valley project is performed, based on flow simulations, by seeking a close match between the recorded wellhead pressure at the PVU-1 wellsite and the numerical estimate.

Different permeability scenarios were investigated and the predicted PVU-1 wellhead pressures were analyzed to determine which scenario was most realistic and which one could be eliminated, based on the quality of the match in trends with the available data. The modeling work is documented in PR2. In all the cases, the Salt and Lower Precambrian were assumed to be impermeable. A slightly different geometrical model was used that accounts for the updated surface elevations provided by USBR. A brine density value of 1153 kg/$m^3$ was used for the simulations (USBR data). The permeability scenarios included:

- Model 1: Impermeable Upper, permeable Leadville, Sedimentary, and Upper Precambrian, and 'transparent' faults.
- Model 2: Impermeable top and bottom of Leadville and all Impermeable Faults (most compartmented model).
- Model 3: Permeable top and bottom of Leadville, and 'transparent' faults (least compartmented model).

The in-situ fluid pressure, which produces a shift in the predicted wellhead pressure curve, was taken as a calibration parameter for the first scenario, and the same value (44.7 MPa) was used for the two following scenarios.

A comparison between the predicted wellhead pressure and the recorded values for Model 1 is plotted versus time in Figure 8.

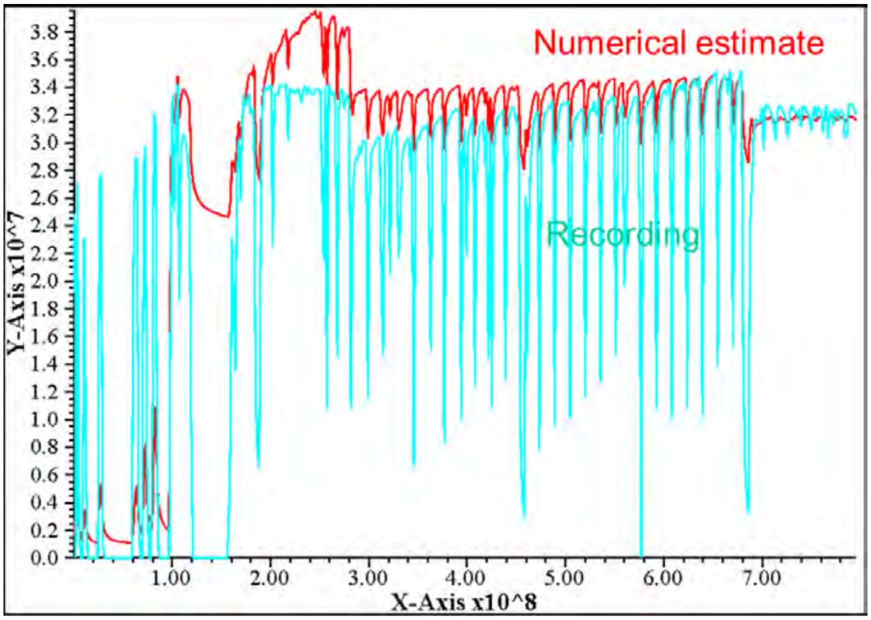



***Figure 8 Wellhead pressure [Pa] versus time [sec]—Model 1.***

There was no significant difference between the wellhead pressure results for Model 3 and Model 1. On the other hand, as shown in Figure 9, model 2, with all major faults considered as impermeable, predicted wellhead pressures that were far too large compared to the recorded data (larger than 150 MPa after 25 years of injection).

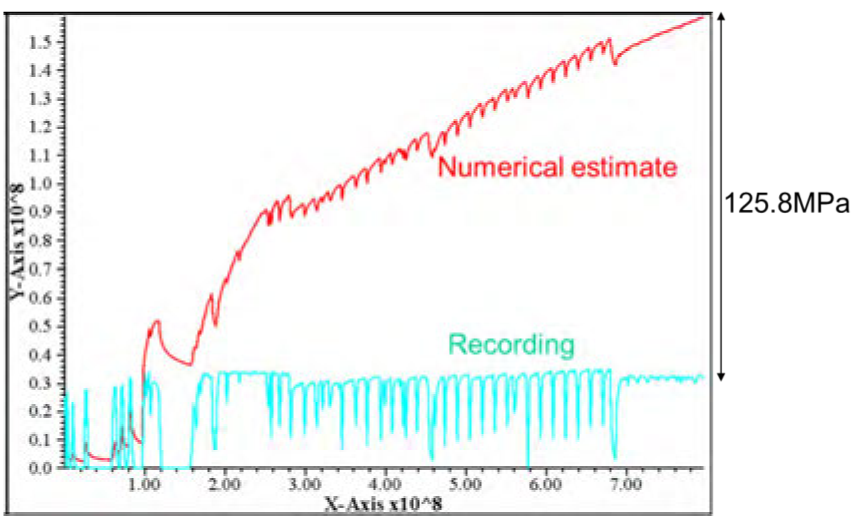



***Figure 9 Wellhead pressure [Pa] versus time [sec]—Model 2.***

The permeability of Model 2 was considered unrealistic based on the wellhead pressure simulation results. Also, a comparison of results for Model 1 and Model 3 indicates that the Upper does not influence the numerical wellhead predictions significantly. This could possibly be attributed to an over-prediction of the continuity of the impermeable salt layer that overlays the Leadville in the model.

To investigate this possibility, a new scenario, Model 4 (a variation on Model 3) was proposed in which Welds (permeable windows through the Salt that connect the Leadville with the Upper) were accounted for. A fifth scenario was put forth that, in addition to Model 4, also includes selected impermeable fault sections:

- Model 4: Permeable Upper, permeable welds (geometry provided by USBR), permeable Leadville, Sedimentary, and Upper Precambrian, and 'transparent' faults.
- Model 5: Same as scenario 4, but with impermeable faults.

A common in-situ fluid pressure value of 44.7 MPa at the injection location was used for all five scenarios. The Welds are represented in plan view in Figure 10. They are implemented as vertical cuts through the Paradox Salt in the model, putting the Leadville in contact with the Upper permeable formation. The flow properties of the Welds are the same as the Upper in the *FLAC3D* model.

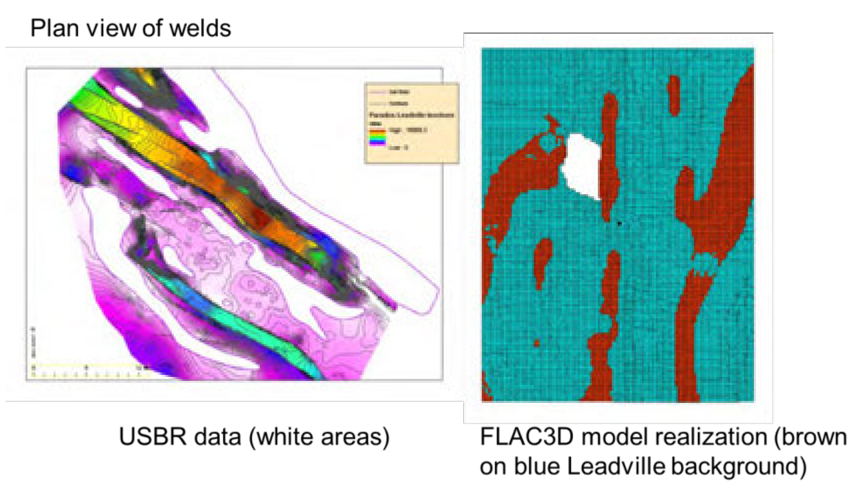



***Figure 10 Welds representation—plan view.***

The fault sections with offset larger than 500 ft are considered to be impermeable. These impermeable faults are represented in plan view in Figure 11.

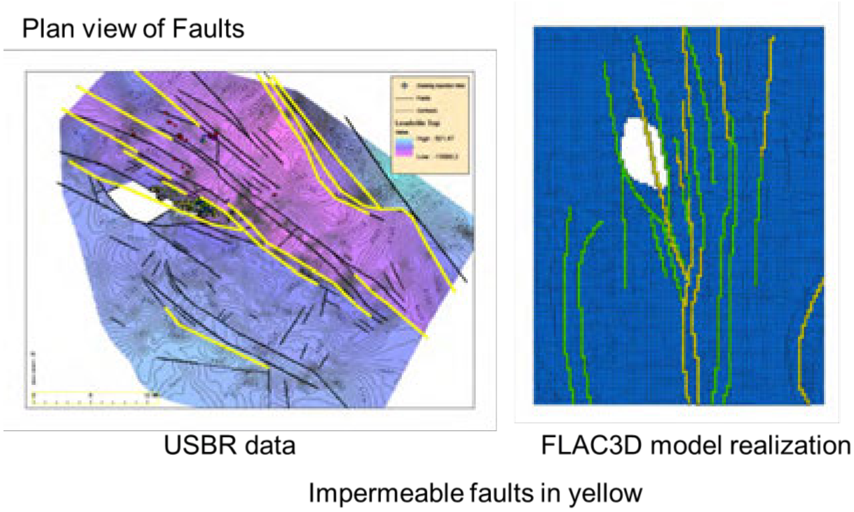



***Figure 11 Plan view of impermeable faults.***

The wellhead pressure prediction for Model 4 is compared to the pressure data in Figure 12.

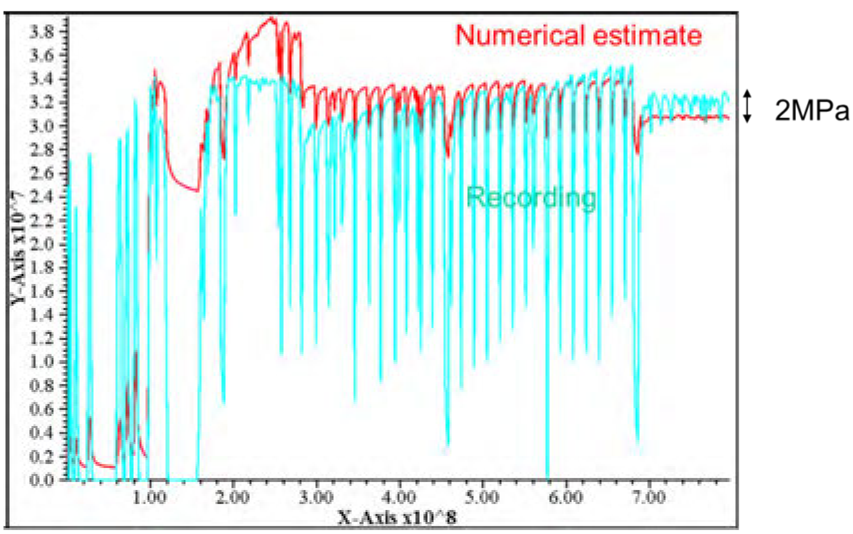



***Figure 12 Wellhead pressure [Pa] versus time [sec]—Model 4.***

A comparison of the simulation results in Figure 12 and Figure 8 indicates that the presence of the welds has the effect of reducing the numerical wellhead pressure prediction by a quasi-uniform value in time. The results make sense. Indeed, since the welds act as openings to permeable regions in the Upper, the flow of fluid is less confined, and the pressure level at the well is reduced.

One trend that is not captured in the wellhead pressure prediction is the gradual increase in pressure observed in the mid and last parts of the recording. Model 5 seeks to address this limitation by adding partial confinement to the flow.

The pressure results for the scenario that considers the impermeable faults sections shown in yellow in Figure 11 are plotted in Figure 13.

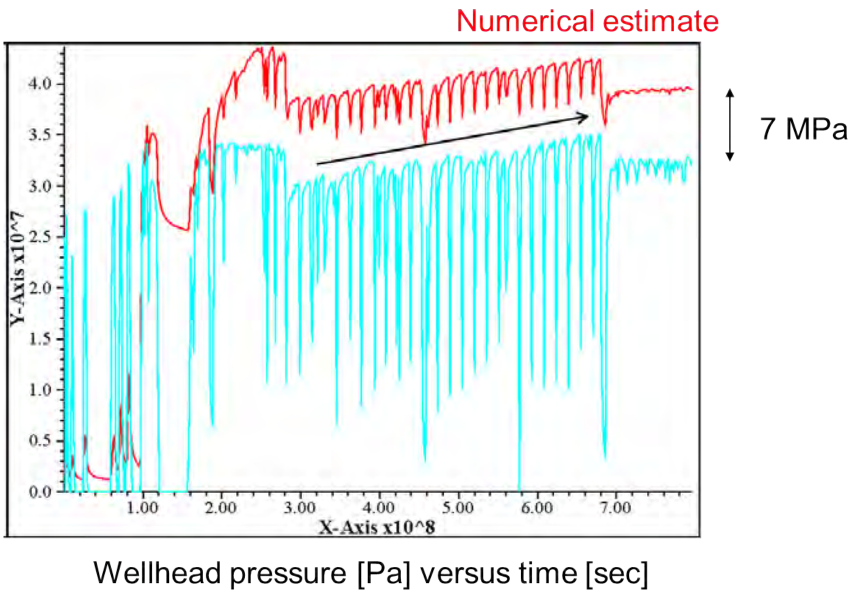



***Figure 13 Wellhead pressure [Pa] versus time [sec]—Model 5.***

The trends obtained in the pressure simulation results for Model 5 appear to match the data quite well, except for a shift in pressure level. As a fresh start, to address this issue, USBR recommended using a realistic value of 42.3 MPa for the in-situ pressure at the injection location (instead of the initial calibrated value of 44.7 MPa). This results in a downward shift of the predicted pressure curve by 2.4 MPa. It was decided to adjust the value of the calibration factor, $\beta$, to accommodate the remaining (~4.6 MPa) pressure shift.

## 2.6 Simulation Results

The numerical prediction of wellhead pressure at PVU-1 for the five permeability scenarios suggests that:

- the existing permeability of the Upper has little influence on the results;
- the presence of the Welds has also little impact;
- major faults are probably not all impermeable; and
- major fault sections with large offsets (> 500 ft) reproduce the trend of an overall pressure increase in the data.

Model 5 could be calibrated to provide a reasonable fit to the data by adjusting the coefficient of the well pressure correction term, $\beta$ (an adjustment of the coefficient produced a shift in the pressure curve).

## 2.7 Calibration Process

After the location of the five additional wells was confirmed by USBR, a new mesh with an adjusted footprint was generated to accommodate all wells while limiting artificial boundary effects (Mesa-1 and Mesa-2 were located too close to the model boundary in the previous model). The mesh footprint is shown in Figure 14.

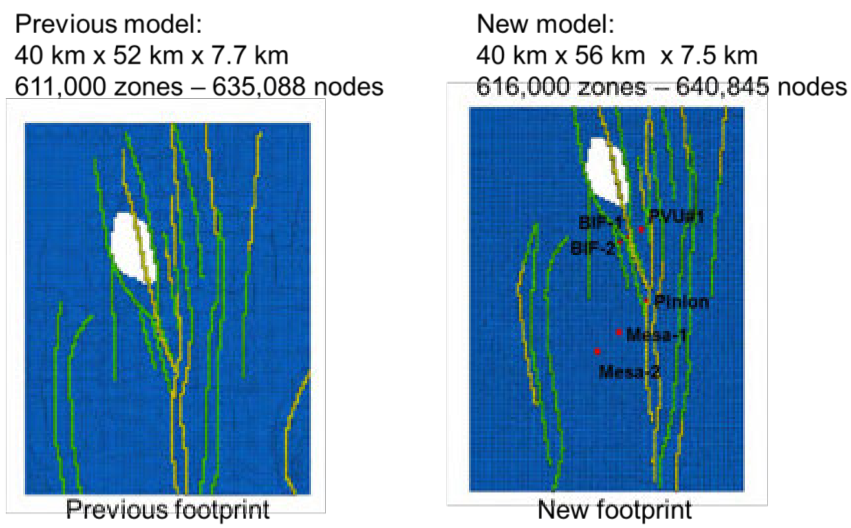



***Figure 14 Mesh footprint, Leadville background with impermeable faults shown in yellow.***

The new mesh was used to complete the PVU-1 model calibration, documented in PR4. The calibration results, obtained using $\beta = 0.78$ are shown in Figure 15.

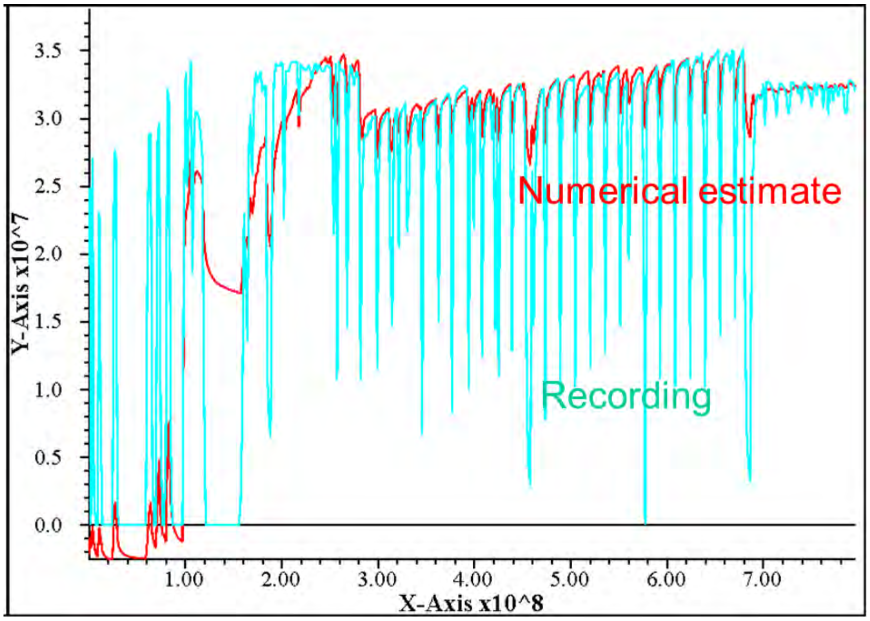



***Figure 15 Wellhead pressure [Pa] versus time [sec]—PVU-1.***

A value of $\beta$ smaller than one accounts for the fact that the bottom boundary of the Leadville is leaky, and only a portion of the injected fluid propagates radially in the Leadville (the well pressure correction, with $\beta = 1$, corresponds strictly to radial flow in the Leadville).

## 3.0 INJECTION PREDICTIONS

The results of injection simulation for the six wells and an injection period of 50 years are documented in PR4 (see also the latest results in PR7). A target wellhead pressure of 34.5 MPa and constant injection rates of 0.0227 $m^3$/sec and 0.0151 $m^3$/sec were specified by USBR. The set objective was to predict which location was most favorable based on the criteria that pressure level should stay below the target value.

With the calibrated *FLAC3D* model and hypotheses used for the simulations, the results show the following:

- For PVU-1, a wellhead pressure of about 35 MPa is predicted after injection is resumed for up to 50 years at a constant rate of 0.0112 $m^3$/s.
- For each of the five additional wells, the predicted wellhead pressure at 25.24 years of injection at the rate of 0.0227 $m^3$/s is predicted to be at least 10 MPa higher than the target pressure of 34.5 MPa.
- If injection at the rate of 0.0151 $m^3$/s is used: Mesa-1 and Mesa-2 are the only two locations where the wellhead pressure is predicted to stay below the target value after 50 years. Note: These are also the shallowest injection sites (3.66 km and 3.73 km, respectively).

The wellhead pressure predictions at 25.24 years and 50 years of injections for the six locations in the latest instance of the Paradox Valley model are listed in Table 2. To produce these results (see PR6), the USBR rate data is used to simulate injection at PVU-1 for the first 25.24 years, and a rate of 0.0112 $m^3$/sec is used after that. Also, a constant injection rate of 0.0151 $m^3$/sec is used for BIF-1, BIF-2, Mesa-1, Mesa-2, and Pinion Ridge.

***Table 2 Wellhead Pressure prediction [MPa] at 25.24, 50 Years of Injection***

| | 25.24 year | 50 year |
|---|---|---|
| PVU-1 | 32.7 | 34.9 |
| BIF-1 | 47.5 | 49.4 |
| BIF-2 | 34.6 | 36.4 |
| Mesa-1 | 29.3 | 30.3 |
| Mesa-2 | 27.9 | 28.8 |
| Pinion Ridge | 43.5 | 45.1 |

## 4.0 HEAVE PREDICTIONS

Fluid mechanical injection simulations are carried out for the six well locations using the Paradox Valley model, and surface heave is evaluated. Each well is considered individually, using the current site selection in the model, and injection is simulated for up to 50 years.

The USBR rate data is used to simulate injection at PVU-1 for the first 25.24 years, and a rate of 0.0112 $m^3$/s is used after that. A constant injection rate of 0.0151 $m^3$/s is used for BIF-1, BIF-2, Mesa-1, Mesa-2, and Pinion Ridge.

The heave induced by the injection was evaluated after specifying the initial in-situ stress state in the model. In the calculation, an in-situ water table is assumed that matches the 42.3 MPa in-situ pressure at the injection location in PVU-1. The initial stress state corresponds to the USBR specifications. In the Salt, the initial stress state is assumed to be isotropic. In all other layers, the maximum horizontal effective stress is set equal to the vertical effective stress, and the minimum horizontal effective stress is assumed to be equal to 0.32 times the vertical effective stress. The value $K_0 = (1-\sin\phi)/(1+\sin\phi) = 0.32$ corresponds to a state of incipient failure, consistent with a cohesionless Coulomb criterion with a friction angle of 31 degrees (USBR data). The direction of maximum (compressive) effective stress in-situ is rotated 25.2 degrees anticlockwise from the Paradox valley axis, which is oriented north in the model.

Initially, to establish the in-situ stress state, it was assumed that all layers behave elastically (according to the premises for this project). However, to enforce an equilibrium stress state in the model while maintaining the specified value of $K_0$ value everywhere in the Leadville proved to be a challenging task (the effort is documented in PR6). To tackle this issue, a Mohr-Coulomb constitutive model with zero cohesion, zero dilation, and a friction angle of 31 degrees was assigned to the Leadville, and the model was run to equilibrium under gravity. The horizontal stresses were specified based on vertical stresses and assumed in-situ water pressure, and the model was run to equilibrium again. In this procedure, the shear modulus in the salt was set to a low value to achieve an isotropic stress state in this material. Finally, an elastic constitutive model with associated properties was reassigned in the Leadville, and a realistic shear modulus was restored in the salt. After application of this procedure, the in-situ stress state satisfies the conditions specified by the USBR. Also, as specified for this project, the stresses and deformations induced by injection in the model will be consistent with the theory of poro-elasticity.

Two sets of simulations were conducted. In the first set (reference case), a Biot coefficient of $\alpha = 1$ was used for all the layers. In the second set of simulations, a Biot coefficient of $\alpha = 0.65$ (same as the value documented by Detournay and Cheng (1993) for Rhur sandstone) was adopted for Upper, Welds, Sedimentary, and Upper Precambrian layers, and the value $\alpha = 0.55$ was assigned to the Leadville (Limestone). The heave predictions for up to 50 years of injection at the six well locations are documented in PR7. Simulation results of surface heave and excess pore pressure in the Leadville are shown for PVU-1 after 25.24 years of injection (using the USBR injection data) in Figure 16.

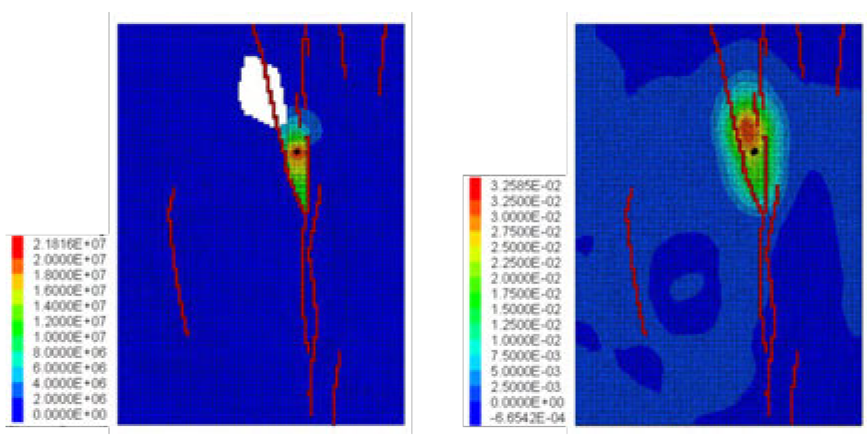



***Figure 16 Simulation results for PVU-1 at 25.24 years of injection. Excess pore pressure [Pa] (left); surface heave [m] (right).***

The results in Figure 16 indicate that the location of maximum predicted surface heave does not necessarily correspond to the location of maximum excess pressure at the well location (indicated by a black dot on the plots). This is an interesting, but not surprising fact, because the elastic properties are not uniform in the model. Additional examples are provided in PR6 and PR7.

The maximum surface heave (centimeter) predicted with the latest instance of the Paradox Valley model for the six simulation cases after 25.24 years of injection are listed in Table 3.

***Table 3 Maximum Value of Surface Heave [cm] in the Model, 25.24 Years of Injection***

| | $\alpha = 1$ | $\alpha < 1$ |
|---|---|---|
| **PVU-1** | 3.5 | 2.1 |
| **BIF-1** | 2.6 | 1.6 |
| **BIF-2** | 2.8 | 1.7 |
| **Mesa-1** | 4.9 | 3.1 |
| **Mesa-2** | 3.6 | 2.3 |
| **Pinion Ridge** | 8.3 | 5.4 |

The maximum surface heave estimates at 50 years of injection are listed in Table 4.

***Table 4 Maximum Value of Surface Heave [cm] in the Model, 50 Years of Injection***

| | $\alpha = 1$ | $\alpha < 1$ |
|---|---|---|
| **PVU-1** | 7.9 | 4.9 |
| **BIF-1** | 5.3 | 3.4 |
| **BIF-2** | 5.6 | 3.6 |
| **Mesa-1** | 8.6 | 5.5 |
| **Mesa-2** | 6.6 | 4.2 |
| **Pinion Ridge** | 14.7 | 9.4 |

The results in Table 3 and 4 are documented in PR7.

## 5.0 RISK OF INDUCED SEISMICITY

The risk of induced seismicity is evaluated with the latest instance of the *FLAC3D* Paradox Valley model. The risk, based on an elastic stress state, is quantified using a Factor of Safety (FoS) with respect to fluid pressure.

The FoS index with respect to fluid pressure is introduced as:

$$FoS = \frac{p_{cr}}{p} \tag{1.5}$$

where $p_{cr}$ is the critical fluid pressure at the onset of slip, based on a Coulomb criterion, and $p$ is the fluid pressure under current conditions.

Yield is predicted to occur (based on an elastic stress distribution) if FoS ≤ 1. The potential occurrence of slip, as detected by the FoS Index, is associated with a risk of seismicity in this project.

The Coulomb criterion (negative compressive stress convention) is:

$$(\sigma_1 + p_{cr}) - (\sigma_3 + p_{cr}) N_\phi + 2c\sqrt{N_\phi} = 0 \tag{1.6}$$

where $\sigma_1 < \sigma_3$, $c$ is cohesion, $\phi$ stands for assumed friction angle, and

$$N_\phi = \frac{1+\sin\phi}{1-\sin\phi} = \left[\sqrt{1+\tan^2\phi} + \tan\phi\right]^2 = \tan^2\left(\frac{\pi}{4} + \frac{\phi}{2}\right) \tag{1.7}$$

Hence:

$$FoS = \frac{\sigma_1 - \sigma_3 N_\phi + 2c\sqrt{N_\phi}}{(1-N_\phi)(p_{ini} + p_{excess})} \tag{1.8}$$

### 5.1 Yield Index limitation

The Factor of Safety with respect to fluid pressure, if less than 1, is taken as an indicator of possible yield in the model. While the index, based on elastic stresses, is quite reliable to detect the onset of yield, the prediction of the extent of the yielding region in the model may be inaccurate because elasto-plastic readjustments would modify the stress-state in the model and make the indicator values unreliable over the whole region initially detected as yielding.

The calculated FoS values are the zone values in the model; they do not consider the well pressure correction, introduced to account for the small size of the well radius, compared to the large horizontal zone size (400 m x 400 m) used in the model. In particular, the potential slip failure in the vicinity of the well is not captured at the scale of the discretization used in the model.

Contours of FoS index smaller than 1 in the Leadville for PVU-1 are plotted in Figure 17 at 5 and 6 years after injection. Note that the minimum FoS value on the plots is 0.98 at 5 years and 0.96 at 6 years.

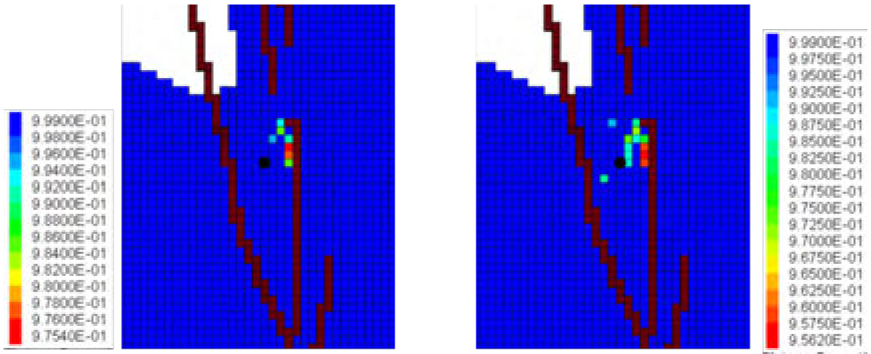



***Figure 17 Contours of FoS Index in the Leadville for PVU-1 at year 5 (left) and year 6 (right).***

At 5 years, the model predicts the occurrence of slip northeast of the well location in Figure 17 (the PVU-1 well marked as a black dot). At 6 years, slip is detected at a location southwest of the well on the plot.

Contour plots at 25.24 years and 50 years are shown in Figure 18. The minimum contour value used in the scale is the minimum FoS value calculated at 25.24 years of injection.

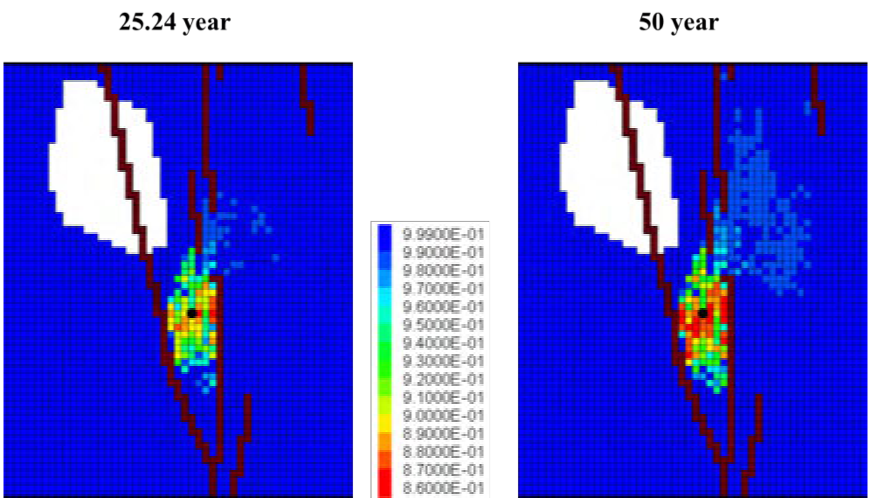



***Figure 18 Contours of FoS Index in the Leadville for PVU-1. After 25.24 years (left) and 50 years (right).***

The plots indicate that the potential for slip at 25.24 years of injection (measured by the Factor of Safety with respect to fluid pressure) is as low as 0.86 in the vicinity of the impermeable fault, shown to the right of PVU-1 in the left plot. Also, slip is predicted to occur at locations northeast of the well (marked by a black dot on the figure). Additional simulation results are included in PR7.

The minimum FoS estimates in the Leadville (rounded to two digits) at 25.24 years of injection for the six well locations are listed in Table 5 for two Biot coefficient cases (see Section 4 for details).

***Table 5 Minimum Recorded Value of FoS in Leadville at 25.24 Years of Injection***

| | $\alpha = 1$ | $\alpha < 1$ |
|---|---|---|
| **PVU-1** | 0.86 | 0.79 |
| **BIF-1** | 0.88 | 0.82 |
| **BIF-2** | 0.96 | 0.89 |
| **Mesa-1** | 0.99 | 0.99 |
| **Mesa-2** | 0.92 | 0.84 |
| **Pinion Ridge** | 1.00 | 0.90 |

The FoS results at 50 year of injection are recorded in Table 6.

***Table 6 Minimum Recorded Value of FoS in Leadville at 50 Years of Injection***

| | $\alpha = 1$ | $\alpha < 1$ |
|---|---|---|
| **PVU-1** | 0.85 | 0.77 |
| **BIF-1** | 0.87 | 0.78 |
| **BIF-2** | 0.95 | 0.87 |
| **Mesa-1** | 0.98 | 0.97 |
| **Mesa-2** | 0.91 | 0.83 |
| **Pinion Ridge** | 0.99 | 0.89 |

For the same well location, the minimum FoS value decreases as injection increases, as expected. Also, for the same well location and the same injection time, the minimum FoS value is smaller for smaller values of Biot coefficient. This observation is consistent with the expectation that a higher value of Biot coefficient generates more stress confinement in response to fluid injection, and thus a lower potential for slip (according to a Coulomb criterion).

## 6.0 EXPLORATION/VERIFICATION TESTS

A series of simulations were performed and documented in PR1 and in PR5 to confirm the Paradox Valley model results. The following items were addressed:

- A simple *FLAC3D* model with three horizontal layers of contrasting permeability values was setup and run to further explore the excess fluid pressure behavior with horizontal isobar observed in the Sedimentary layer of the *FLAC3D* Paradox Valley model. In the simulation, quasi-vertical isobars were observed with a vertical character more pronounced in the long term (tens of years) and away from the injection site. The behavior is reasonable: the pressure contours away from the injection point are almost vertical (although the Sedimentary horizon is relatively impermeable) because the fluid diffusion also takes place in the vertical direction from permeable and pressured Leadville into the sedimentary. Also, at a distance that is large compared to the thickness of three layers, the details of the mode of injection are lost to the fluid flow (injection appears to originate over the full height of the three layers instead of a single zone in the Leadville). On the other hand, the specific discharge magnitude in a specific layer reflects the permeability in that layer. In particular, it is smallest in the Sedimentary layer where permeability is lowest. The results are documented as part of PR1.
- The difference in simulated wellhead pressures at the BIF-1 and BIF-2 locations after 50 years of continuous injection at a rate of 0.0151 $m^3$/sec (about 13 MPa larger for BIF-1) appeared surprisingly large, given the relative proximity (about 1.4 km) of the two wells. Exploratory runs were performed a) adjusting the distance between the wells in the Paradox Valley model, and b) using a simple model geometry (horizontal layer, strait impermeable fault). The difference in wellhead pressure prediction was attributed to the closer proximity of BIF-1 (compared to BIF-2) to an impermeable fault. The runs also demonstrated a good consistency of results with respect to a variation of well locations in the Paradox Valley model.
- Using the Paradox Valley model, exploration runs were performed to investigate if the PVU-1 injection activity influences the wellhead pressure behavior at BIF-1 and BIF-2. With the hypothesis adopted in the model (no change of porosity/permeability induced by deformation), no cross-influence was expected because BIF-1 and BIF-2 are separated from PVU-1 by an impermeable fault in the model, and this was confirmed by the simulation results.
- A simple *FLAC3D* model with one horizontal layer, using the Leadville properties and the same zone size (400 m x 400 m x 100 m) as in the Paradox valley model, was used to simulate injection for up to 50 years at a rate of 0.0151 $m^3$/sec. The fluid pressure was monitored at various locations in the model and compared to the Theis transient analytical solution. The well pressure prediction, using the well correction, was monitored and compared to the Theis solution, using the same assumed well radius. A very good match between numerical and analytical

solutions was obtained over the 50-year injection period. In particular, the relative discrepancy between well pressure prediction and Theis solution was less than 2%.

## 7.0 DISCUSSION OF RESULTS

The results of injection simulations at six potential well sites in the calibrated *FLAC3D* Paradox Valley model (see Figure 18) show that, with the data used in the work, the potential for wellhead pressure to reach the target value of 34.5 MPa is smallest for the locations of Mesa-2 and Mesa-1 and highest for BIF-1 and Pinion Ridge.

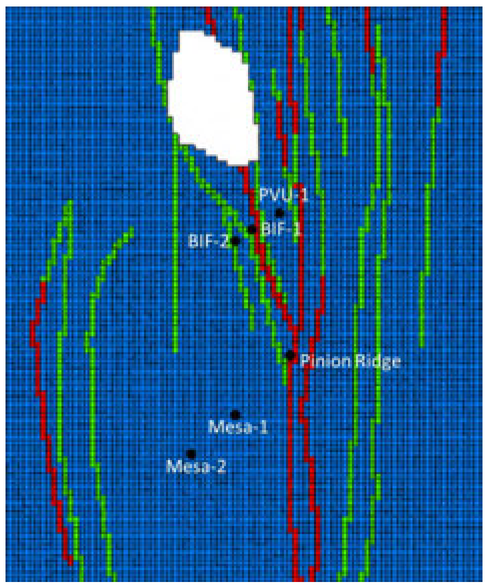



***Figure 19 Well locations in the FLAC3D model.***

The higher estimate of wellhead pressure at BIF-1 and Pinion Ridge is attributed primarily to the close proximity of those wells to impermeable fault sections in the model, and vise-versa for Mesa-1 and Mesa-2.

Also, the potential for slip (at distances larger than 200 m from the well), as measured by the minimum FoS index in the simulations, is smallest for Pinion Ridge and Mesa-1 and largest for PVU-1 and BIF-1.

Finally, the potential for surface heave, as measured by the maximum surface heave in the model, is smaller for BIF-1 and BIF-2 and larger for Pinion Ridge and Mesa-1.

The relatively high heave predicted by injection at Pinion Ridge is attributed to a combination of the location of injection at the edge of the Salt dome feature (see Figure 19) and the relatively high induced fluid pressure (the Salt has a lower density and a higher compliance than the Upper overburden).

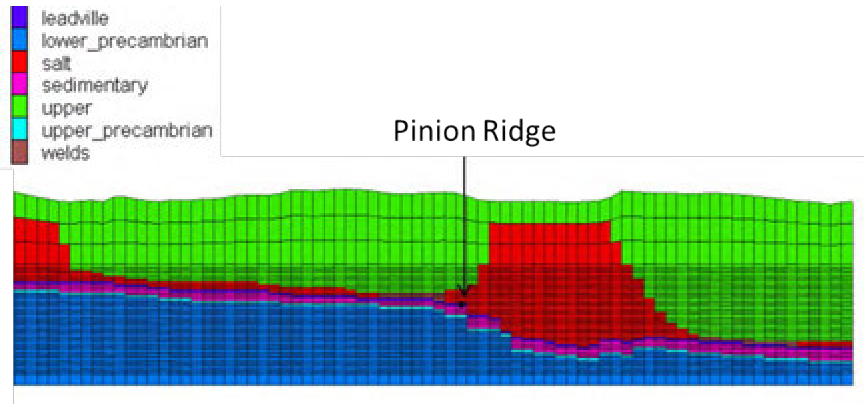



***Figure 20 Vertical cut showing the stratigraphy near Pinion Ridge.***

## 8.0 CONCLUSIONS AND RECOMMENDATIONS

The numerical results from the current version of the calibrated *FLAC3D* Paradox Valley model indicate that, with the model and properties used for the simulations, none of the six well locations meets simultaneously a minimum value for the three evaluation parameters investigated in this work: 1) ratio of wellhead pressure to target pressure; 2) FoS index; and 3) surface heave.

The ratio of wellhead pressure to target pressure is used as an indicator of the risk of induced fracturing at the injection depth. The FoS index quantifies the potential risk of slip-induced seismicity. The surface heave gives an indication of potential differential surface displacements that could affect the integrity of surface infrastructures.

The results of the quantification (listed in PR7) are illustrated in Figure 21.

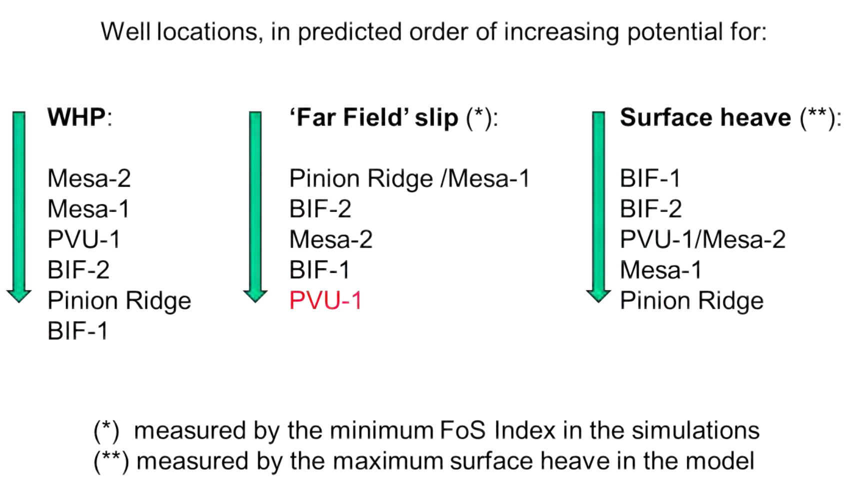



***Figure 21 Summary of quantification analysis for up to 50 years of injection.***

In particular, according to the model predictions, Pinion Ridge and Mesa-1 have a low potential for slip, but also have the highest potential for heave induced by injection. Pinion Ridge and Mesa-1 would be good candidates for brine reinjection if the primary concern is to minimize the potential for slip. However, they would be the worst candidates of the six if a change in surface elevation was a concern for the stability of existing surface structures. Also, BIF-1 has the highest predicted wellhead pressure and the lowest value of heave associated with injection. Interestingly, the modeled PVU-1 (existing well) is estimated to have the highest potential for slip, according to the FoS measure based on elastic stresses.

The results reported in this document are intended to serve as guidance for comparing potential second injection well sites only. Due to the limited formation property data and other data, the accuracy of modeling predictions is likely to be limited. To improve the quality of the model predictions, it is recommended to run the simulations using an elasto-plastic mechanical framework instead of relying on elasticity for the prediction of potential slip induced by injection. Also, a model of finer discretization around the well location will likely be able to capture aspects of the physics more accurately.

## 9.0 REFERENCES

Detournay, E. and A.H.-D. Cheng (1993) "Fundamentals of Poroelasticity, Comprehensive Rock Engineering," Vol.2, Chapter 5, editor J.A. Hudson, Pergamon Press, Oxford.

Itasca Consulting Group, Inc. (2012) *FLAC3D — Fast Lagrangian Analysis of Continua in Three-Dimensions,* Ver. 5.0. Minneapolis: Itasca.

Itasca Consulting Group, Inc. (2012) *FLAC3D*, Ver. 5.0 — ***Fluid-Mechanical Interaction*** manual, Minneapolis: Itasca.

## 10.0 APPENDIX A: PARTIAL UNCOUPLING

Substitution of the fluid mass balance $-q_{i,i} + q_v = \frac{\partial \zeta}{\partial t}$ in the constitutive equation for the pore fluid $\frac{1}{M}\frac{\partial p}{\partial t} = \frac{\partial \zeta}{\partial t} - \alpha \frac{\partial \varepsilon}{\partial t}$ gives the expression for the fluid continuity equation:

$$\frac{\partial p}{\partial t} = M\left[\left(-q_{i,i} + q_v\right) - \alpha \frac{\partial \varepsilon}{\partial t}\right] \tag{1.9}$$

This equation shows that the diffusion of pore pressure is coupled with the rate of change of volumetric strain.

Combination of Equation (1.9) with Darcy's law $q_i = -k\left[p - \rho_f x_j g_j\right]_{,i}$ yields

$$\frac{\partial p}{\partial t} = kM\left(\nabla^2 p + \frac{q_v}{k}\right) - \alpha M \frac{\partial \varepsilon}{\partial t} \tag{1.10}$$

Following Terzaghi, for the case of predominantly uniaxial elastic deformation in the *z*-direction, Hooke's law gives:

$$\sigma_z + \alpha p = \alpha_1 \varepsilon_z \tag{1.11}$$

with

$$\alpha_1 = K + 4G/3 \tag{1.12}$$

Using Equation (1.11), the volumetric strain can be eliminated from Equation (1.10):

$$\frac{\partial p}{\partial t} = \frac{kM\alpha_1}{\alpha_1 + \alpha^2 M}\left(\nabla^2 p + \frac{q_v}{k}\right) - \frac{\alpha M}{\alpha_1 + \alpha^2 M}\frac{\partial \sigma_z}{\partial t} \tag{1.13}$$

As a first approximation, for a medium in quasi-static equilibrium: $\partial\sigma_z / \partial t = 0$. The last term in Equation (1.13) can be neglected, and the uncoupled diffusion equation is obtained:

$$\frac{\partial p}{\partial t} = c\left(\nabla^2 p + \frac{q_v}{k}\right) \tag{1.14}$$

where $c$ is the true diffusivity:

$$c = kM^a \tag{1.15}$$

and $M^a$ is the apparent Biot modulus:

$$M^a = \frac{M\alpha_1}{\alpha_1 + \alpha^2 M} \tag{1.16}$$

The apparent Biot modulus takes into account the compliance of the fluid and the solid matrix; an alternate expression for this term is:

$$M^a = \frac{1}{S} \tag{1.17}$$

where $S$ is the storage coefficient:

$$S = \frac{1}{M} + \frac{\alpha^2}{\alpha_1} \tag{1.18}$$

## 11.0 APPENDIX B: COMPARISON WITH THEIS SOLUTION

A comparison of fluid pressure prediction with analytical solution is analyzed.

Constant injection in a horizontal Leadville layer of thickness 100 m is simulated for up to 50 years at a rate of 0.0151 $m^3$/s. Again, we use the same zone size and properties as in the Paradox Valley model.

The pore pressure is fixed at zero on the model boundaries. The pore pressure is monitored at gridpoints located 600 m, 1000 m, 1400 m, 2200 m, 4200 m, 6200 m, and 8200 m from the center of the injection zone. The values are compared to the Theis analytical solution:

$$p_{ana} = \frac{Q}{4\pi k^{Flac} h} E_1(u) + p_0 \tag{1.19}$$

where

$$u = \frac{r^2}{4ct} \tag{1.20}$$

and $E_1$ is the exponential integral.

The following Leadville quantities are used:

| | |
|---|---|
| $r$ [m] | radial distance from well axis |
| $c = 0.21 \text{ m}^2/\text{s}$ | diffusivity |
| $t$ [sec] | time |
| $Q = 0.0151 \text{ m}^3/\text{sec}$ | flow rate |
| $k = 4.45.10^{-12} \text{ m}^2 / \text{Pa.sec}$ | mobility coefficient |
| $h = 100$ m | layer thickness |
| ($p_0 = 0$ Pa | far field pressure ) |

A plan view of the *FLAC3D* model is shown in Figure B1 with contours of excess pore pressure [Pa] at 50 years of injection.

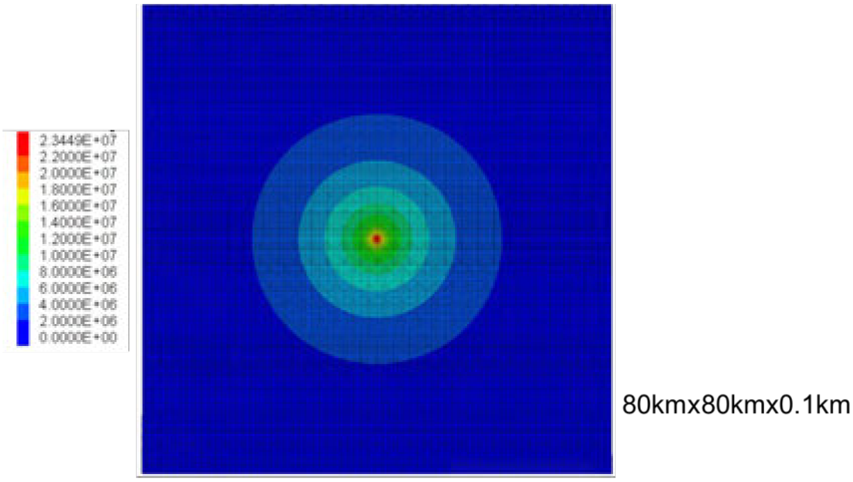



***Figure B1 Pore pressure contours at 50 years of injection.***

A close-up view of the *FLAC3D* model near the well is shown in Figure B2 together with the location of the monitoring points.

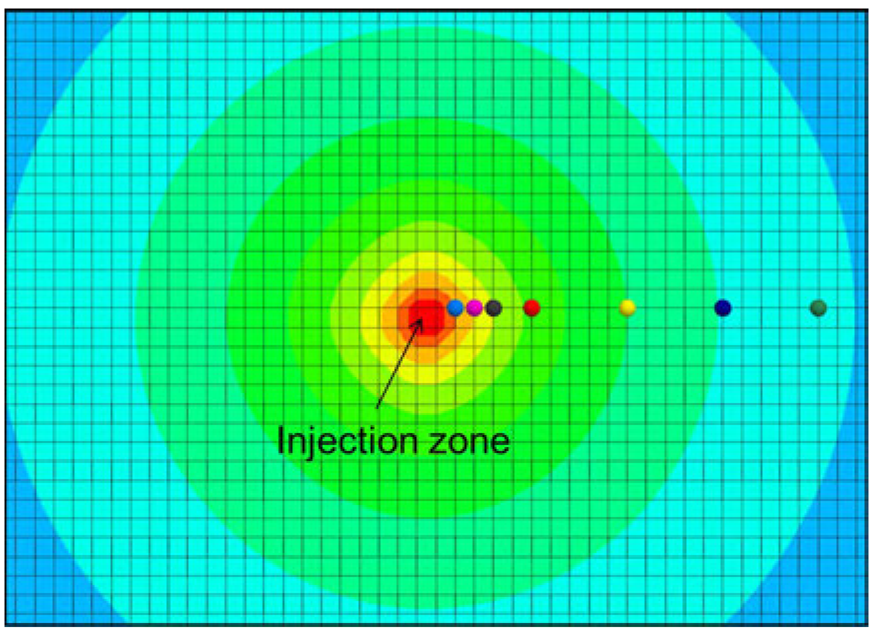



***Figure B2 Location of monitoring points in the FLAC3D model.***

The numerical fluid pressure predictions at the monitoring points are compared to the Theis analytical solution in Figure B3.

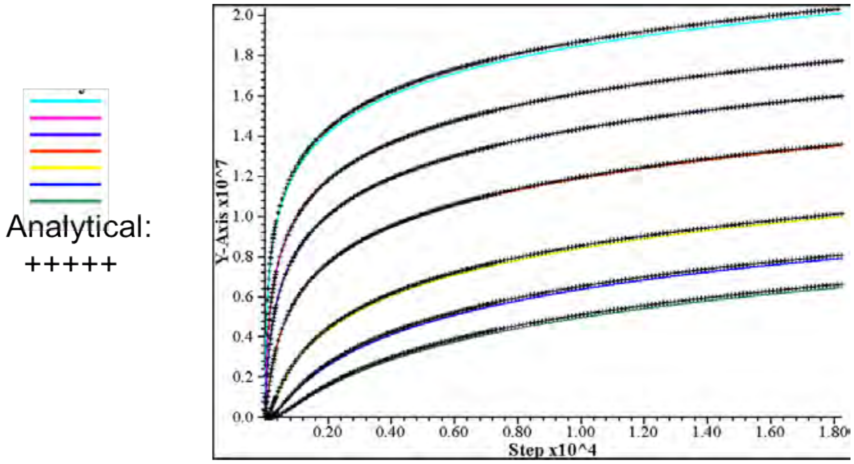



***Figure B3 Excess pore pressure [Pa] versus time [sec] at seven monitoring points.***

**Well Pressure Prediction**

In the Paradox Valley model, the excess pressure at the well is evaluated as the sum of the zone pressure at the injection location and a well pressure correction (to account for the relatively large zone size compared to well radius).

The well pressure correction is defined as:

$$\Delta p_w = \alpha \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r} \qquad (1.21)$$

where the following quantities are used for the test:

| | |
|---|---|
| $r_0 = \sqrt{2.*200^2 + 50^2}$ m | distance between injection zone center and its nodes |
| $r = 0.5$ m | assumed well radius |
| $h = 100$ m | injection interval |
| $k = 4.45.10^{-12}$ m$^2$ / Pa.sec | Leadville mobility coefficient |
| $Q = 0.0151$ m$^3$/sec | flow rate |
| $\alpha$ | calibration parameter |

A comparison between the well pressure prediction, obtained by applying the above correction to the injection zone value, and Theis solution, with the same assumed value of well radius is shown in Figure B4.

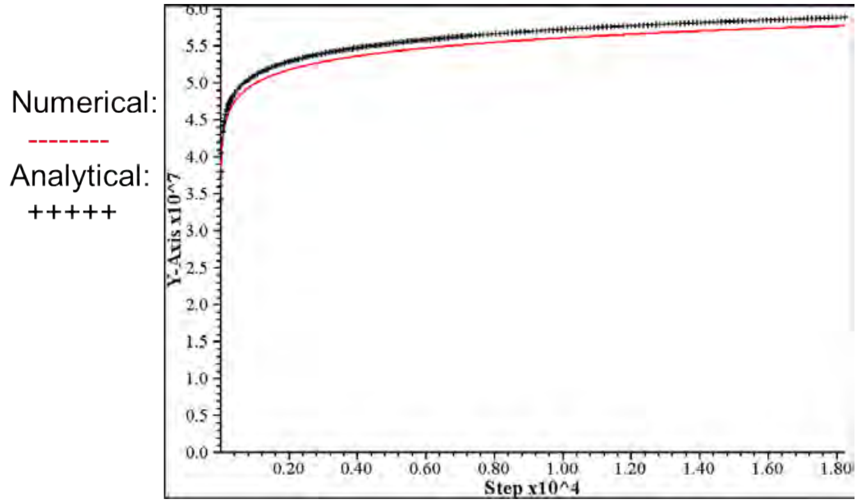



***Figure B4 Comparison of well pressure prediction and Theis solution [Pa] versus time [sec].***

As may be seen from the results of the comparison between numerical predictions and Theis solution presented above:

- a good match between numerical and analytical pressure values is obtained at the monitoring points over the 50-year injection period, even at nodes close to the injection zone; and
- the well pressure (zone pressure with applied well correction) is also captured reasonably well in the model; for a well radius of 0.5 m, the relative discrepancy with Theis solution is less than 2%.

## 12.0 APPENDIX C: POWERPOINT PROGRESS REPORTS: PR1 – PR7

# Paradox Valley Project

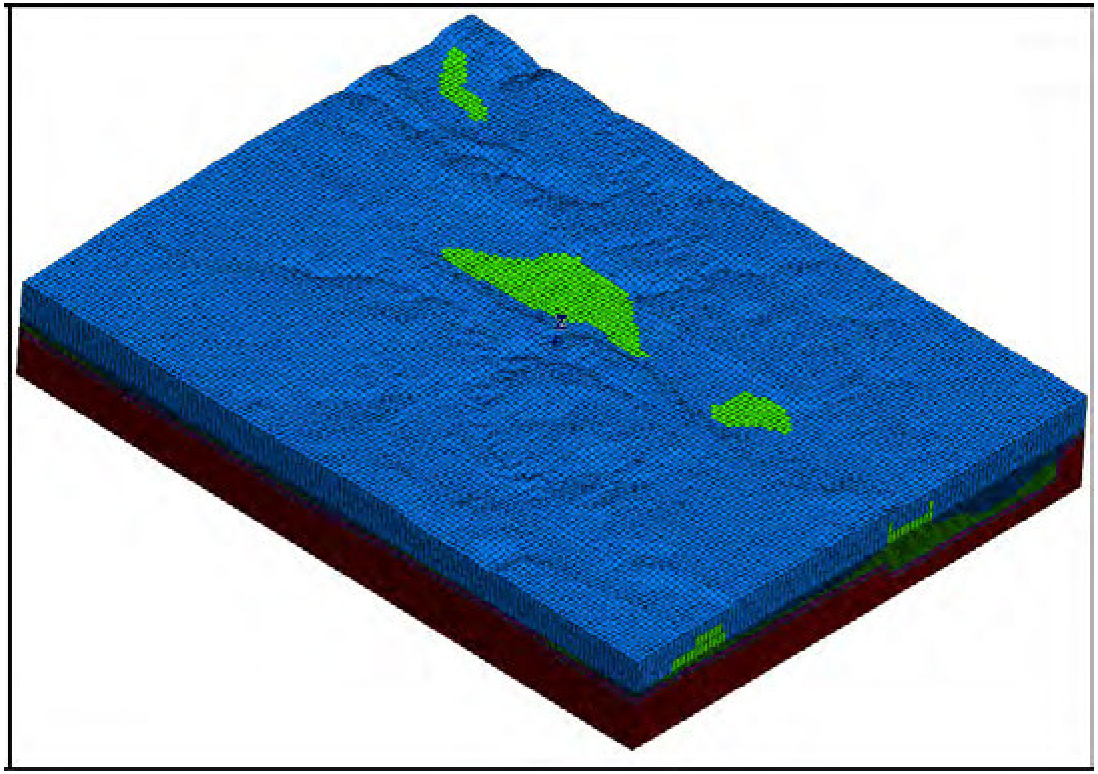
## Progress Report to Bureau of Reclamation

December 5, 2016

Christine Detournay, Ed Dzik, Branko Damjanac
Itasca Consulting Group, Inc.

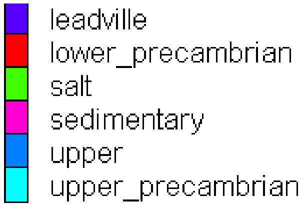
# *FLAC3D* model

6 Layer model

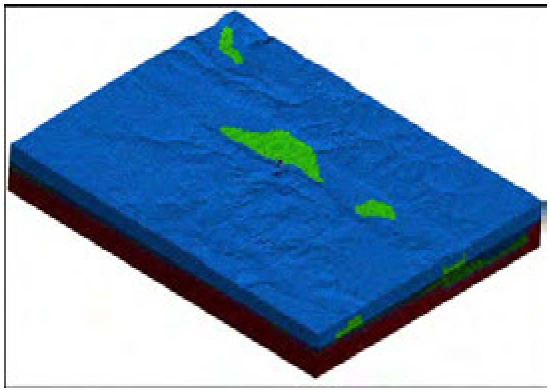


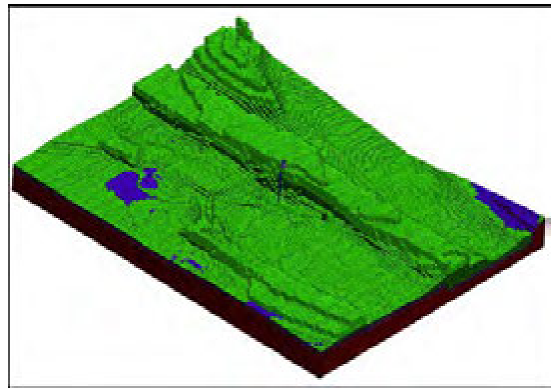
- Upper
- Salt
- Leadville
- Sedimentary
- Upper Precambrian
- Lower Precambrian

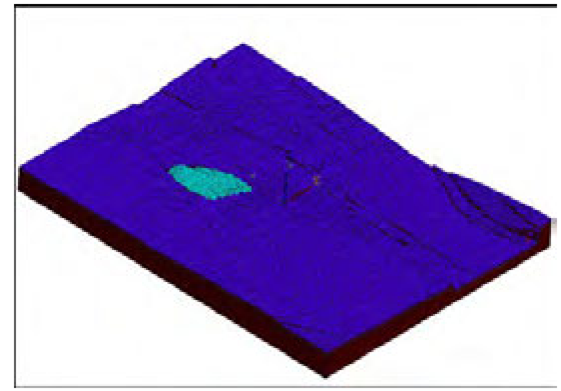
40 km x 52 km x 7.7 km

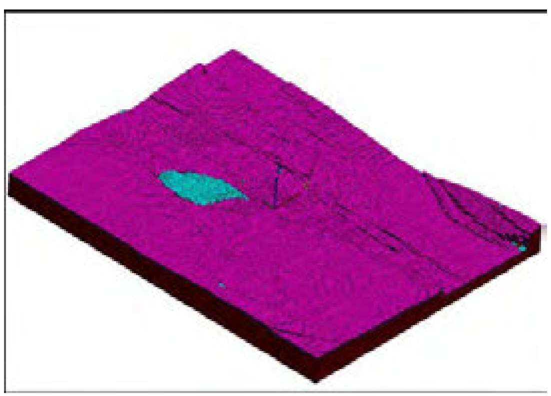


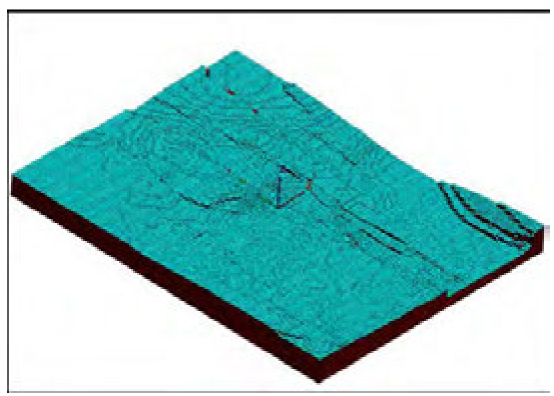

# Layer tops

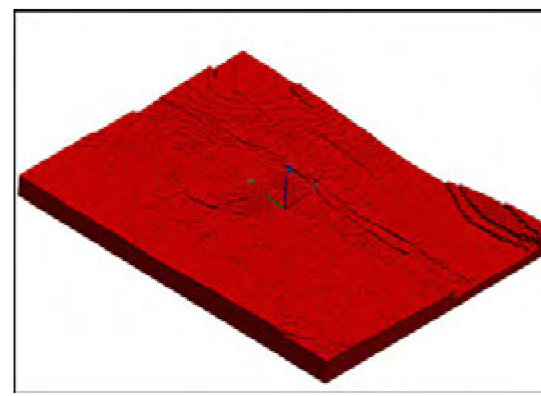

Upper


Salt

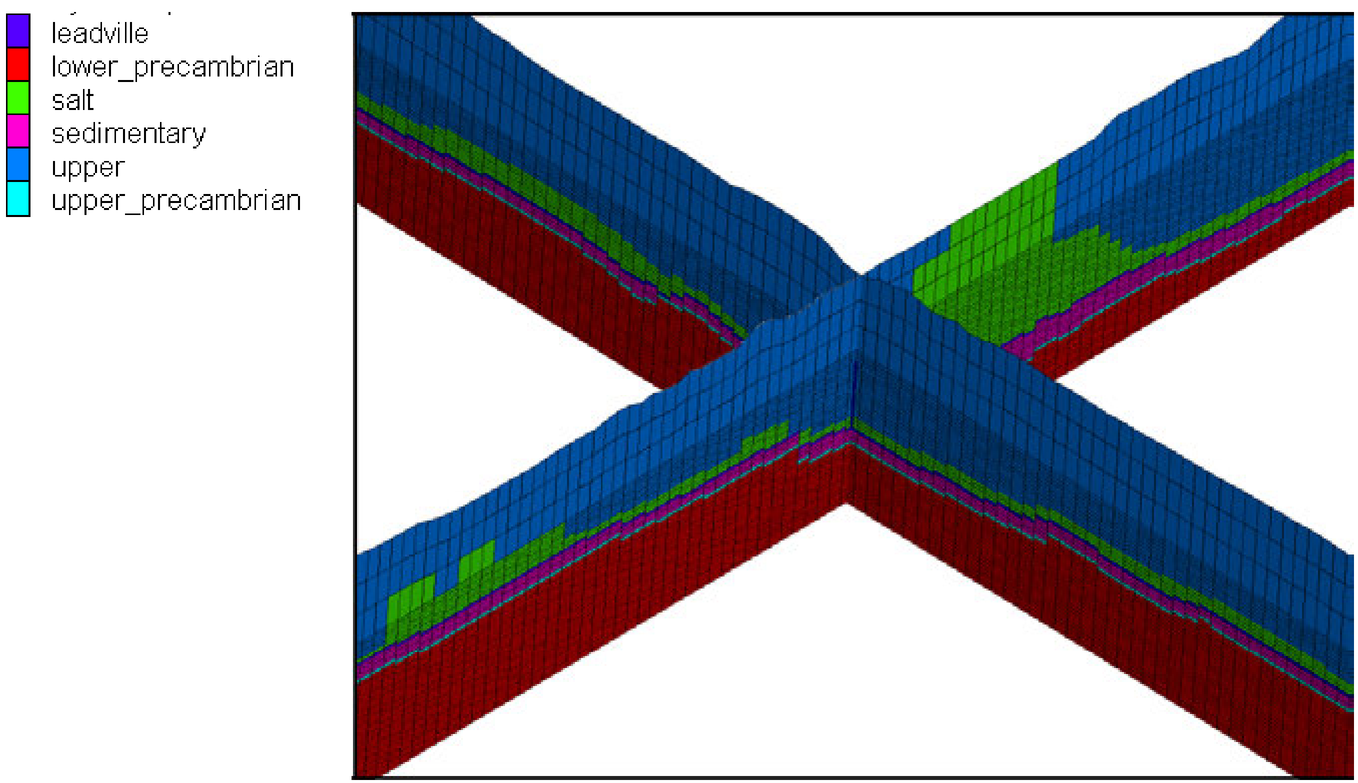

Leadville


Sedimentary


Upper Precambrian


Lower Precambrian

# Stratigraphy at well location




Projection on two orthogonal planes crossing at the well location

# *FLAC3D* model specifics

**Mesh**:
Zone size in Leadville:
100m in vertical direction, 400m x 400m horizontally

611,000 zones - 635,088 nodes

**Modeling methodology**:
Calculation of:
- Excess fluid pressure caused by up to 50 years of injection
- Stress changes and deformations induced by injection

Total fluid pressures and stresses will be evaluated by superposition with initial fluid pressure and insitu stress (this step is not yet included)

# Layer Properties

| Layer | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **Layer description** | Formations above salt | Salt | Leadville | Sedimentary layers below Leadville | Precambrian | Lower Precambrian |
| **Density** | 2.53 g/cm$^3$ | 2.16 g/cm$^3$ | 2.69 g/cm$^3$ | 2.56 g/cm$^3$ | 2.65 g/cm$^3$ | 2.65 g/cm$^3$ |
| **Bulk modulus** | 29.8 GPa | 25.3 GPa | 64.8 GPa | 50.6 GPa | 50.1 GPa | 50.1 GPa |
| **Young's modulus** | 43.1 GPa | 35.8 GPa | 76.2 GPa | 66.8 GPa | 83.0 GPa | 83.0 GPa |
| **Shear modulus** | 17.1 GPa | 14.2 Gpa | 29.2 GPa | 26.1 GPa | 33.9 GPa | 33.9 GPa |
| **Poisson's ratio** | 0.260 | 0.264 | 0.304 | 0.280 | 0.224 | 0.224 |
| **Permeability** | 0.1 mD | 0 mD | 6 mD | 0.1 mD | 1.5 mD | 0 mD |
| **Porosity** | 0.06 | 0 | 0.05 | 0.01 | 0.03 | 0 |
| **Diffusivity (before 1/8/02)** | 0.0019 m$^2$/s | 0 m$^2$/s | 0.20 m$^2$/s | 0.0043 m$^2$/s | 0.051 m$^2$/s | 0 m$^2$/s |
| **Diffusivity (after 1/8/02)** | 0.0020 m$^2$/s | 0 m$^2$/s | 0.21 m$^2$/s | 0.0044 m$^2$/s | 0.053 m$^2$/s | 0 m$^2$/s |

Note: current results assume impermeable formations above salt

# Assumptions

Geometrical data:

- Upper
- Salt
- Leadville → 100 m thick (90m)
- Sedimentary
- Precambrian → 100 m thick (58m)
- Lower Precambrian

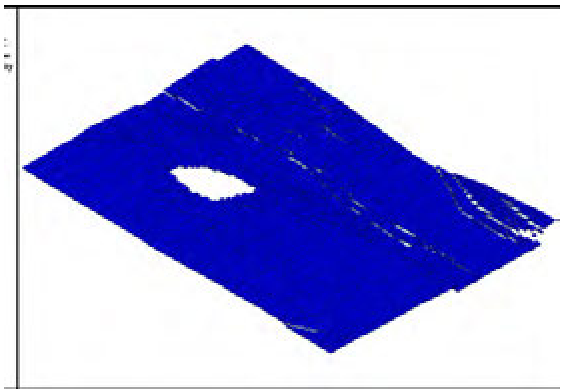
Injection:

in Leadville: 0.01198 m^3/s (719 l/min, 7,000 barrels/day), continuous, up to 50 years

Fluid properties:

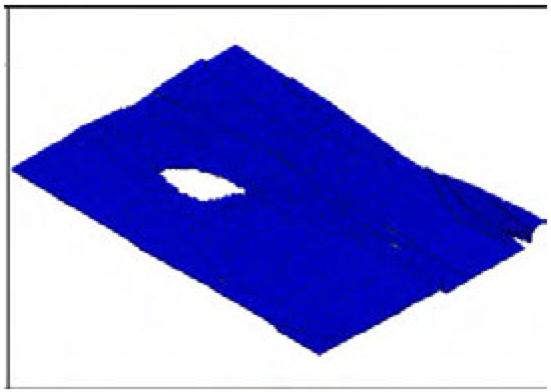
- Brine density: 1173 kg/m^3
- Brine viscosity: 0.001348 Pa.sec

# Permeable layers



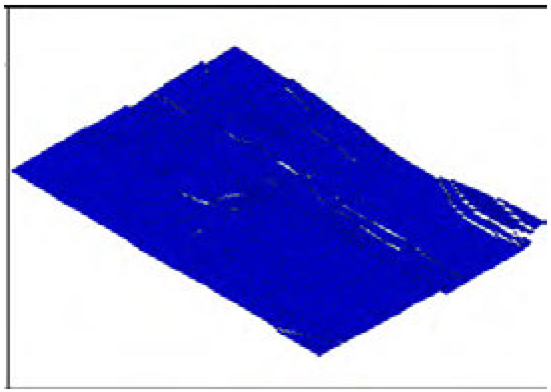
Leadville

k=4.45e-12
m2/Pa.sec



Sedimentary

k=7.41e-14
m2/Pa.sec

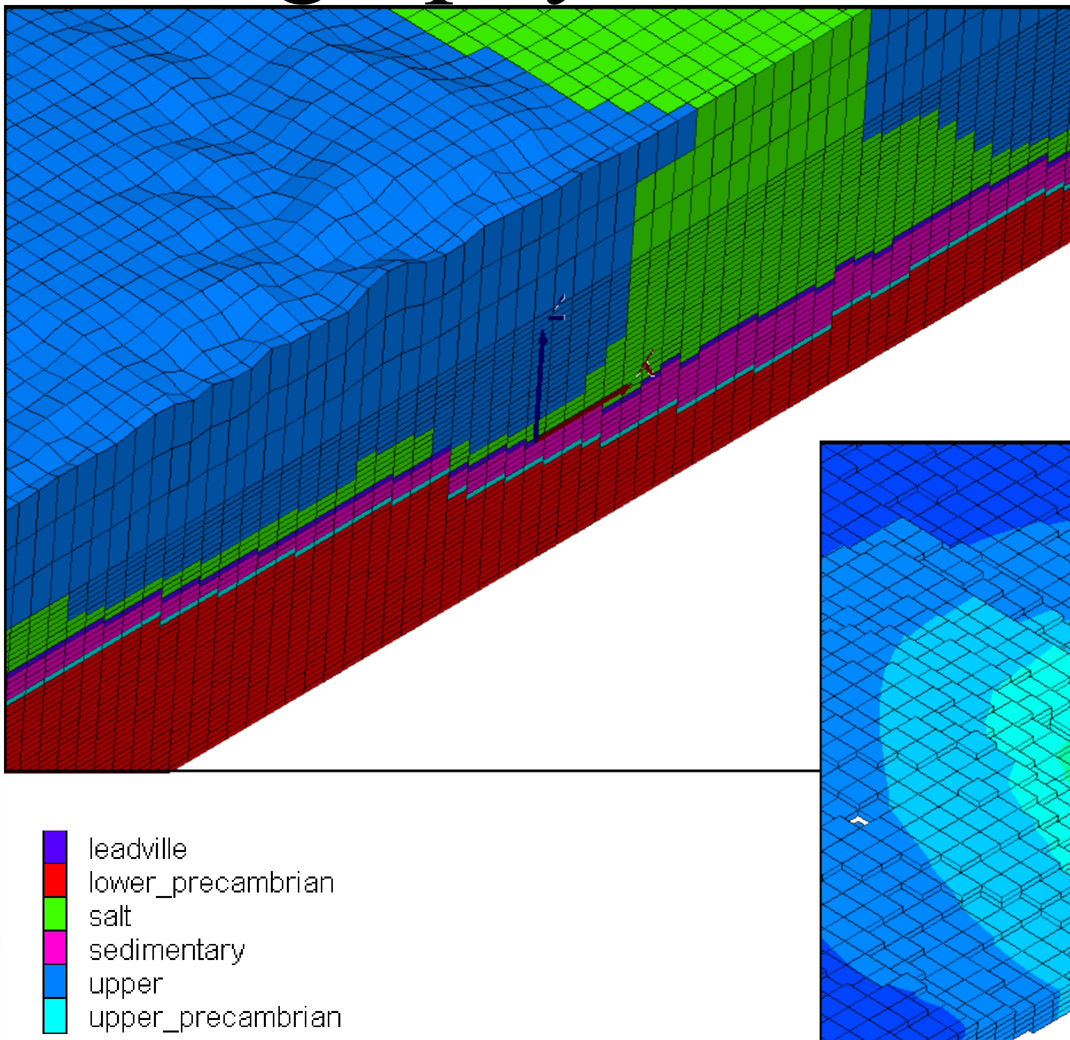


UpperPrecambrian

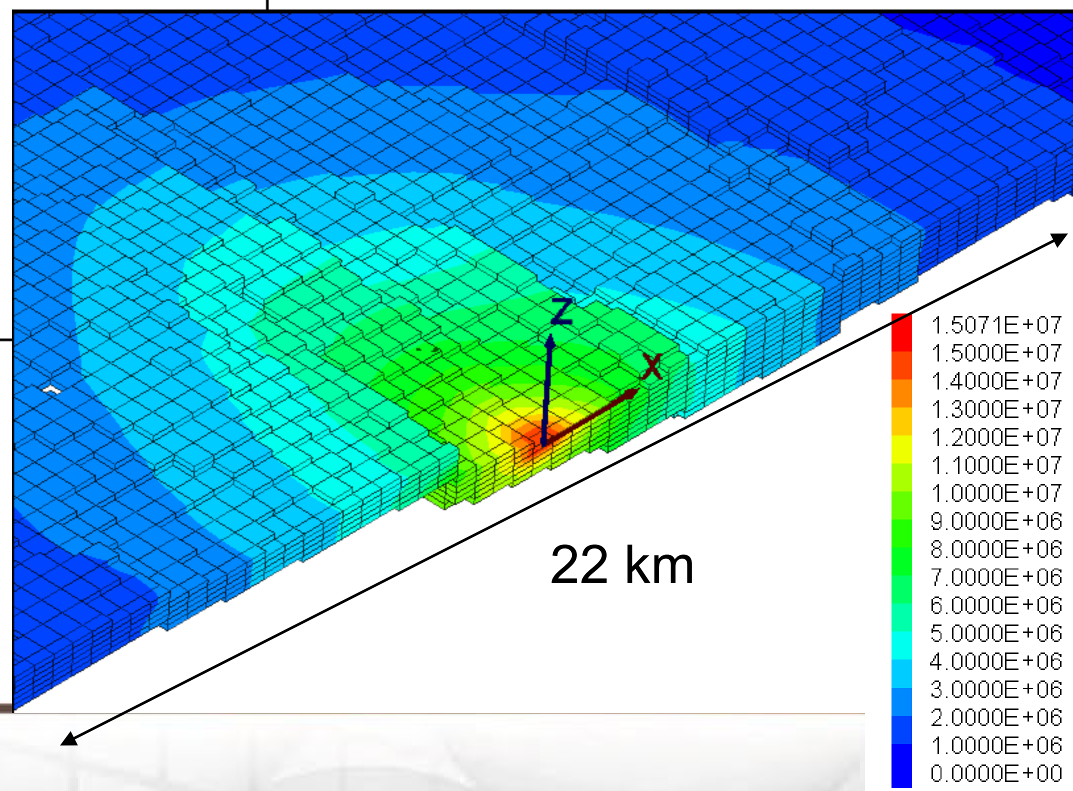
k=1.11e-12
m2/Pa.sec

# PRELIMINARY SIMULATION RESULTS

# Stratigraphy & Induced fluid pressures



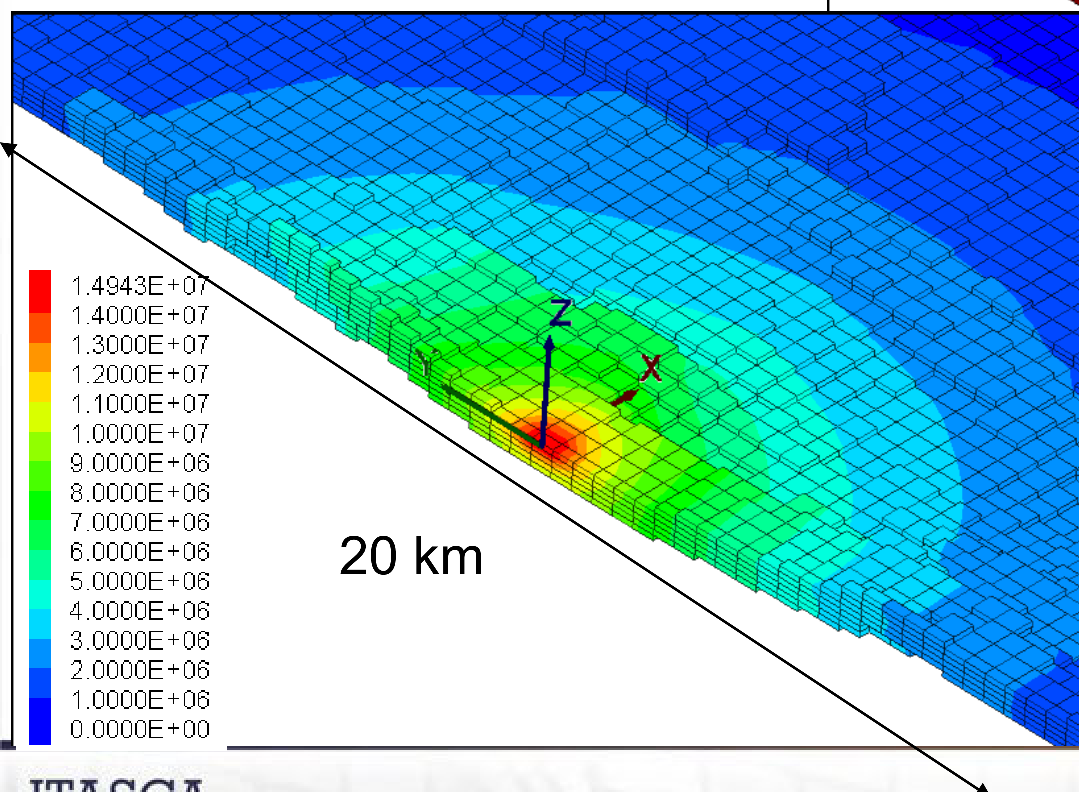

50 years

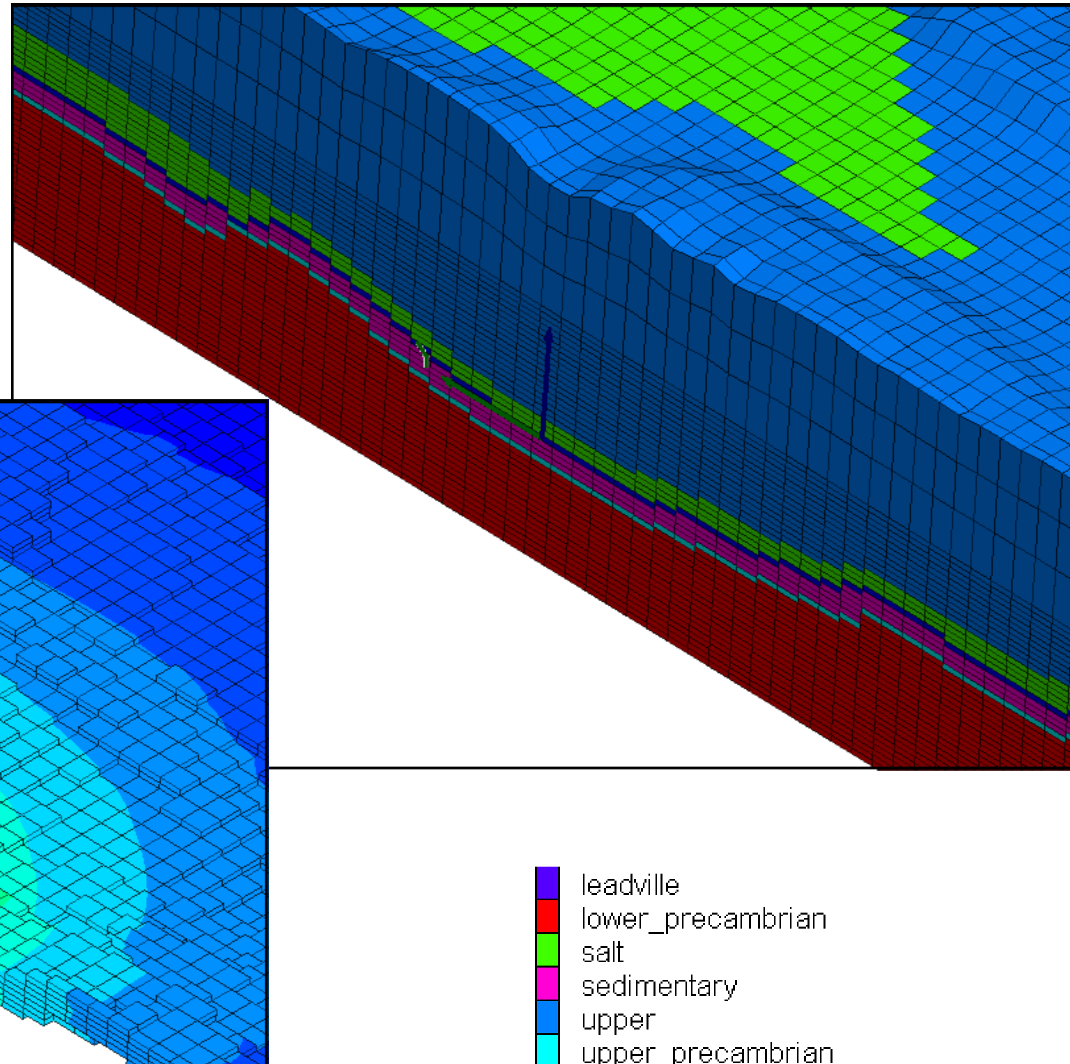



ITASCA

# Stratigraphy & Induced fluid pressures

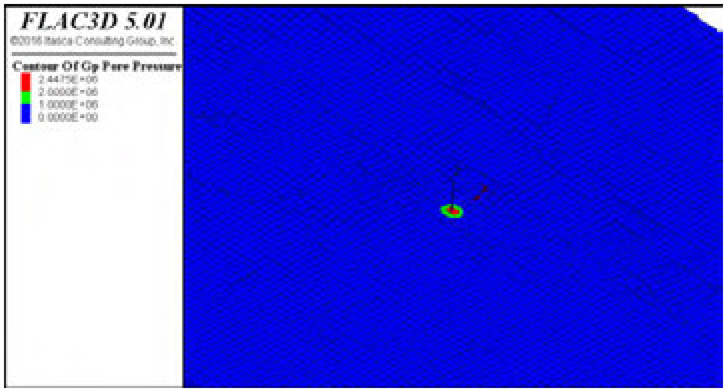
50 years



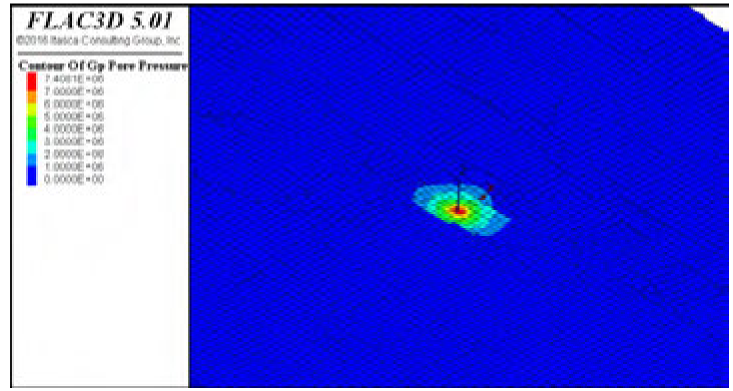



# Induced fluid pressure contours

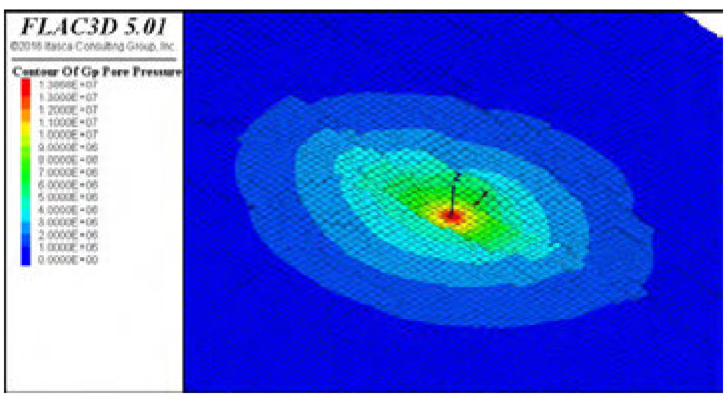
## Leadville



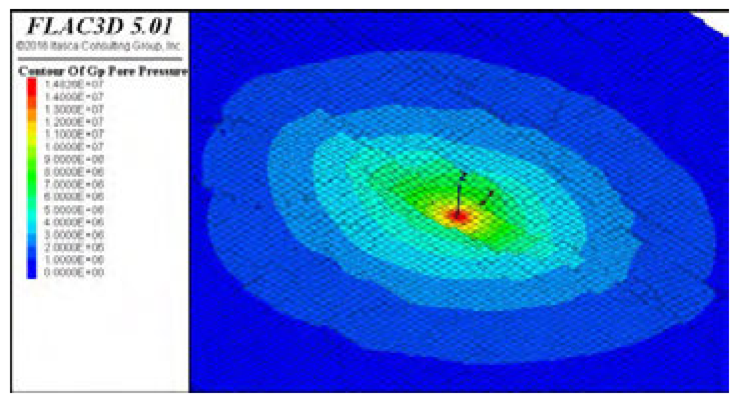

1 week (max: 2.4 Mpa)




1 year (max: 7.4 MPa)



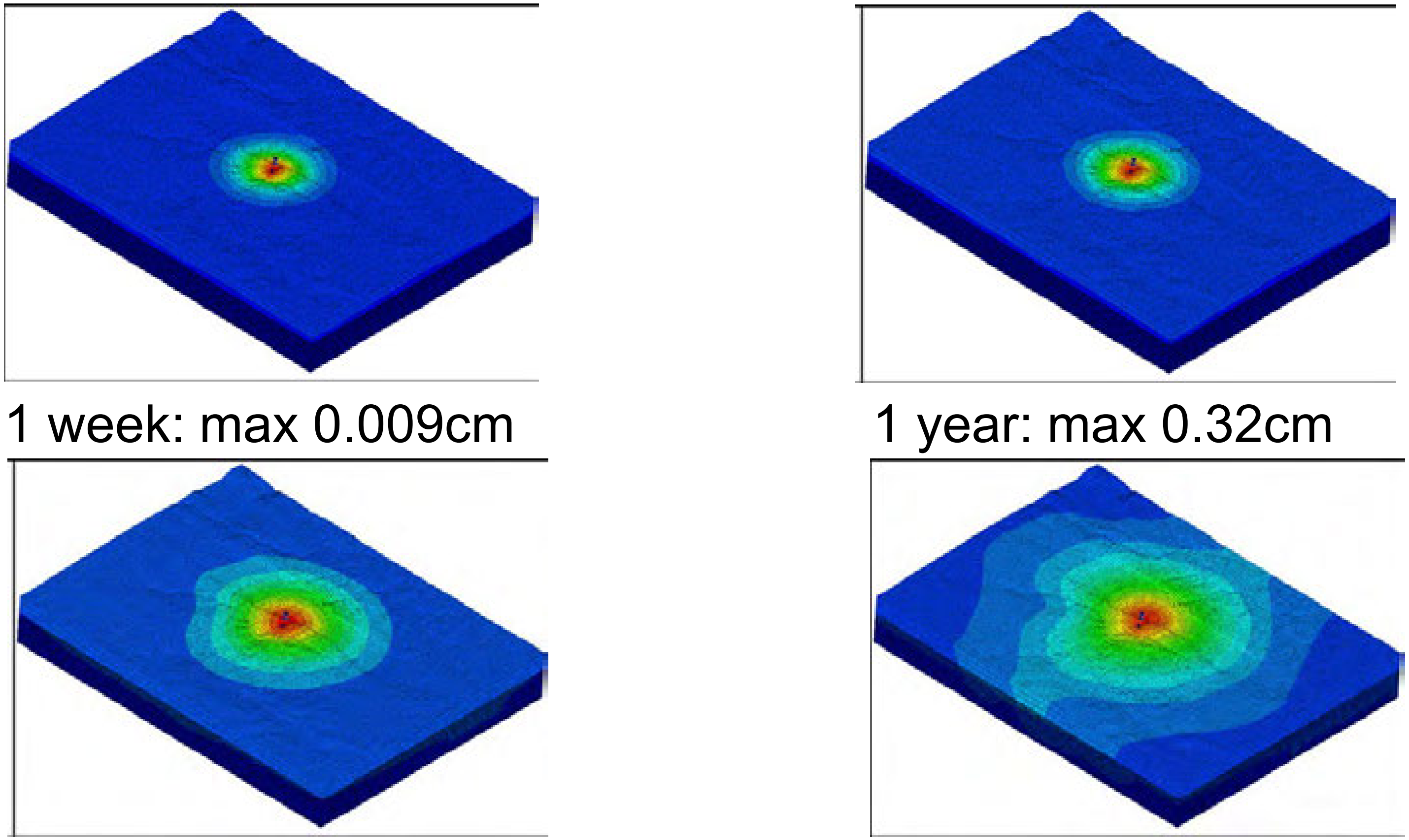

20 years (max 13.9 Mpa)




50 years (max 14.8 Mpa)

# Vertical displacements

## Ground surface



1 week: max 0.009cm

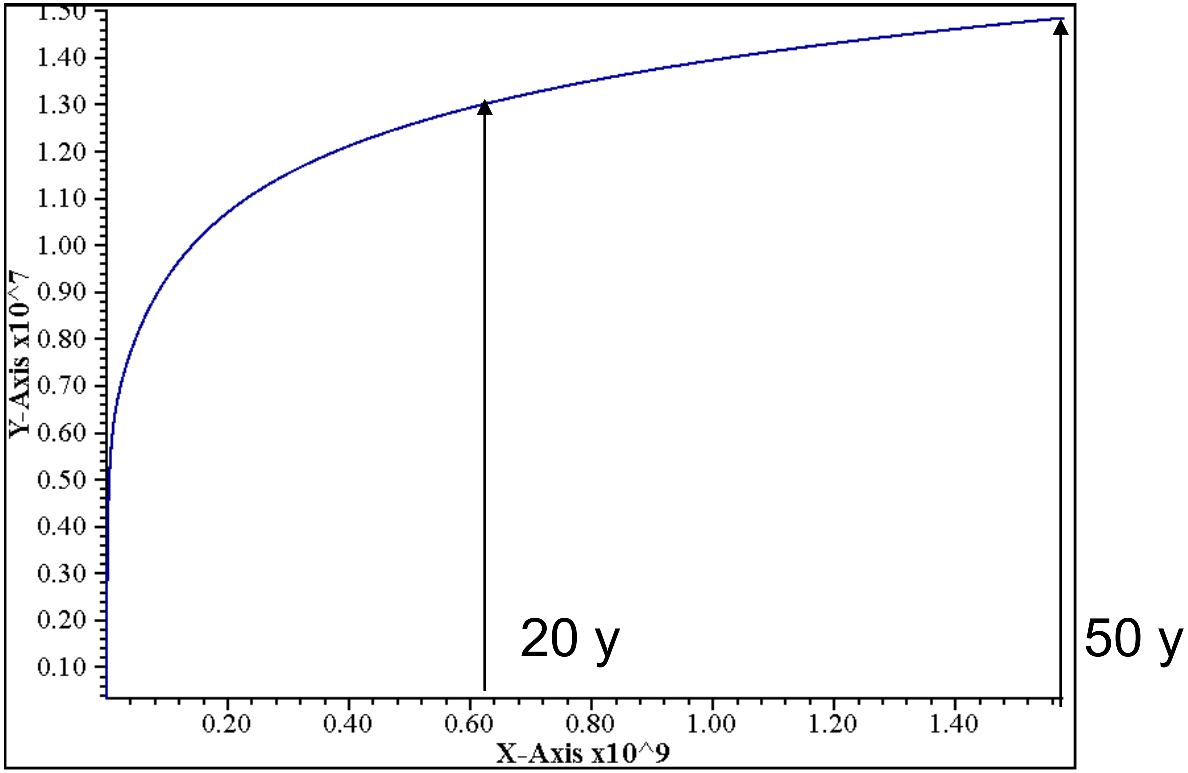
1 year: max 0.32cm

20 years: max 2.34cm

50 years: max 3.43cm

# Excess pressure in injection zone

Fluid pressure [Pa]




Time [sec.]

# Well pressures - definitions

**Downhole**:

- Excess pressure in injection zone:
  p_z = simulation result
- Excess pressure at the well:
  p_w = p_z + well pressure correction
- Total well pressure:
  p_down = p_w + insitu fluid pressure

**Well head**:

- p_up = p_down – brine static pressure

# Well pressures - downhole

Well pressure correction:

$$\Delta p = \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

$$\Delta p \sim 25.7 \text{ MPa}$$

Insitu fluid pressure:

$$p_{insitu} = \rho_w g H$$
$$= 43.1 \text{ MPa}$$

Brine static pressure:

$$p_{brine} = \rho_{brine} g H$$
$$= 50.6 \text{ MPa}$$

| | | |
|---|---|---|
| $r_0$ | $= 200$ m | half zone lateral size |
| $r$ | $= 0.5$ m | well radius |
| $h$ | $= 100$ m | injection interval |
| $Q$ | $= 0.012\ \text{m}^3/\text{sec}$ | total flow rate |
| $k$ | $= 4.45 \cdot 10^{-12}\ \text{m}^2/\text{Pa.sec}$ | mobility coefficient |
| $\rho_{insitu}$ | $= 1000\ \text{kg/m}^3$ | water density |
| $\rho_{brine}$ | $= 1173\ \text{kg/m}^3$ | brine density |
| $H$ | $= 4396$ m | injection depth |

# Well pressure results - MPa

| | Downhole | Downhole | Downhole | Wellhead |
|---|---|---|---|---|
| | Zone-excess | Well-excess (+25.7) | Well-total (+43.1) | Total (-50.6) |
| 1 week | 2.4 | 28.1 | 71.2 | 20.6 |
| 1 year | 7.4 | 33.1 | 76.2 | 25.6 |
| 20 years | 13.0 | 38.7 | 81.8 | 31.2 |
| 50 years | 14.8 | 40.5 | 83.6 | 33.0 |

Note: 12,000 psi ~ 82.7 MPa
5,000 psi ~ 34.5 MPa

# THANK YOU!

# Paradox Valley Project

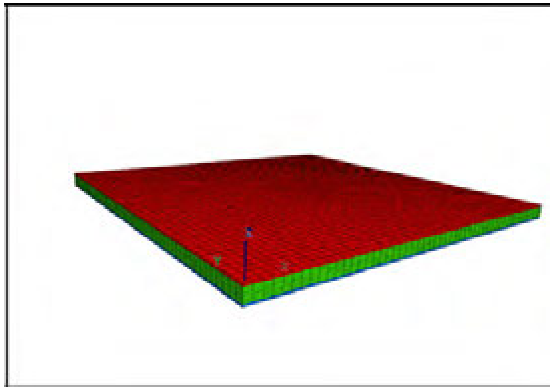
Injection in a 3 layer model  with contrasting permeability values

December 6, 2016

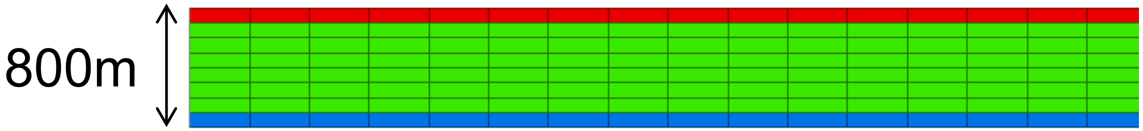
Christine Detournay
Itasca Consulting Group, Inc.

# *FLAC3D* model

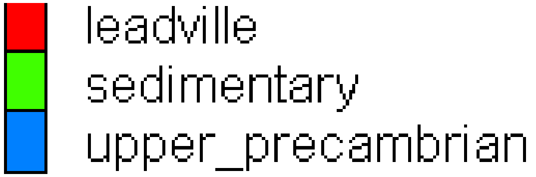
Flow analysis in three horizontal layers



Quarter symmetry




Elevation view



# Model specifics

Injection in Leadville (zone at top left in model elevation view)

Compared to Paradox model:

- Same zone size: 400mx400mx100m
- Same fluid properties
- Same total flow rate

| Permeability | Leadville | Sedimentary | U.Precambrian |
|---|---|---|---|
| $10^{-15} m^2$ | 6 | 0.1 | 1.5 |

# Characteristic length

Gives order of magnitude of distance travelled by a pore pressure perturbation in a given amount of time

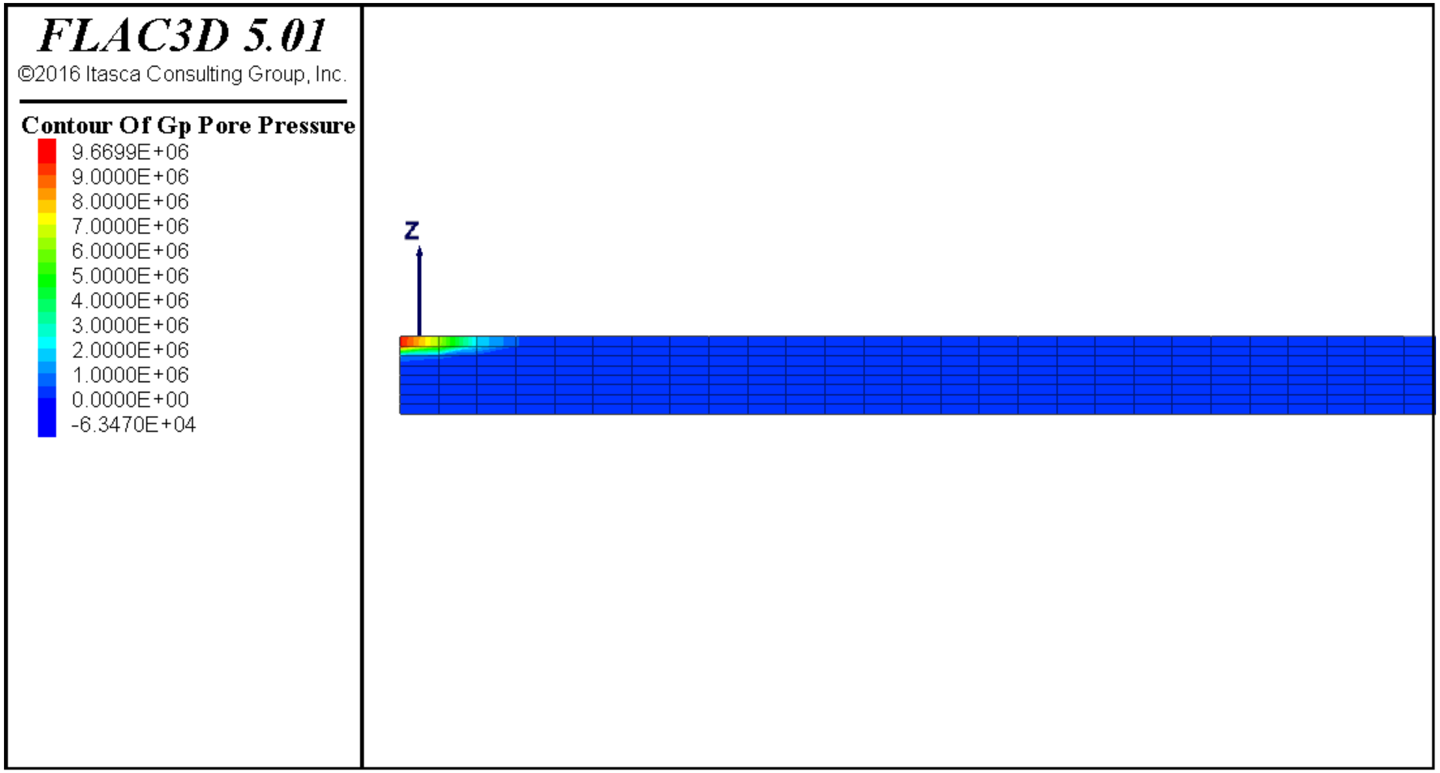
$$L_{cr} = 2\sqrt{ct}$$

C: diffusivity
t : time

| $L_{cr}$ | **Leadville** | **Sedimentary** | **U-Precambrian** |
|---|---|---|---|
| | (c=0.21 $m^2$/sec ) | (c=0.0044 $m^2$/sec) | (c=0.053 $m^2$/sec) |
| 1 week | 0.7km | 0.1km | 0.4km |
| 1 year | 5 km | 0.7km | 3km |
| 20 years | 23km | 3km | 12km |
| 50 years | 36km | 5km | 18km |

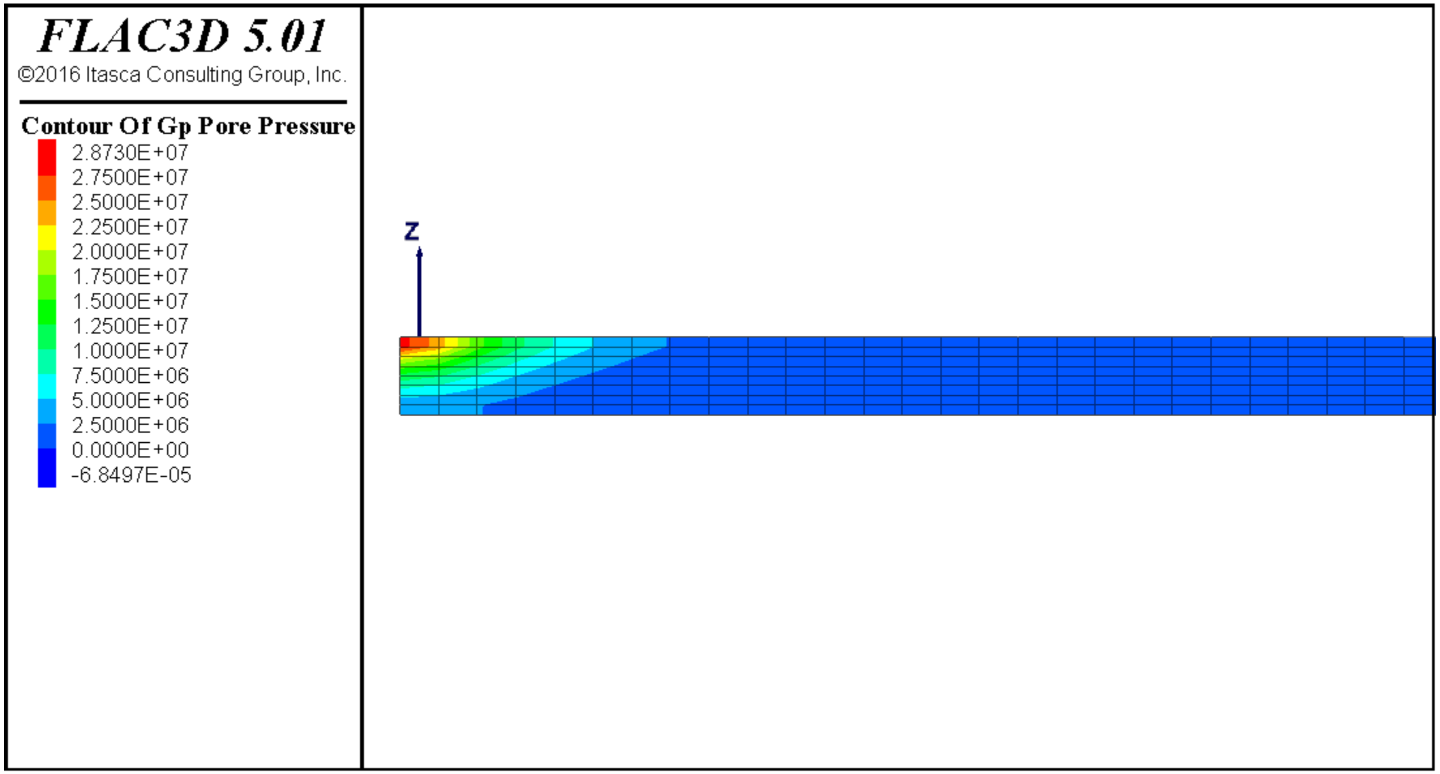
# SIMULATION RESULTS

# Pore pressure results – 1week



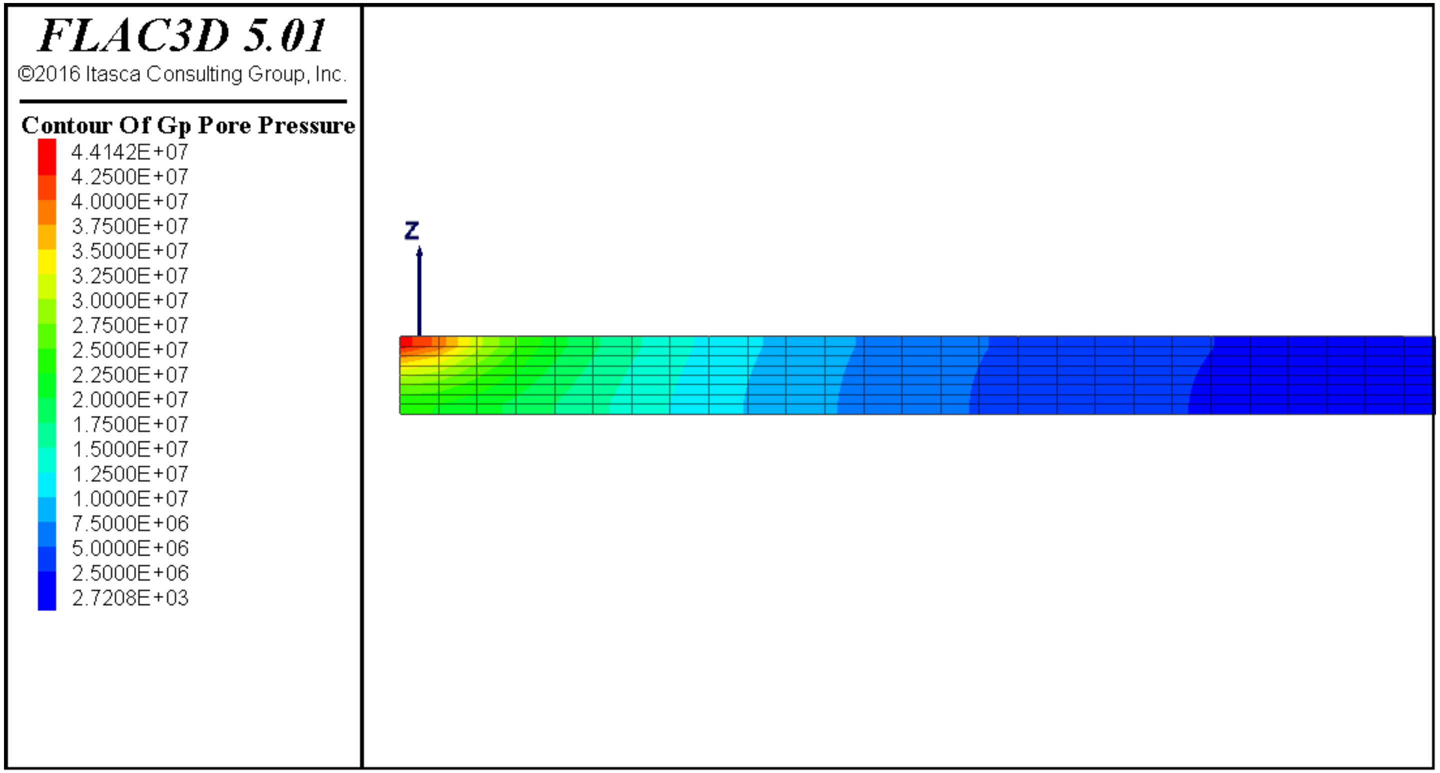

Short time response: fluid pressure perturbation concentrated mostly in the Leadville, up to L~700m in Leadville

# Pore pressure results – 1 year



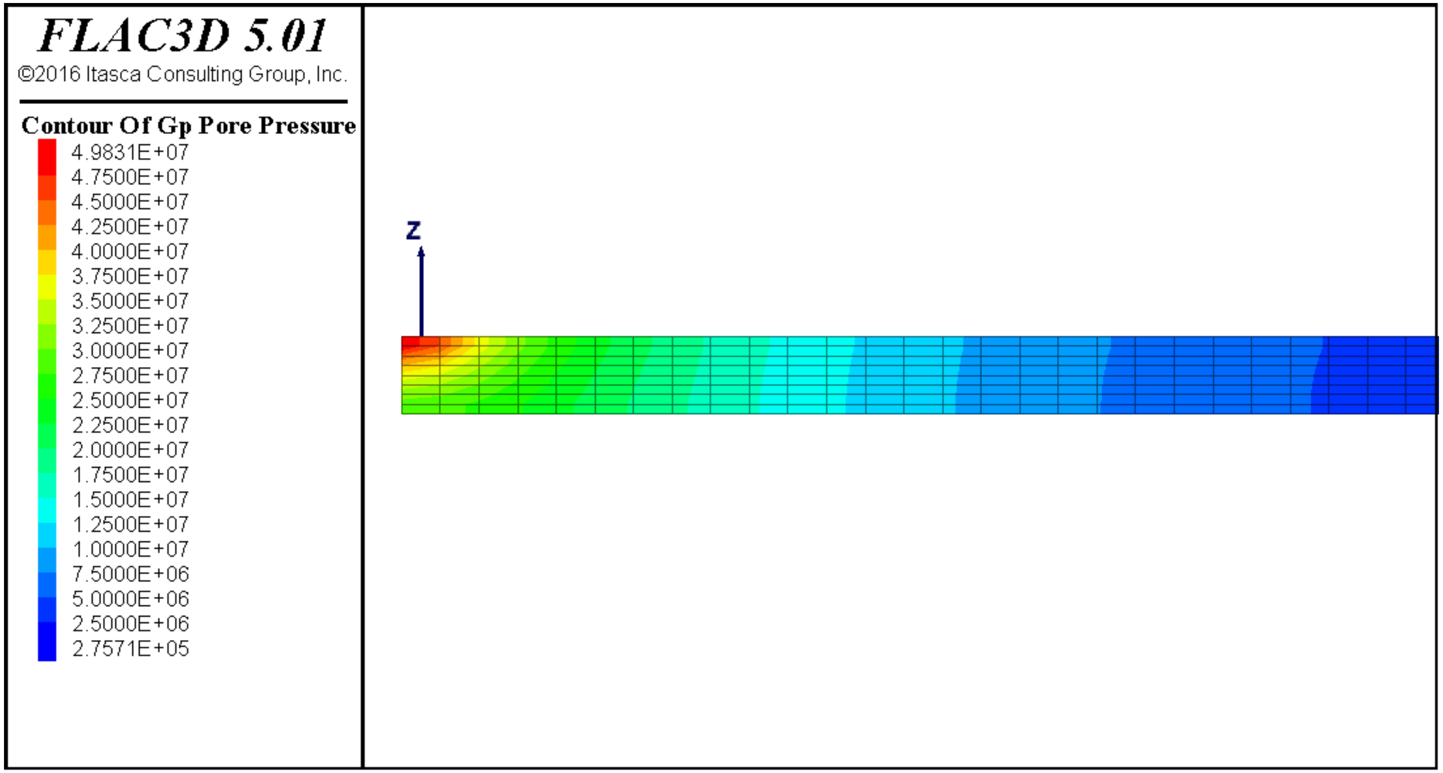

Medium time response: the fluid pressure ‘front’ has reached the bottom of the Sedimentary layer → L~700m in Sedimentary

# Pore pressure results – 20 years



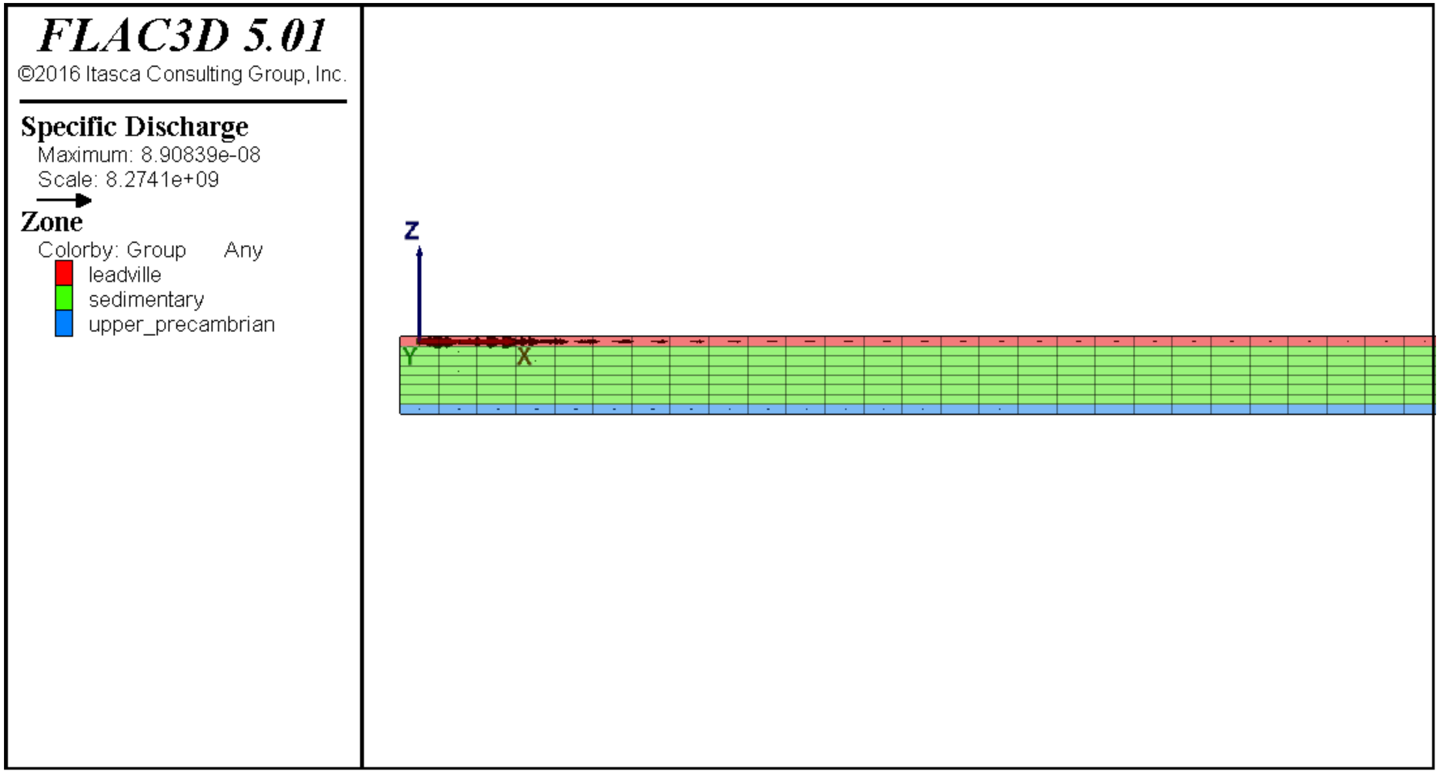

Long time response: half-spherical fluid pressure behavior near the source …

# Pore pressure results – 50 years




… and radial fluid pressure behavior away from the source!

# Flow vectors – 50 years




The specific discharge is in proportion to the permeability:
it is much larger in the Leadville than in the Upper Precambrian,
and smaller in the Sedimentary than in the Upper Precambrian.

# SUMMARY

A simple *FLAC3D* simulation, with 3 horizontal layers of contrasting permeability values, has been performed to further explore the fluid pressure behavior (with vertical isobar) observed in the Sedimentary layer of the *FLAC3D* Paradox Valley model.

In the simulation, quasi-vertical isobars are observed; the vertical character is more pronounced:

- .in the long term (tens of years), and
- away from the injection site

The pressure contours away from the injection point are almost vertical (although the sedimentary is relatively impermeable) because the fluid diffusion also take place in the vertical direction from permeable and pressurized Leadville into the sedimentary.

The behavior is reasonable:

- At a distance large compared to the thickness of the 3-layers, the details of the mode of injection are lost to the fluid flow (injection appears to originate over the full height of the 3-layers, instead of over a single zone in the Leadville)
- The specific discharge magnitude in a layer reflects the permeability in that layer (in particular, it is smallest in the Sedimentary layer where permeability is lowest).

# Paradox Valley Project

## Permeability model investigation

December 19, 2016

Christine Detournay
Itasca Consulting Group, Inc.

# Objective

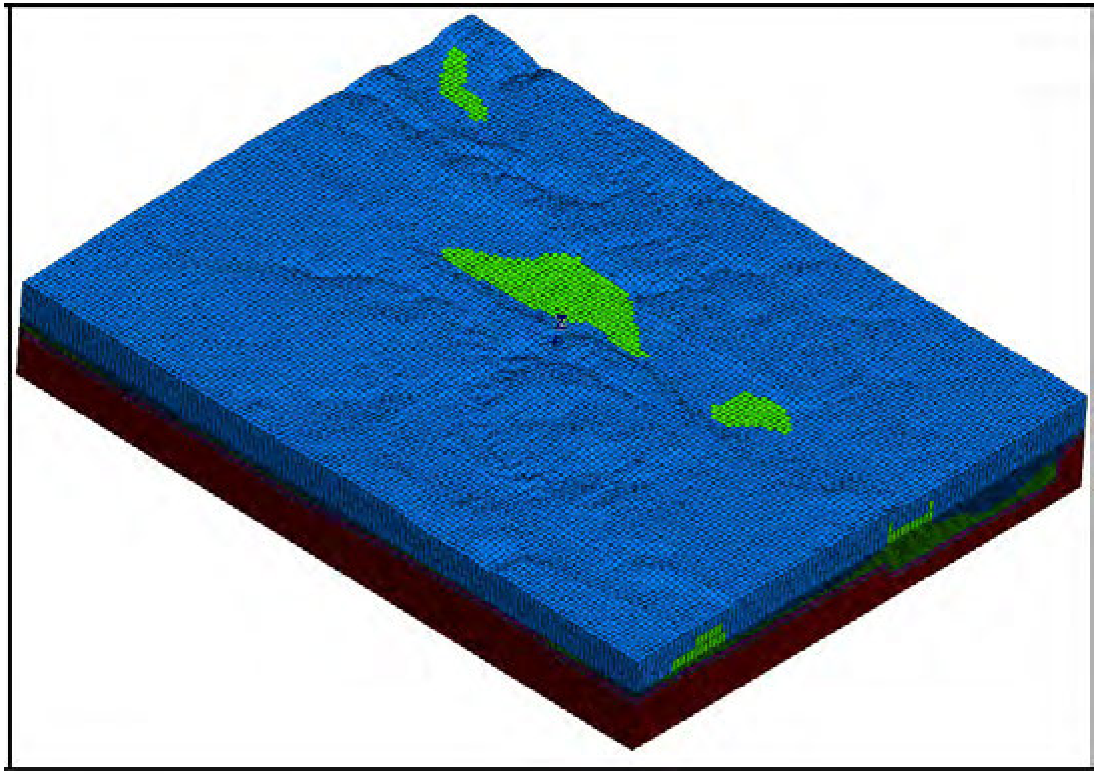
Determine if the PVU well-head and pressure data can help distinguish between the following 3 Permeability Models:

1. Impermeable top of Leadville, permeable layers below Leadville, and “transparent” faults (current Itasca model)
2. Impermeable top and bottom of Leadville, and impermeable faults (most compartmented model)
3. Permeable top and bottom of Leadville, and “transparent” faults (least compartmented model)

Ref.: December 12, 2016 email form Christopher Wood

# *FLAC3D* model

## 6 Layer model – *with latest changes in surface elevation*



- Upper
- Salt
- Leadville
- Sedimentary
- Upper Precambrian
- Lower Precambrian

40 km x 52 km x 7.7 km

Zone size in Leadville:
100m in vertical direction,
400m x 400m horizontally

611,000 zones - 635,088 nodes

# Flow only simulations

Geometrical data: *updated surfaces* (*)

- Upper
- Salt
- Leadville → 100 m thick (90m)
- Sedimentary
- Precambrian → 100 m thick (58m)
- Lower Precambrian

Injection: in Leadville

- daily rate provided by USBR (*), up to 25.24 years
- constant rate of 0.012 m^3/sec used for reference

Fluid properties:

- Brine density: 1153 kg/m^3 (*)
- Brine viscosity: 0.001348 Pa.sec

(*) Christopher Wood, email of Dec 5, 2016

# Planned work

Run the 3 contrasting permeability models:
- with the injection rate provided by USBR
- with constant rate of 0.012 m^3/sec (7000 barrels/day), (*) to use as reference

Compare the predicted surface pressure at the well location with the surface pressure data from USBR:

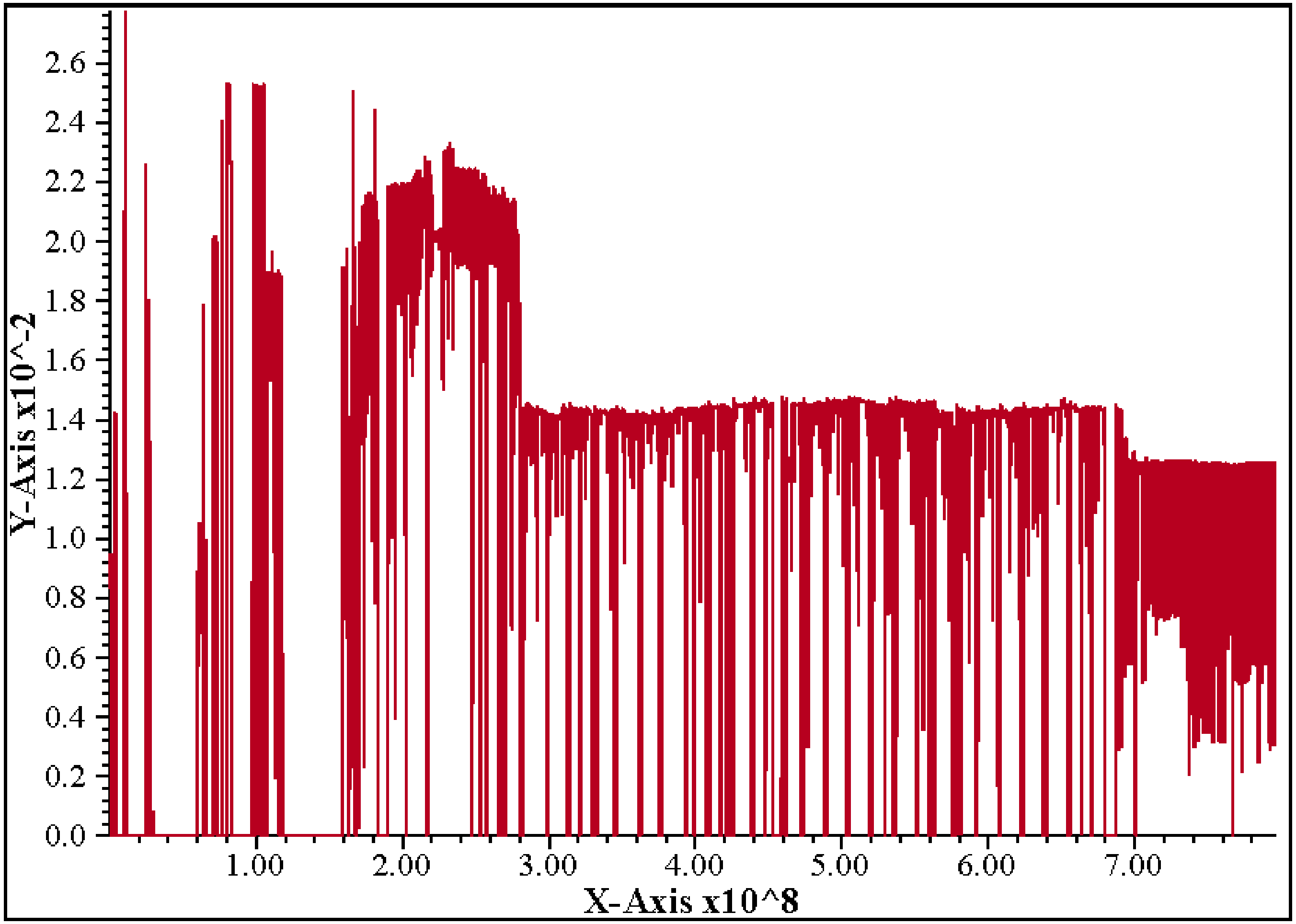
- Estimate which of the 3 permeability models provides a best fit to the available wellhead pressure data.
- Estimate which of the 3 permeability models can be eliminated, based on the inability to fit the numerical response to the available wellhead pressure data.

(*) PWS p1

# Layer Properties

| Layer | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Layer description | Formations above salt | Salt | Leadville | Sedimentary layers below Leadville | Precambrian | Lower Precambrian |
| Density | 2.53 g/cm$^3$ | 2.16 g/cm$^3$ | 2.69 g/cm$^3$ | 2.56 g/cm$^3$ | 2.65 g/cm$^3$ | 2.65 g/cm$^3$ |
| Bulk modulus | 29.8 GPa | 25.3 GPa | 64.8 GPa | 50.6 GPa | 50.1 GPa | 50.1 GPa |
| Young's modulus | 43.1 GPa | 35.8 GPa | 76.2 GPa | 66.8 GPa | 83.0 GPa | 83.0 GPa |
| Shear modulus | 17.1 GPa | 14.2 Gpa | 29.2 GPa | 26.1 GPa | 33.9 GPa | 33.9 GPa |
| Poisson's ratio | 0.260 | 0.264 | 0.304 | 0.280 | 0.224 | 0.224 |
| Permeability | 0.1 mD | 0 mD | 6 mD | 0.1 mD | 1.5 mD | 0 mD |
| Porosity | 0.06 | 0 | 0.05 | 0.01 | 0.03 | 0 |
| Diffusivity (before 1/8/02) | 0.0019 m$^2$/s | 0 m$^2$/s | 0.20 m$^2$/s | 0.0043 m$^2$/s | 0.051 m$^2$/s | 0 m$^2$/s |
| Diffusivity (after 1/8/02) | 0.0020 m$^2$/s | 0 m$^2$/s | 0.21 m$^2$/s | 0.0044 m$^2$/s | 0.053 m$^2$/s | 0 m$^2$/s |

# Injection rate data




Injection rate [m^3/sec] versus time [sec]

# Fluid pressures - definitions

**Insitu pressure:**
Hydrostatic pressure (overpressure in Leadville) -
taken into account in the models (this is different from PR1)

**Downhole**:
- Total pressure in injection zone:
  p_z = simulation result
  = excess pressure in zone + insitu fluid pressure
- Total pressure at the well:
  p_down = p_z + well pressure correction

**Well head**:
- p_up = p_down – brine static pressure

# Well pressures - downhole

Well pressure correction:

$$\Delta p = \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

$$\Delta p \sim 25.7 \text{ MPa}$$

Insitu fluid pressure:

$$p_{insitu} = \rho_w g H$$
$$= 43.1 \text{ MPa}$$

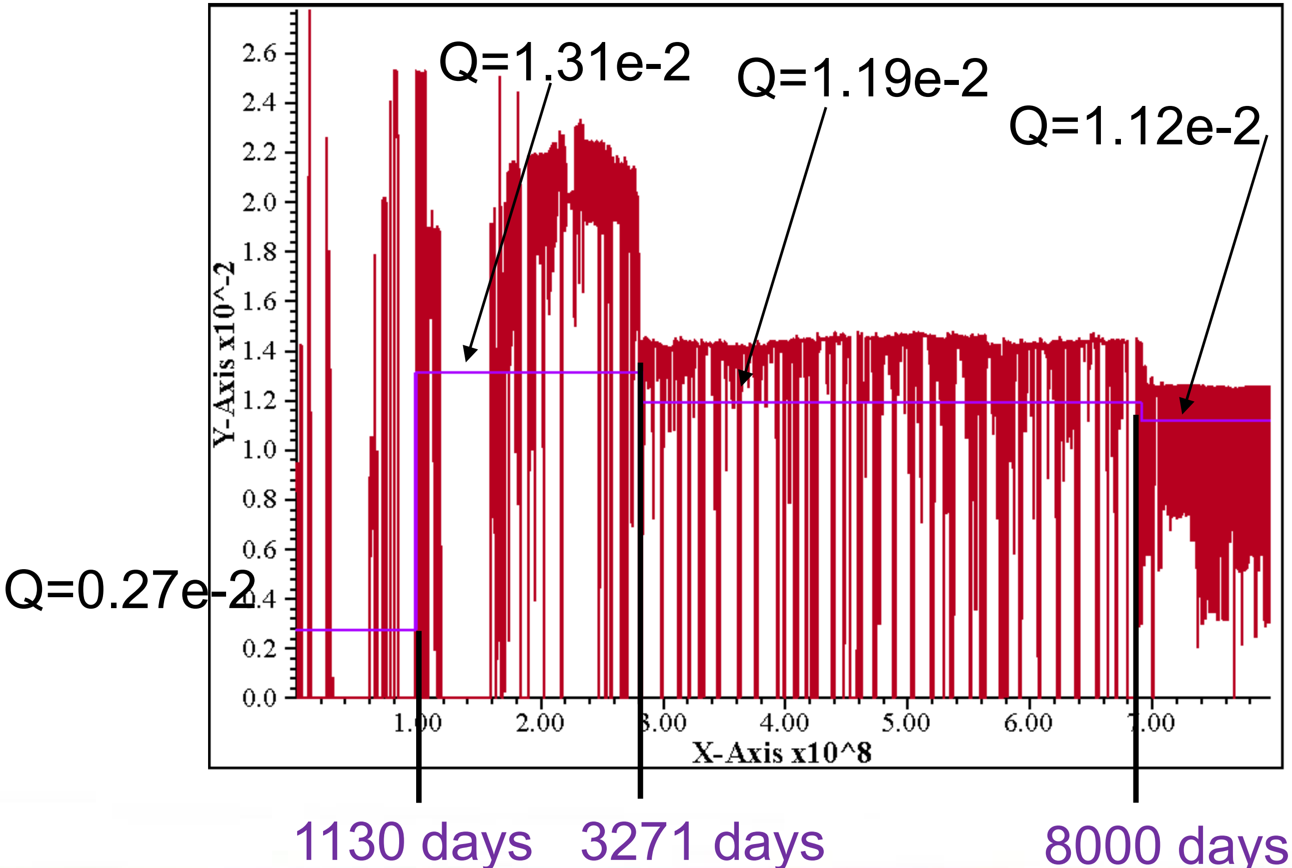
Brine static pressure:

$$p_{brine} = \rho_{brine} g H$$
$$= 50.6 \text{ MPa}$$

| | | |
|---|---|---|
| $r_0$ | $= 200$ m | half zone lateral size |
| $r$ | $= 0.5$ m | well radius |
| $h$ | $= 100$ m | injection interval |
| $Q$ | $= 0.012\ \text{m}^3/\text{sec}$ | total flow rate |
| $k$ | $= 4.45 \cdot 10^{-12}\ \text{m}^2/\text{Pa.sec}$ | mobility coefficient |
| $\rho_{insitu}$ | $= 1000\ \text{kg/m}^3$ | water density |
| $\rho_{brine}$ | $= 1173\ \text{kg/m}^3$ | brine density |
| $H$ | $= 4396$ m | injection depth |

# Flow rate used in well correction

Arithmetic average [m^3/sec] based on daily rate data



# Well pressures quantities

Well pressure correction:

$$\Delta p = \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

$$\Delta p = [5.8\ , 28.1\ , 25.5\ , 24.0]\ \text{MPa}$$

Insitu fluid pressure:

$$p_{insitu} = 44.7\ \text{MPa}\ (*)$$ ⟹ Calibration parameter

Brine static pressure:

$$p_{brine} = \rho_{brine} g H = 49.7\ \text{MPa}$$

| | | |
|---|---|---|
| $H$ | $= 4396$ m | injection depth |
| $\rho_{brine}$ | $= 1153$ kg/m$^3$ | brine density |

(*) compare to 42 MPa from the map (Bremkamp &Harr) in Fig 11 of King et al., 2014

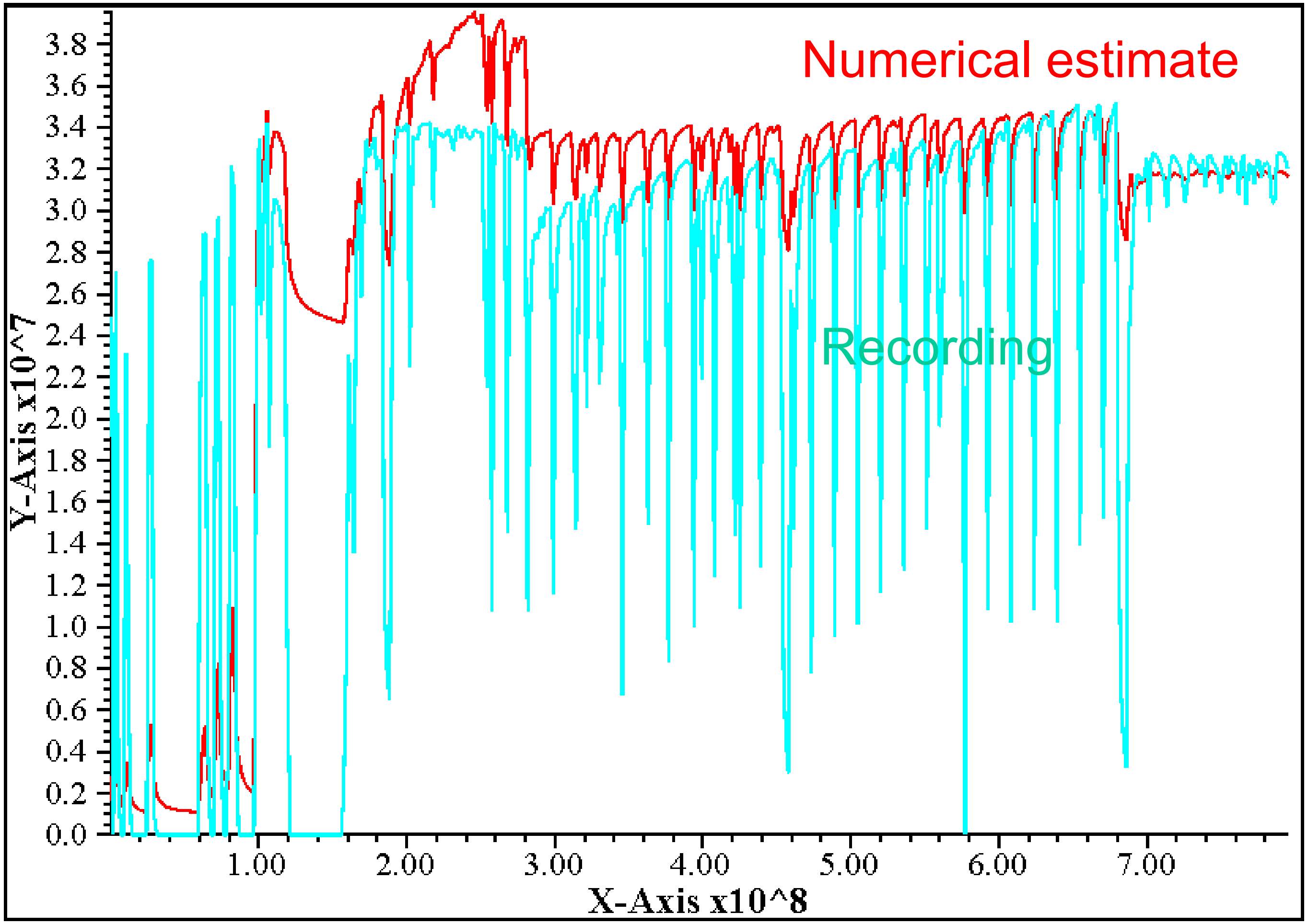
# FLOW SIMULATION RESULTS

# Permeability Model 1

Current Itasca model

- Impermeable top of Leadville,
- Permeable layers below Leadville,
- “Transparent” faults

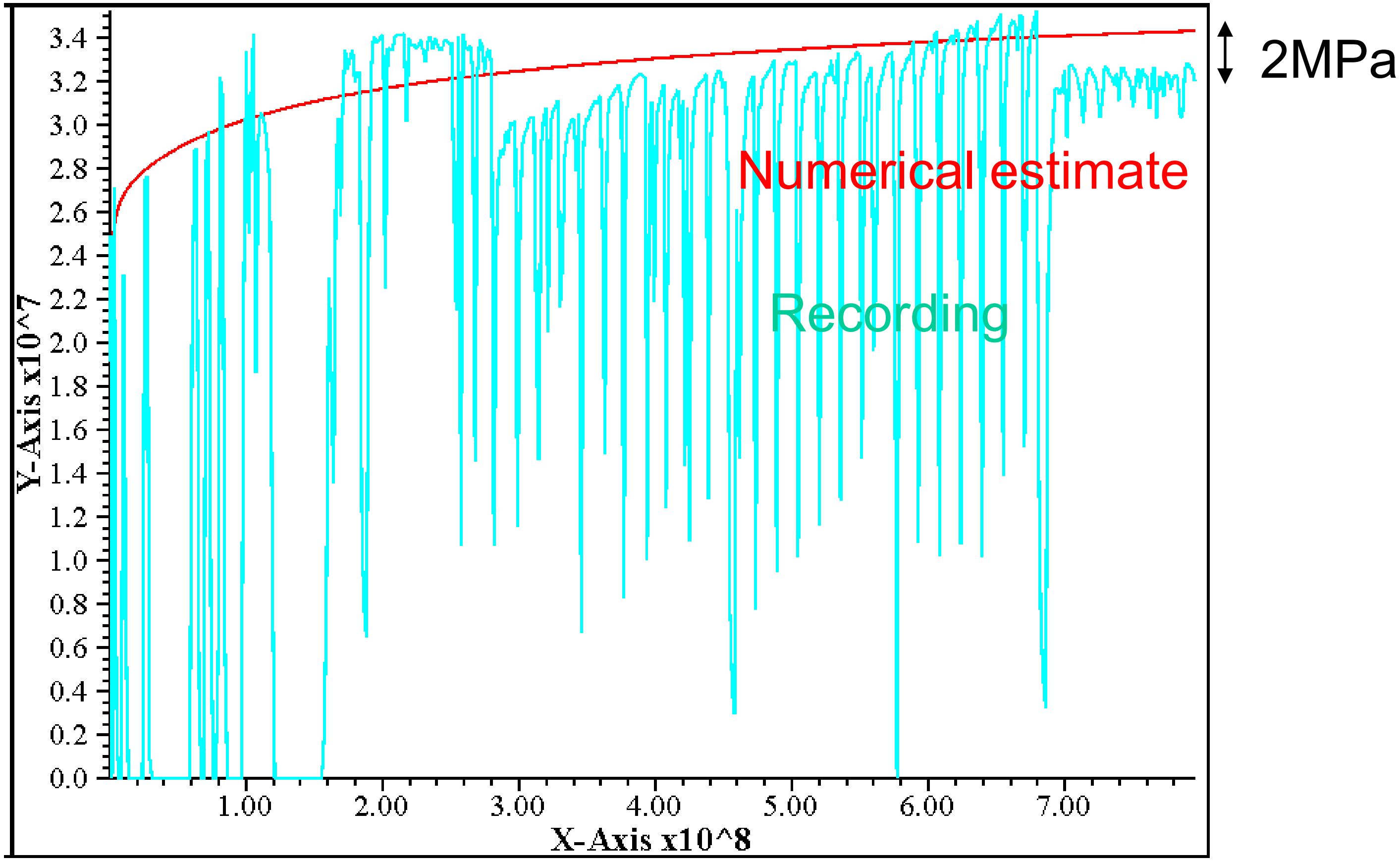
# Model 1




Wellhead pressure [Pa] versus time [sec]

# Model 1 – constant Q

Q=0.012 m^3/sec (7000 barrels/day) (*)



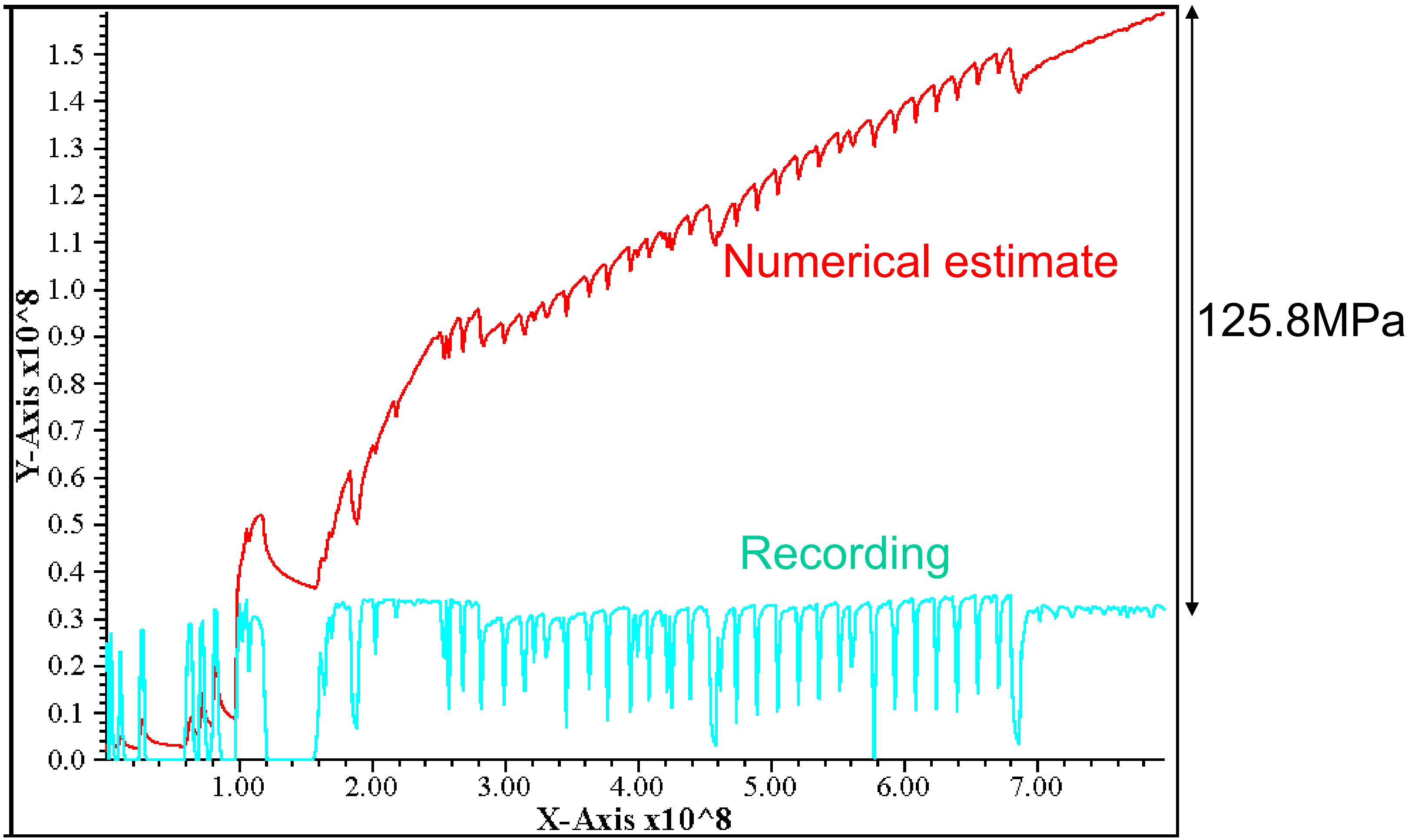

Wellhead pressure [Pa] versus time [sec]

# Permeability Model 2

Most compartmented model

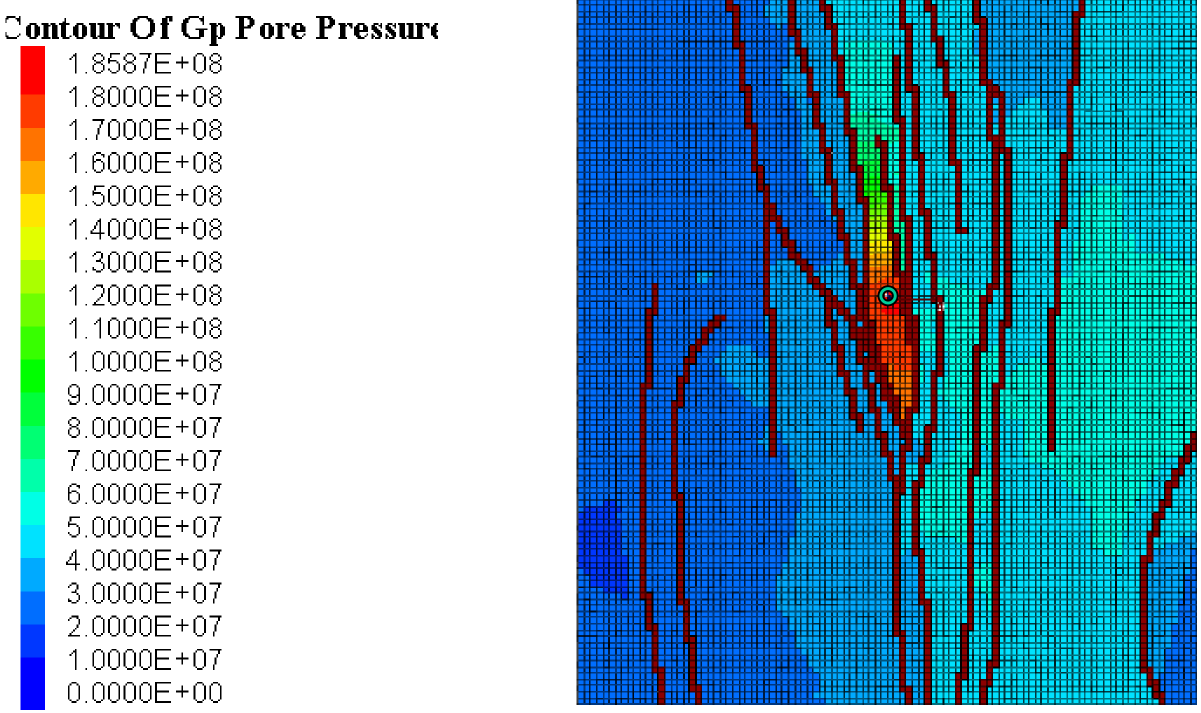
- Impermeable top of Leadville
- Impermeable bottom of Leadville
- Impermeable faults

# Model 2 - case 1: Impermeable faults




Wellhead pressure [Pa] versus time [sec]

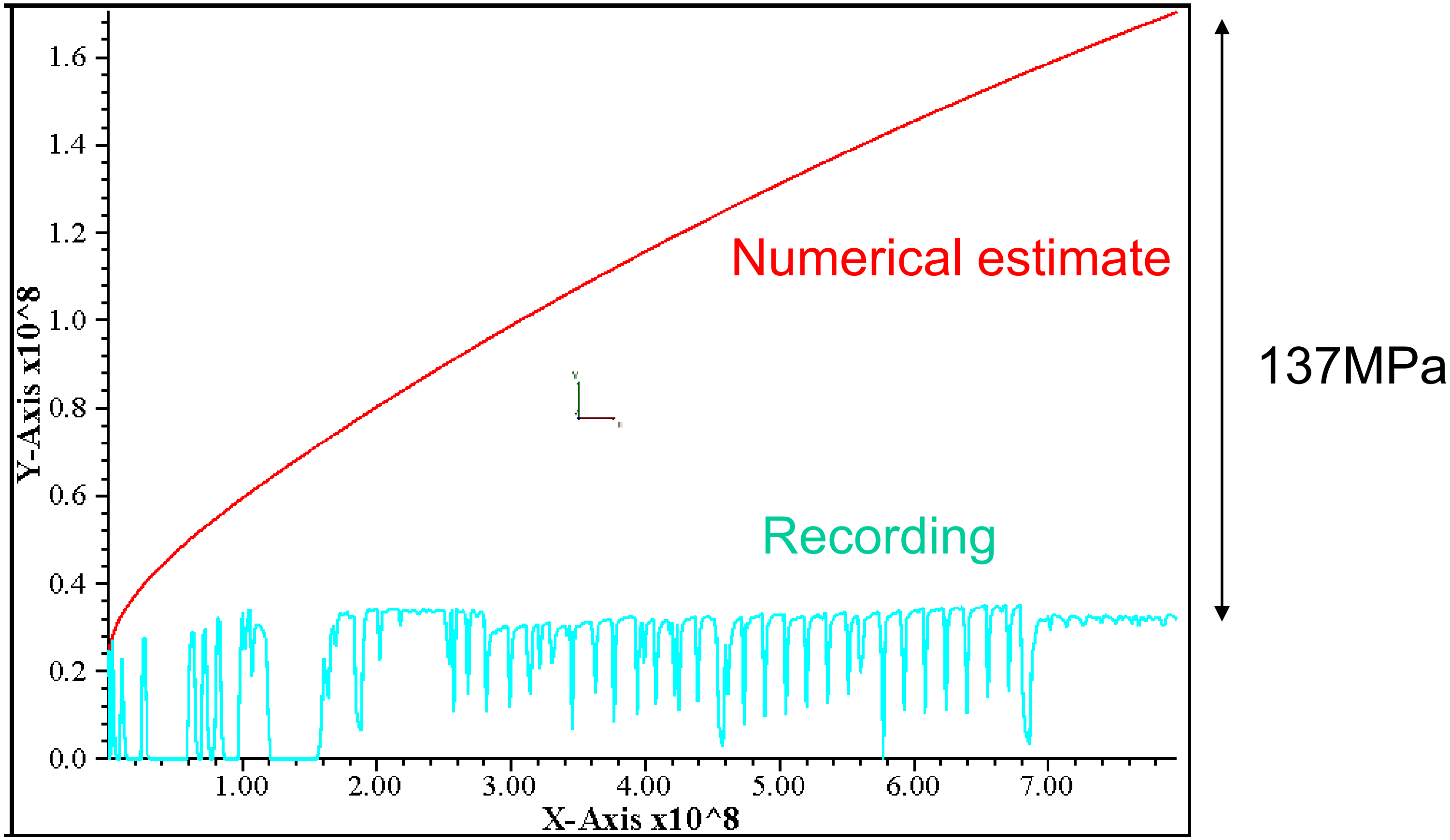
# Model 2 - Impermeable faults




Fluid pressure contours in the Leadville after ~ 25.24 years with Faults shown in brown

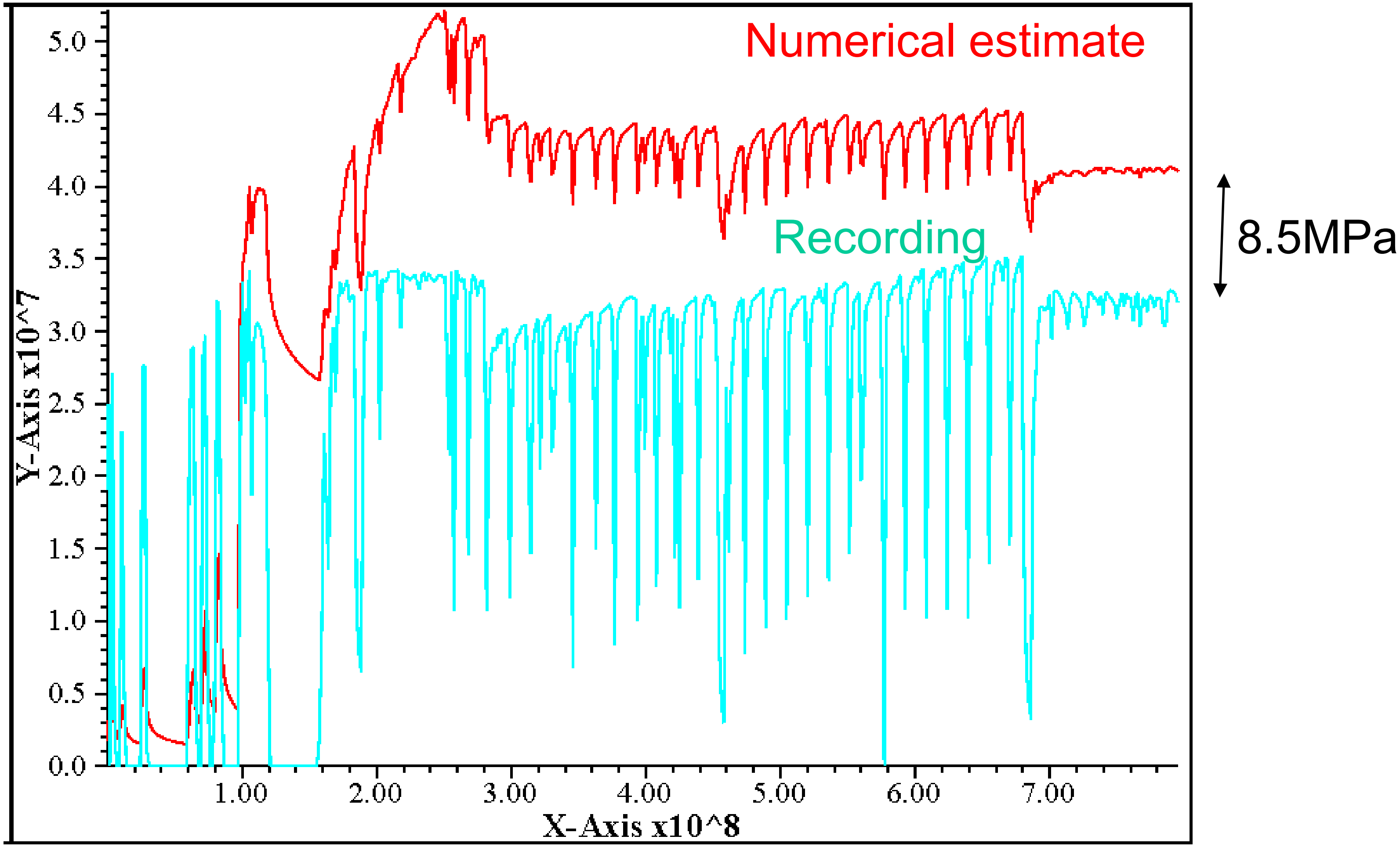
# Model 2 – Imp. faults - constant Q

Q=0.012 m^3/sec (7000 barrels/day) (*)



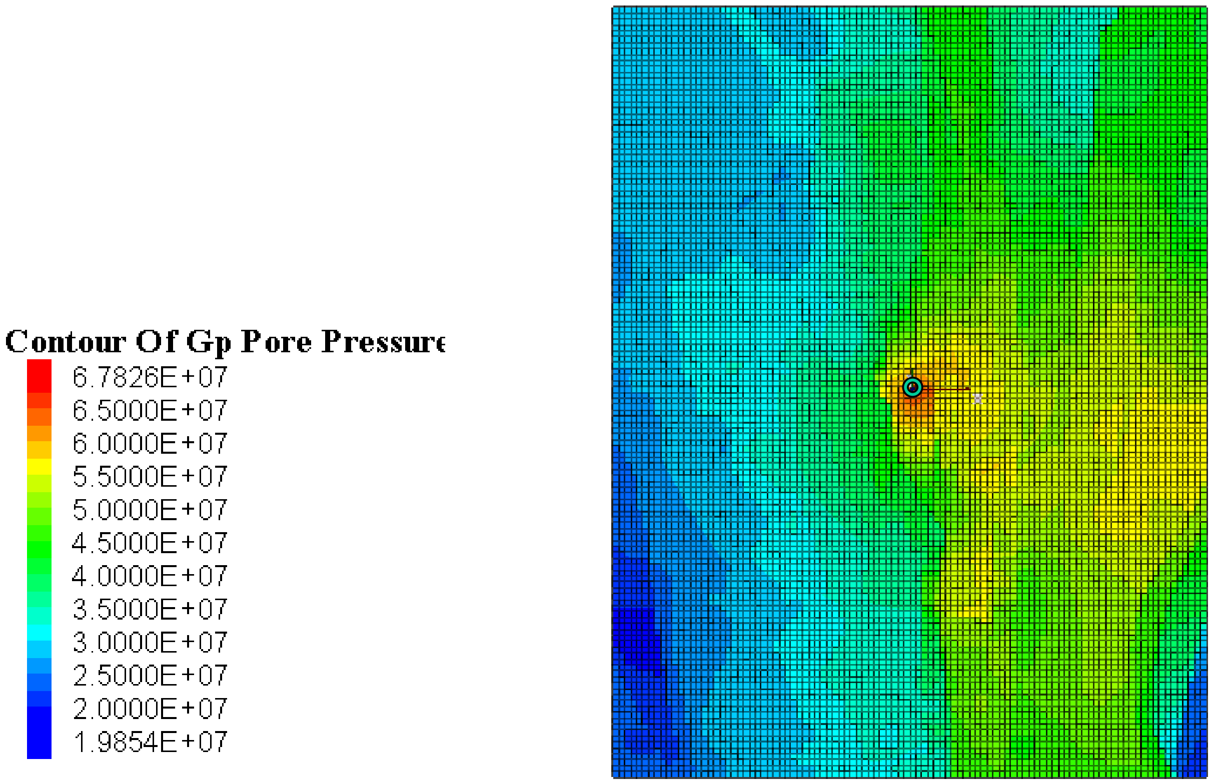

Wellhead pressure [Pa] versus time [sec]

# Model 2 - case 2: Transparent faults




Wellhead pressure [Pa] versus time [sec]

# Model 2 - Transparent faults




Fluid pressure contours in the Leadville after ~ 25.24 years

# Permeability Model 3

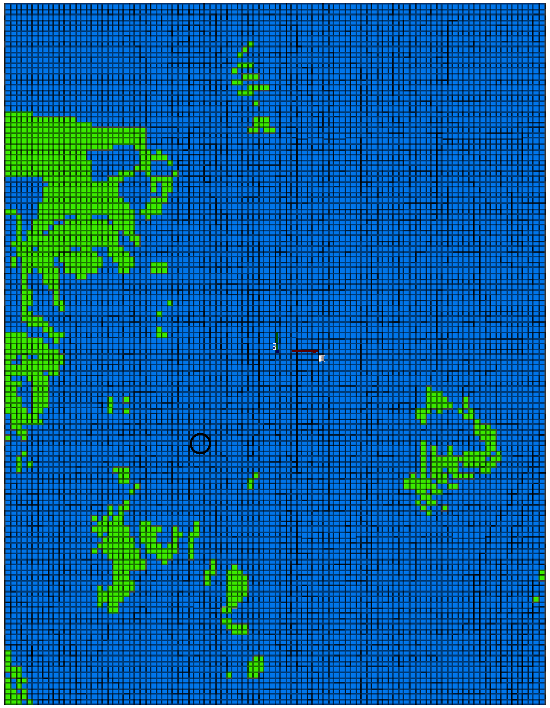
Least compartmented model

- Permeable top of Leadville
- Permeable bottom of Leadville
- “Transparent” faults

This model has 4 permeable layers: Upper, Leadville, Sedimentary, Upper-Precambrian, and welds have the same flow properties as Upper.

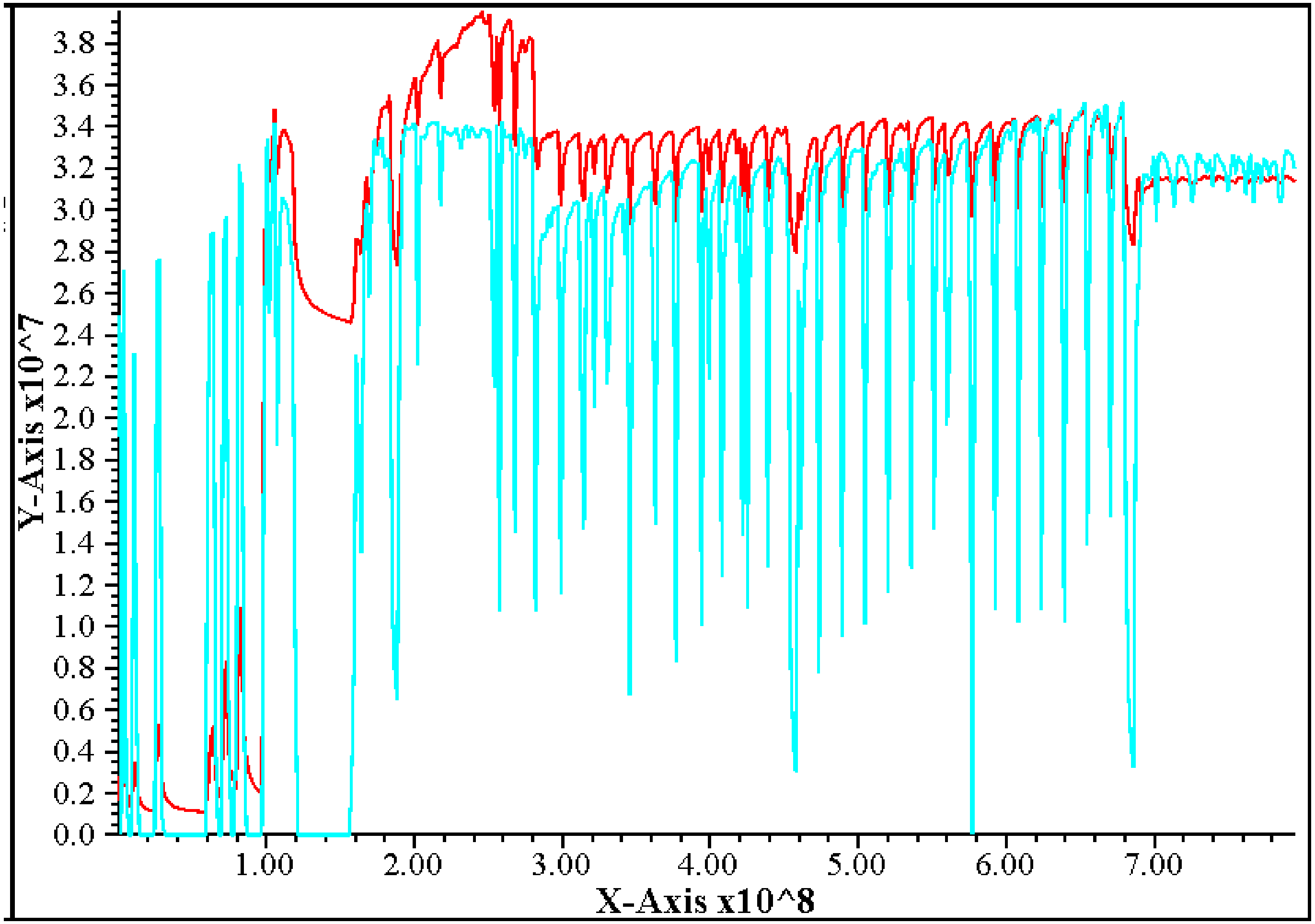
# Model 3 - case 1: 100m Salt welds

Salt layer less than 100m thick above Leaderville is taken as weld with same fluid properties as Upper formations



Welds colored in green on plan view

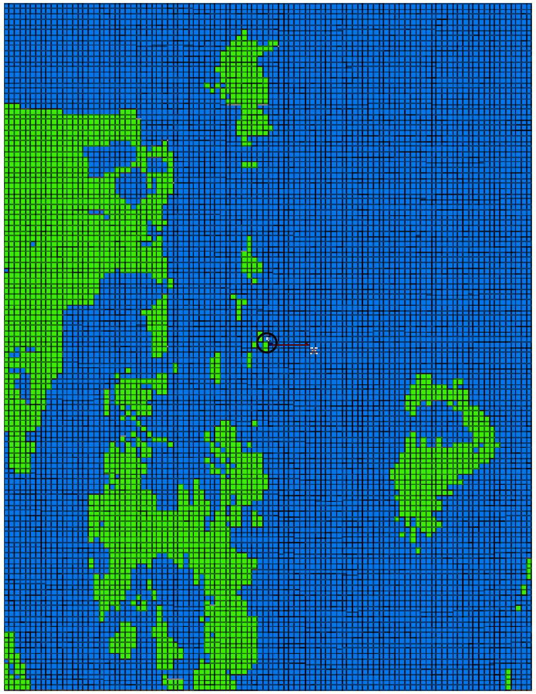
# Model 3 – 100m Salt welds




Wellhead pressure [Pa] versus time [sec]

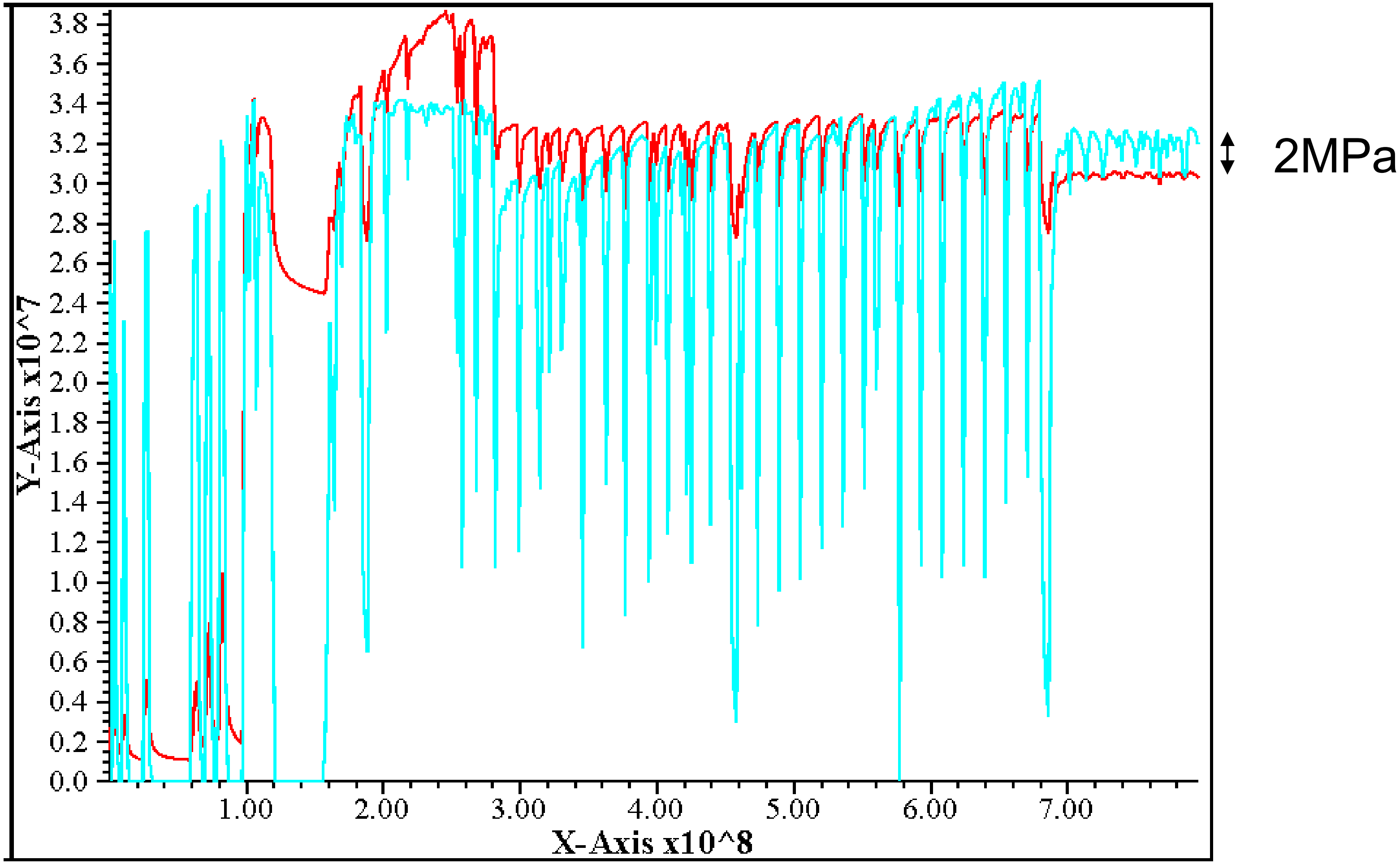
# Model 3 - case 2: 200m Salt welds

Salt layer less than 200m thick above Leaderville is taken as weld with same fluid properties as Upper formations



Welds colored in green on plan view

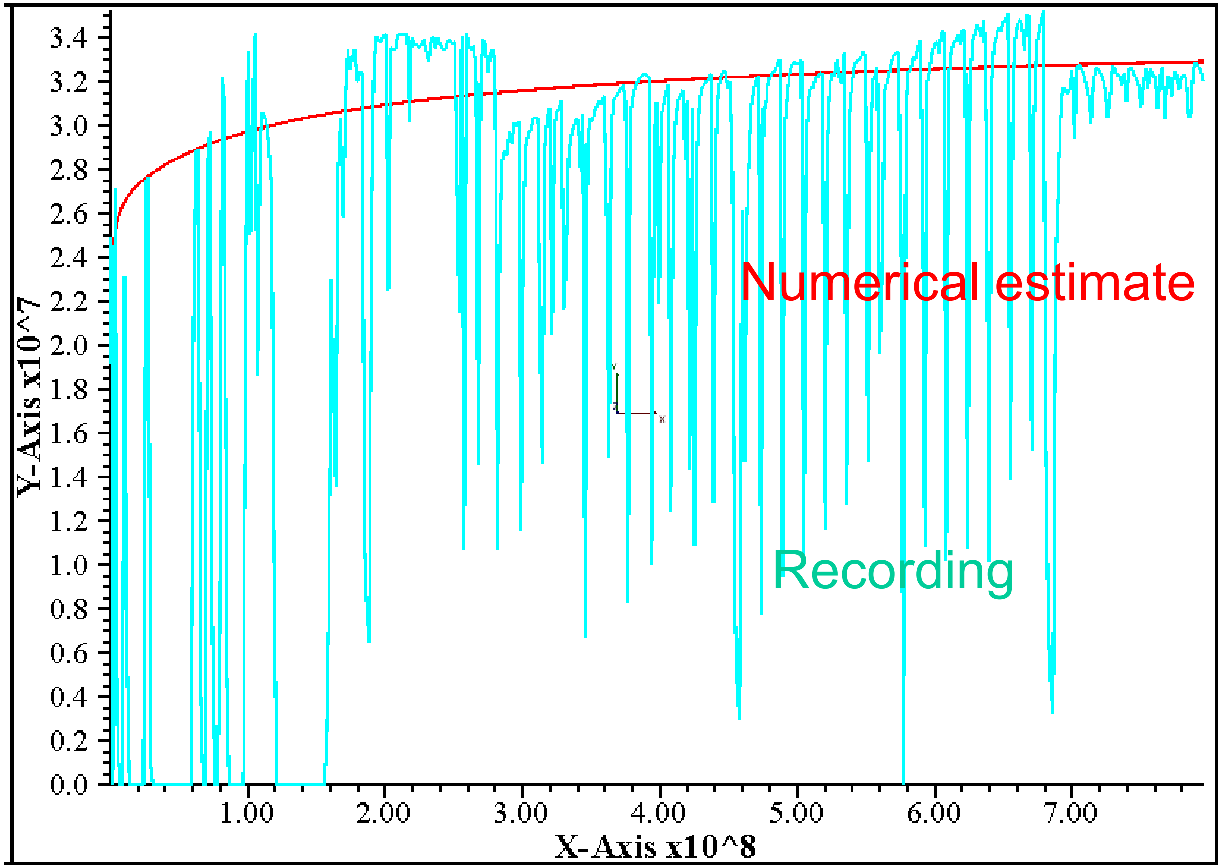
# Model 3 – 200m Salt welds




Wellhead pressure [Pa] versus time [sec]

# Model 3 – 200m Welds - constant Q

Q=0.012 m^3/sec (7000 barrels/day) (*)




Wellhead pressure [Pa] versus time [sec]

# Summary

The comparison between wellhead pressure data and simulation results indicates that, with the FLAC3D model and the well pressure correction considered in the simulations:

- The best match is obtained using Model 1 or Model 3
- Model 2 gives the worst fit
- The results of Model 3 are similar to those of Model 1 especially in the short time; this is attributed to the ‘far away’ location from the well of  simulated welds.

# THANK YOU!

# Paradox Valley Project

## Permeability model investigation
## - continuation -

December 11, 2016

Ed Dzik, Christine Detournay
Itasca Consulting Group, Inc.

# Initial objective

Using Flow only simulations, determine if the PVU well-head and pressure data can help distinguish between the following 3 Permeability Models:

1. Impermeable top of Leadville, permeable layers below Leadville, and “transparent” faults (current Itasca model)
2. Impermeable top and bottom of Leadville, and impermeable faults (most compartmented model)
3. Permeable top and bottom of Leadville, and “transparent” faults (least compartmented model)

Ref.: December 12, 2016 email form Christopher Wood

# Additional cases

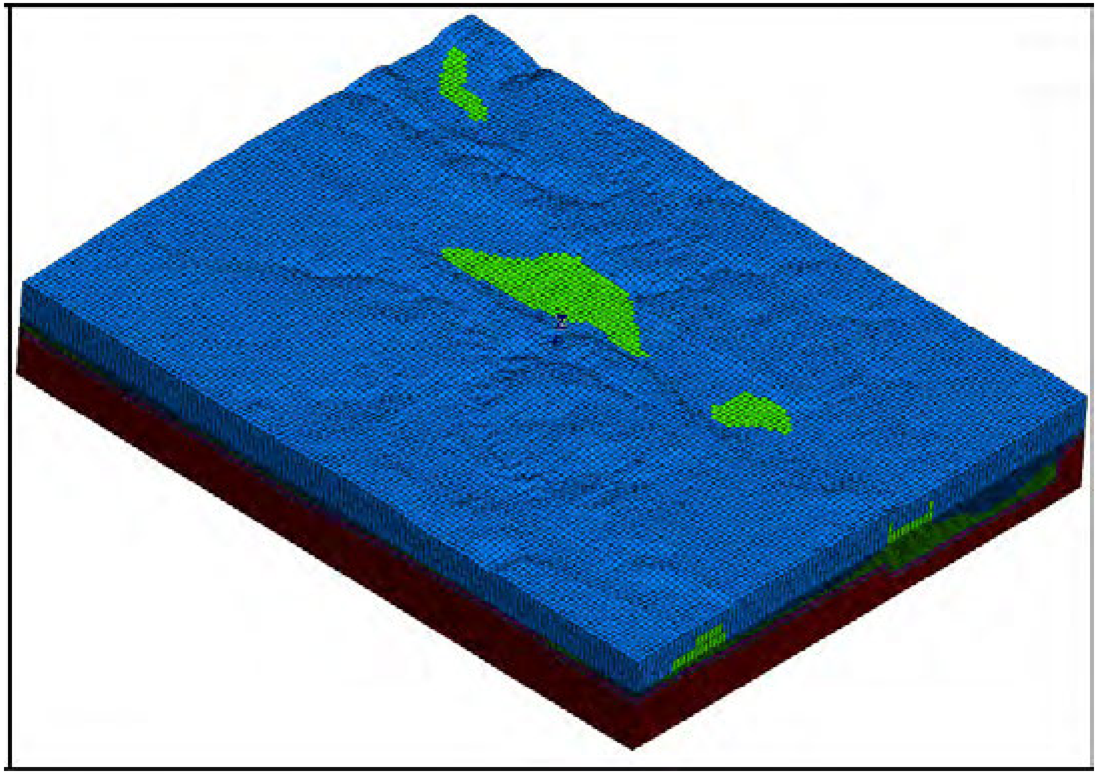
Case 2 was considered unrealistic, based on the high wellhead fluid pressures obtained in the simulations results documented in PR2

Two new cases were proposed at the December 19, 2016 meeting:

4. Permeable Upper and permeable Welds (geometry provided by USBR) at top of Leadville, permeable bottom of Leadville and “transparent” faults
5. Same as Case 4, with impermeable Faults (specified by USBR) cutting through the Leadville, Sedimentary, and Upper Precambrian

# *FLAC3D* model

6 Layer model + welds + impermeable faults



- Upper
- Salt + welds
- Leadville
- Sedimentary
- Upper Precambrian
- Lower Precambrian

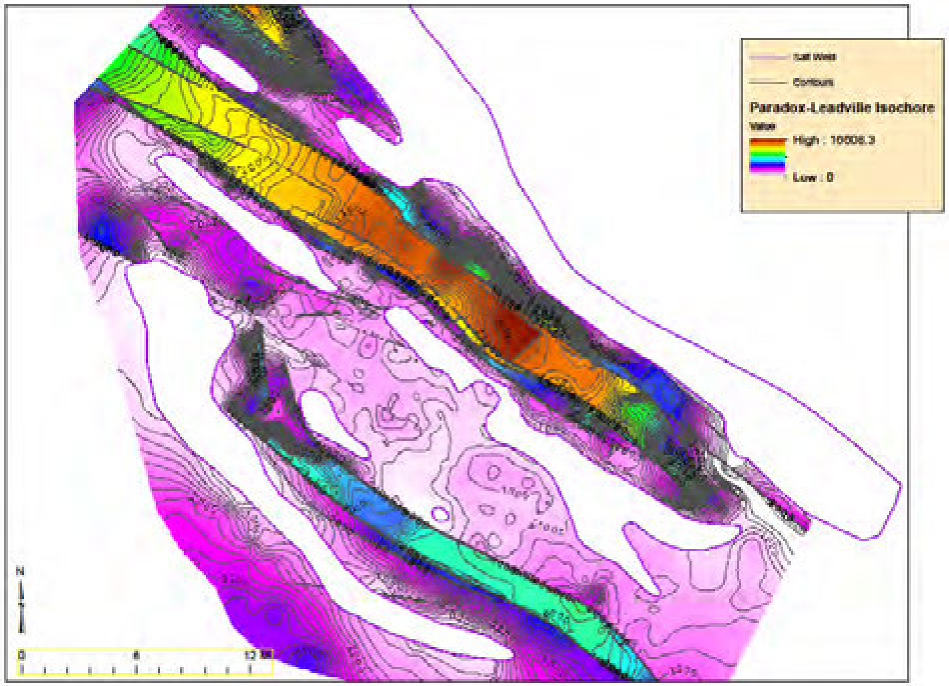
40 km x 52 km x 7.7 km

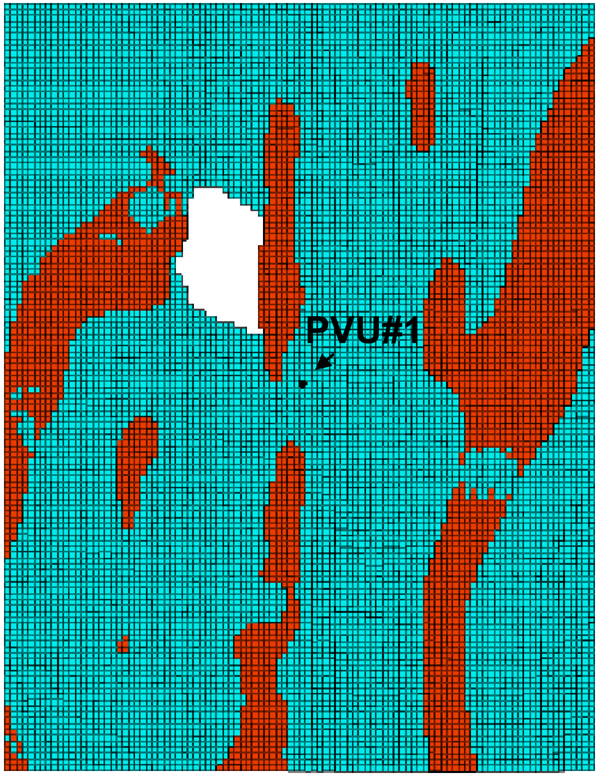
Zone size in Leadville:
100m in vertical direction,
400m x 400m horizontally

611,000 zones - 635,088 nodes

# New additions: Welds

Plan view of welds



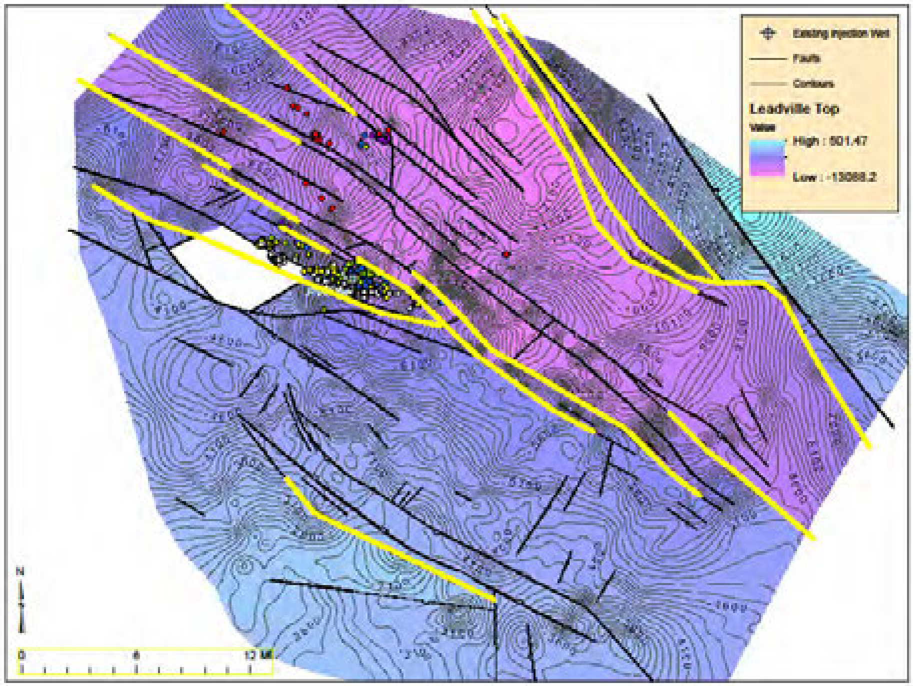




USBR data (white areas)

FLAC3D model realization (brown on blue Leadville background)

# New additions: Impermeable Faults

Plan view of Faults




USBR data

FLAC3D model realization

Impermeable faults in yellow

# Planned work

Run the 2 flow only permeability models: Case 4 and Case 5,
- with the injection rate provided by USBR
- with constant rate of 0.012 m^3/sec (7000 barrels/day), (*)
  to use as reference

Compare the predicted surface pressure at the well location with
the surface pressure data from USBR:

- Estimate the impact of the presence of the welds on the numerical estimate of wellhead pressure.
- Determine if one of the permeability models can be favored, based on the ability to better fit the numerical response to the available wellhead pressure data.

(*) PWS p1

# Additional data for the simulations

Geometrical data: same as in PR2, plus welds and impermeable Faults

- Upper
- Salt → Welds (Cut through the Salt)
- Leadville → 100 m thick (90m)
- Sedimentary
- Precambrian → 100 m thick (58m)
- Lower Precambrian

Injection: in Leadville

- daily rate provided by USBR, up to 25.24 years
- constant rate of 0.012 m^3/sec used for reference

Fluid properties:

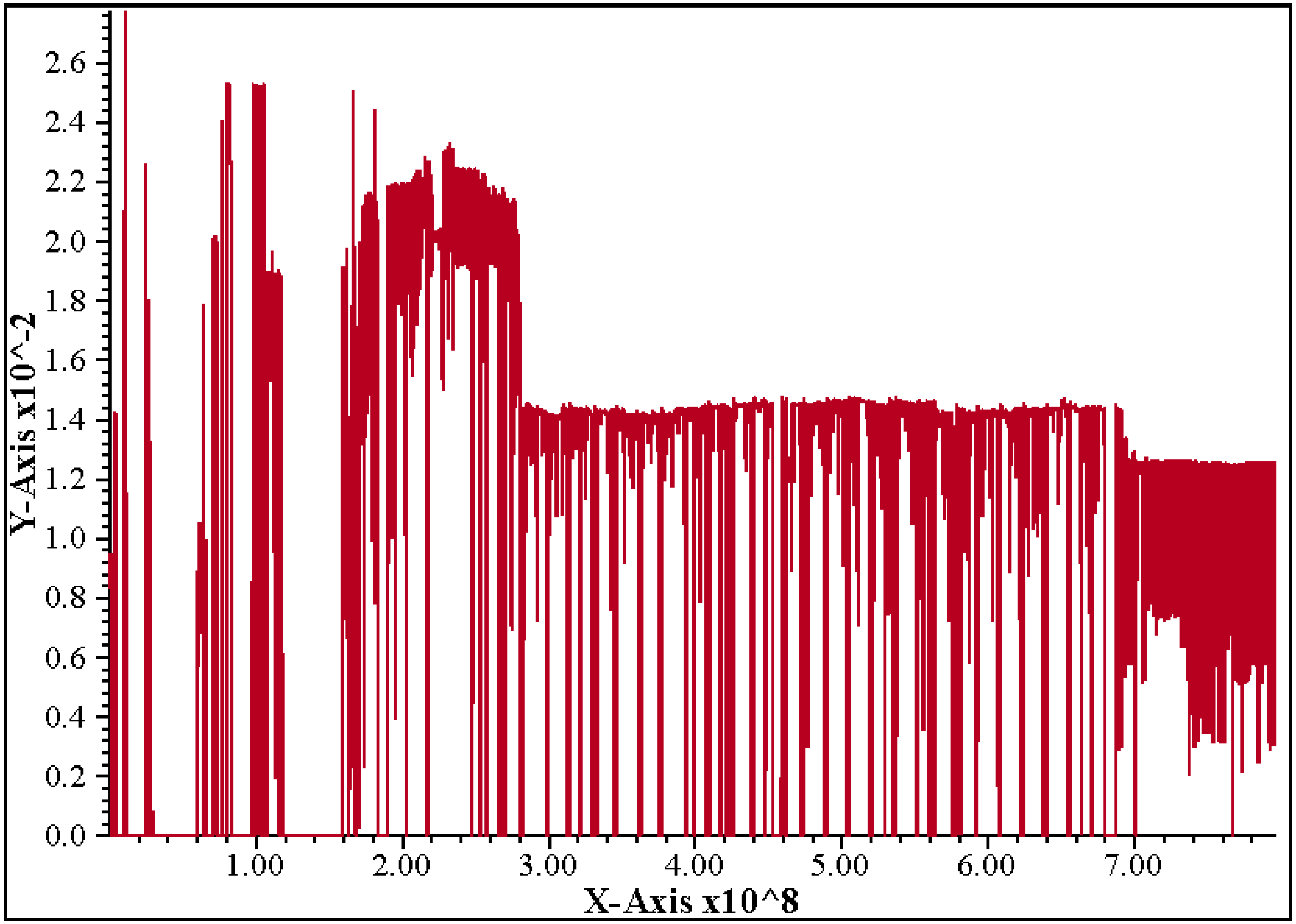
- Brine density: 1153 kg/m^3
- Brine viscosity: 0.001348 Pa.sec

# Layer Properties data

| Layer | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Layer description | Formations above salt | Salt | Leadville | Sedimentary layers below Leadville | Precambrian | Lower Precambrian |
| Density | 2.53 $g/cm^3$ | 2.16 $g/cm^3$ | 2.69 $g/cm^3$ | 2.56 $g/cm^3$ | 2.65 $g/cm^3$ | 2.65 $g/cm^3$ |
| Bulk modulus | 29.8 GPa | 25.3 GPa | 64.8 GPa | 50.6 GPa | 50.1 GPa | 50.1 GPa |
| Young's modulus | 43.1 GPa | 35.8 GPa | 76.2 GPa | 66.8 GPa | 83.0 GPa | 83.0 GPa |
| Shear modulus | 17.1 GPa | 14.2 Gpa | 29.2 GPa | 26.1 GPa | 33.9 GPa | 33.9 GPa |
| Poisson's ratio | 0.260 | 0.264 | 0.304 | 0.280 | 0.224 | 0.224 |
| Permeability | 0.1 mD | 0 mD | 6 mD | 0.1 mD | 1.5 mD | 0 mD |
| Porosity | 0.06 | 0 | 0.05 | 0.01 | 0.03 | 0 |
| Diffusivity (before 1/8/02) | 0.0019 $m^2/s$ | 0 $m^2/s$ | 0.20 $m^2/s$ | 0.0043 $m^2/s$ | 0.051 $m^2/s$ | 0 $m^2/s$ |
| Diffusivity (after 1/8/02) | 0.0020 $m^2/s$ | 0 $m^2/s$ | 0.21 $m^2/s$ | 0.0044 $m^2/s$ | 0.053 $m^2/s$ | 0 $m^2/s$ |

Note: Welds have same flow properties as Upper

# Injection rate data




Injection rate [m^3/sec] versus time [sec]

# Fluid pressure - definitions

**Excess pressure:**
Induced by injection → simulation result (same as in PR1)

**Downhole**:

- Excess pressure in injection zone:
  p_z =  excess pressure in zone + insitu fluid pressure

- Total pressure at the well:
  p_down = p_z + well pressure correction

**Well head**:

- p_up = p_down – brine static pressure

# Well pressures quantities

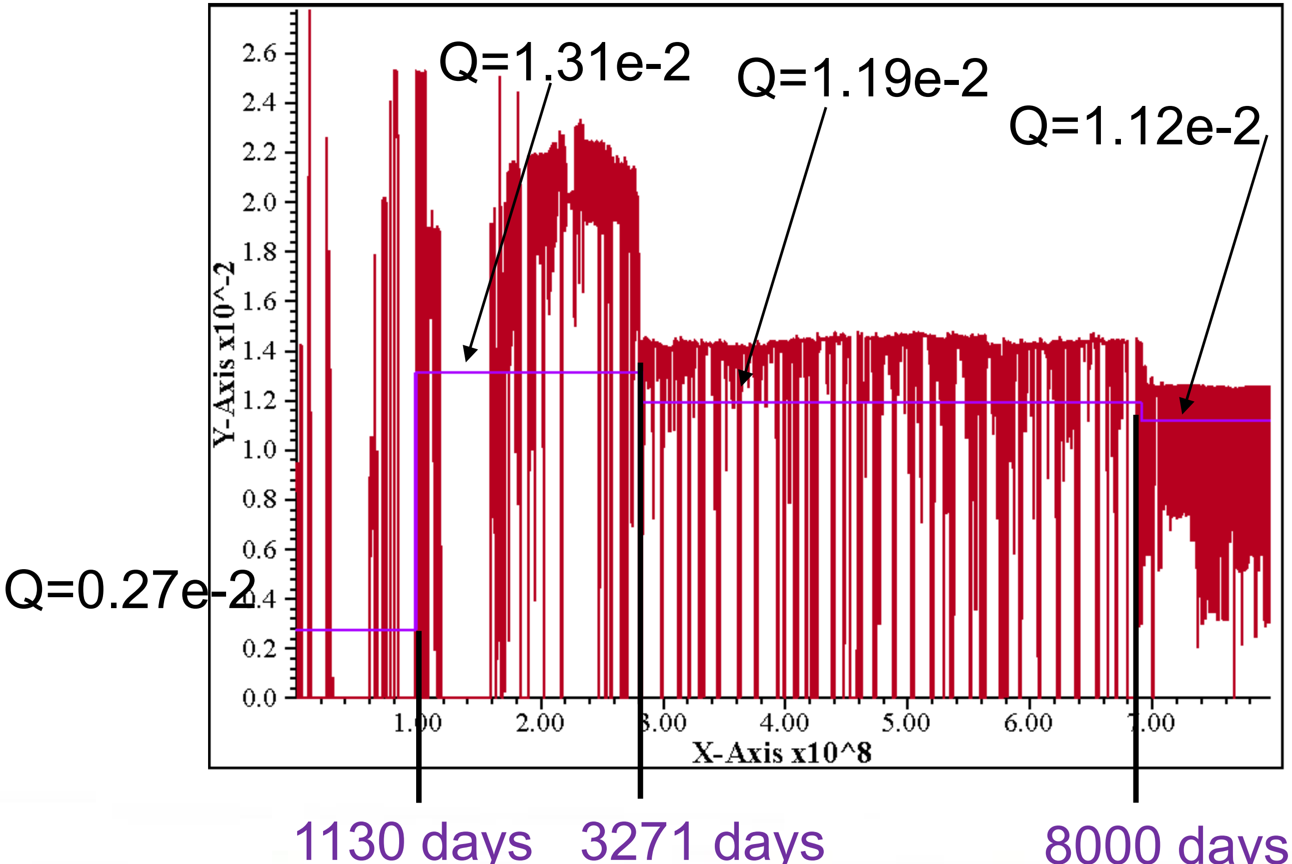
Well pressure correction:

$$\Delta p = \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r} = 2.14 \text{ x } 10^9 \; Q \text{ [Pa]}$$

| | |
|---|---|
| $r_0 = 200$ m | half zone lateral size |
| $r = 0.5$ m | well radius |
| $h = 100$ m | injection interval |
| $k = 4.45.10^{-12}$ m$^2$ / Pa.sec | mobility coefficient |
| $Q =$ m$^3$/sec, see next slide... | flow rate |

# Flow rate used in well correction

Arithmetic average [m^3/sec] based on daily rate data



# Well pressures quantities

Well pressure correction:

$$\Delta p = \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

$$\Delta p = [5.8\ , 28.1\ , 25.5\ , 24.0]\ \mathrm{MPa}$$

Insitu fluid pressure:

$$p_{insitu} = 44.7\ \mathrm{MPa}\ (*) \Longrightarrow$$ Calibration parameter

Brine static pressure:

$$p_{brine} = \rho_{brine} g H = 49.7\ \mathrm{MPa}$$

$H = 4396$ m injection depth

$\rho_{brine} = 1153$ kg/m$^3$ brine density

(*) compare to 42 MPa from the map (Bremkamp &Harr) in Fig 11 of King et al., 2014

# FLOW SIMULATION RESULTS

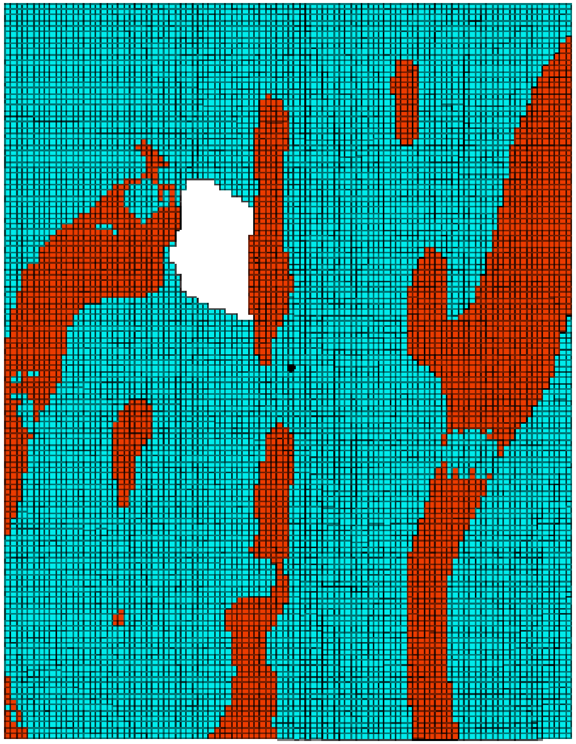
Transparent Faults

# Permeability Model 4

- Permeable Upper (above Salt)
- Permeable USBR Salt Welds
- Permeable layers below Leadville (Sedimentary, Upper Precambrian),
- "Transparent" Faults

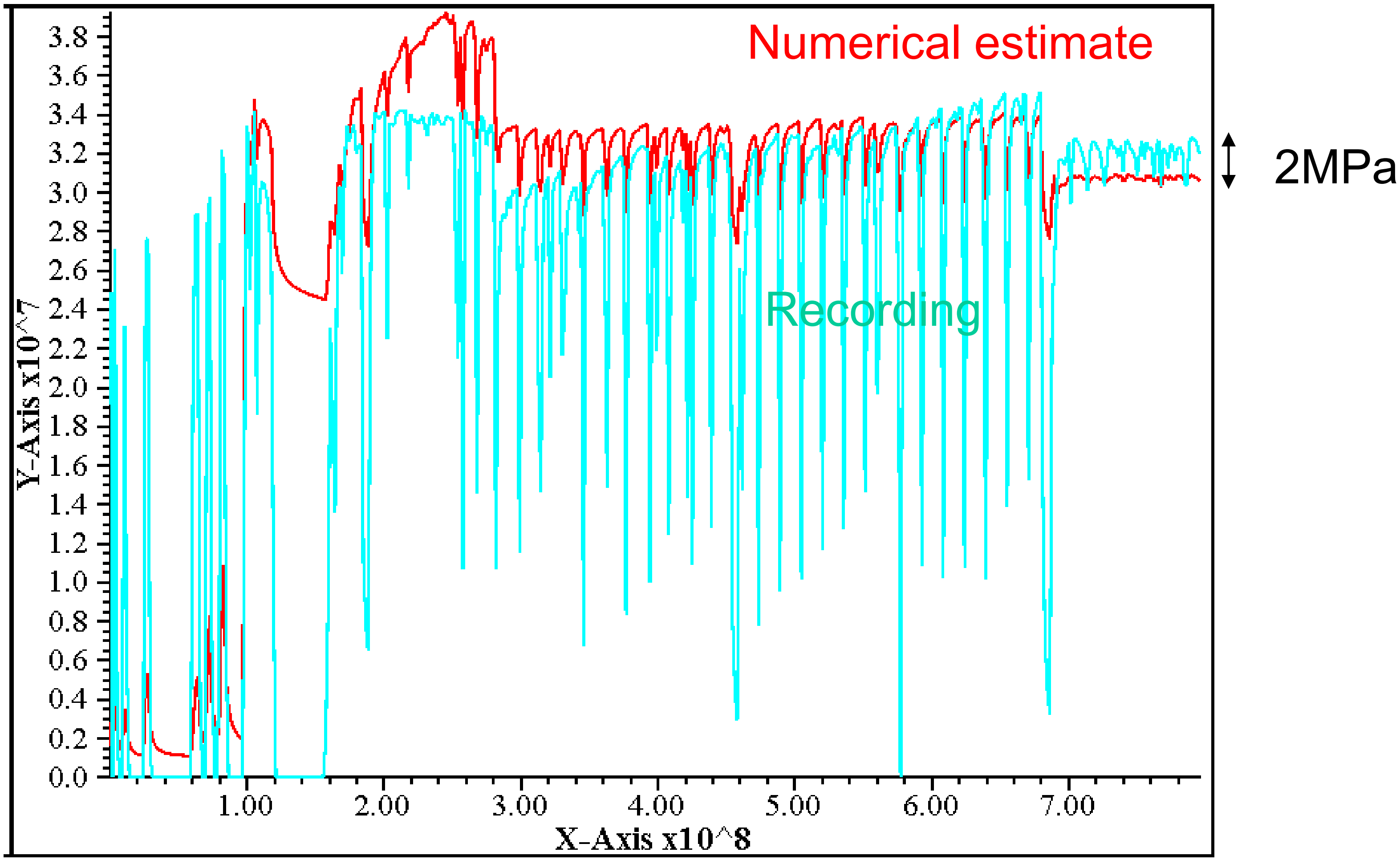
# Model 4 – USBR Salt welds

Regions outlined by USBR are defined as welds in the Salt layer with same fluid properties as Upper formations



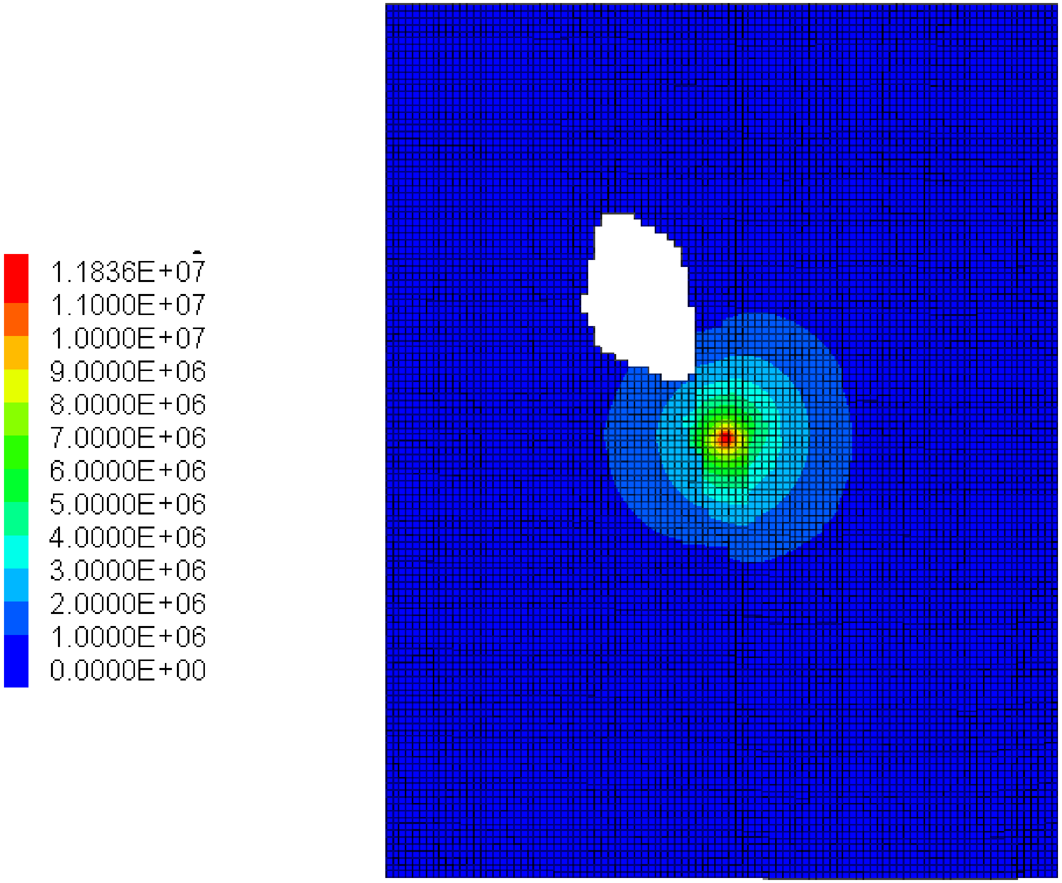
Welds colored in brown on plan view

# Model 4 – PVU1 Injection data




Wellhead pressure [Pa] versus time [sec]

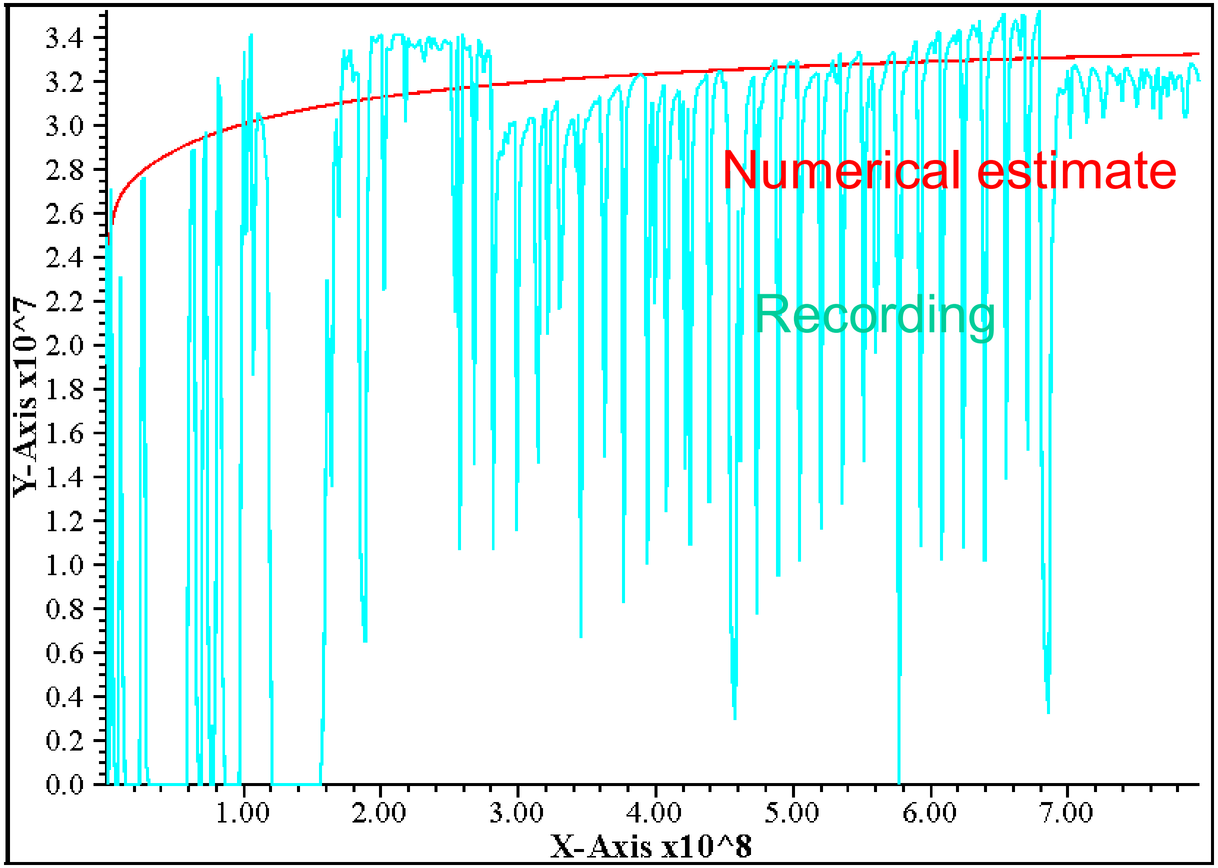
# Model 4 – PVU1 Injection data




Excess fluid pressure contours in the Leadville [Pa]

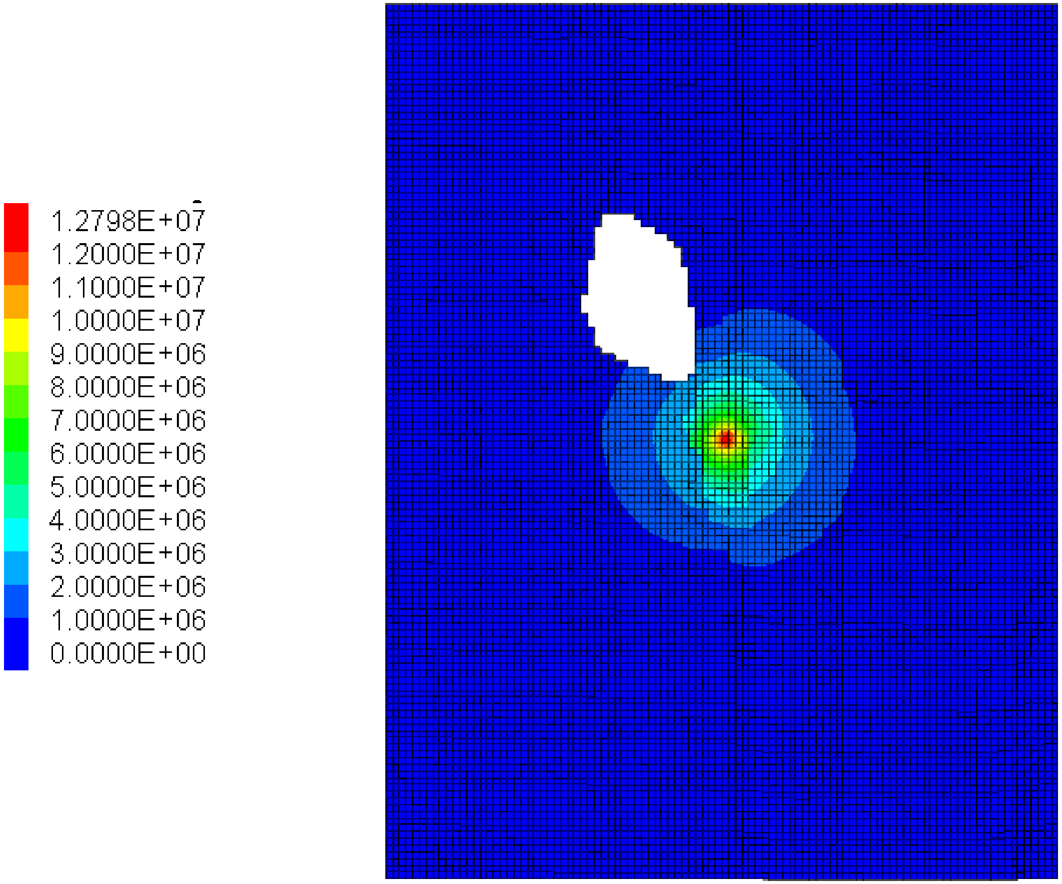
# Model 4 – constant Q

Q=0.012 m^3/sec (7000 barrels/day)




Wellhead pressure [Pa] versus time [sec]

# Model 4 – constant Q




Excess fluid pressure contours in the Leadville [Pa]

# FLOW SIMULATION RESULTS

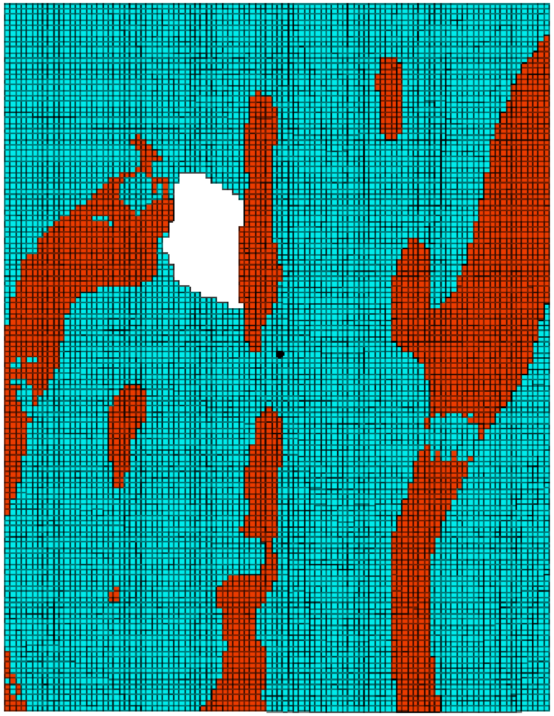
Impermeable Faults

# Permeability Model 5

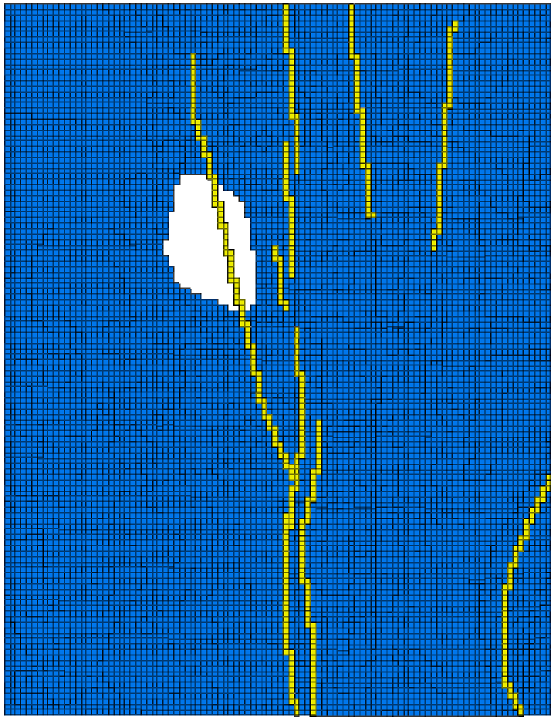
- Permeable Upper
- Permeable USBR Welds
- Permeable layers below Leadville (Sedimentary, Upper Precambrian),
- Impermeable Faults (USBR data), the others are "Transparent" Faults

# Model 5 - Salt welds and Impermeable Faults

Plan views with Leadville background

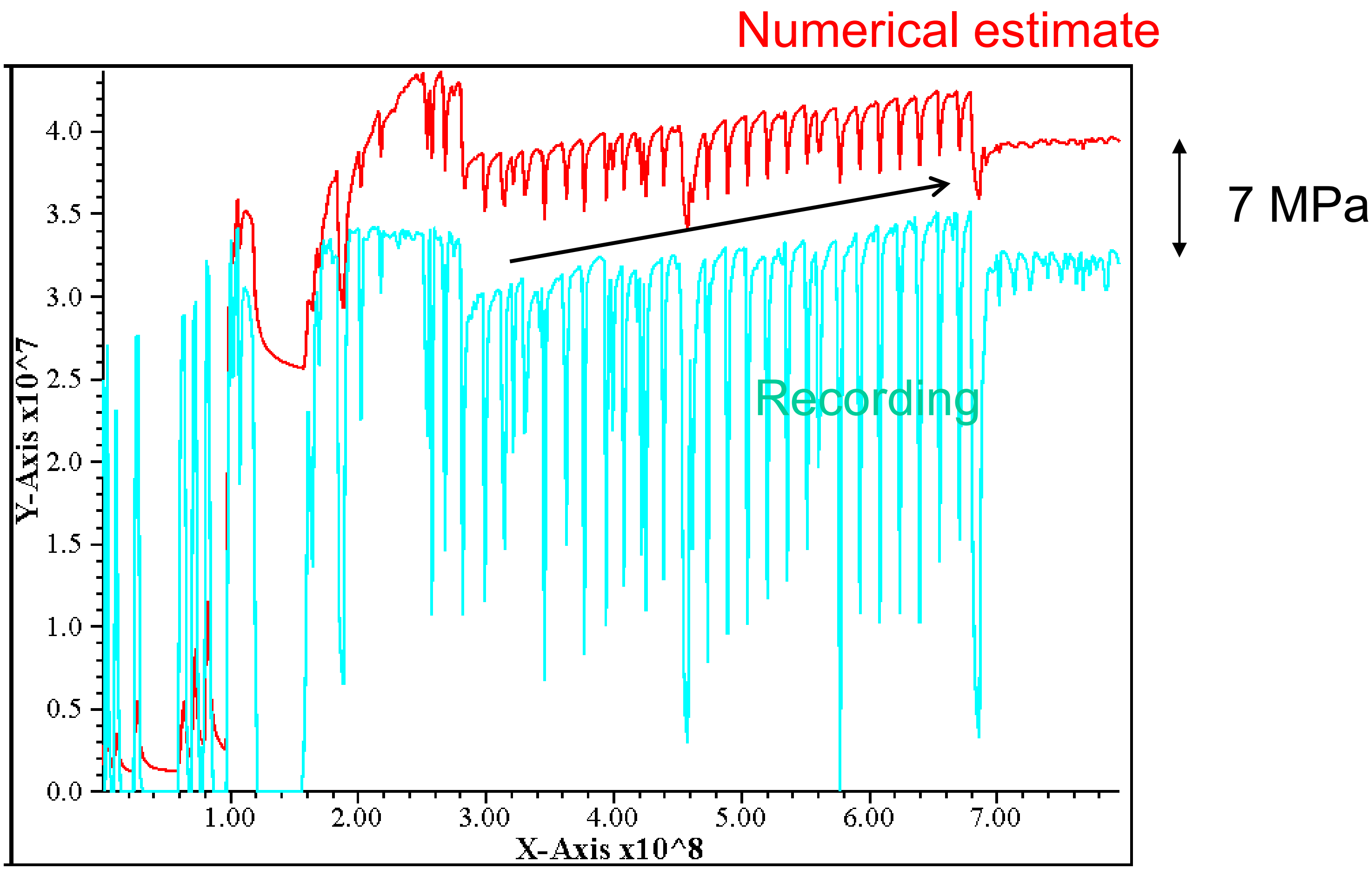


Welds colored in brown



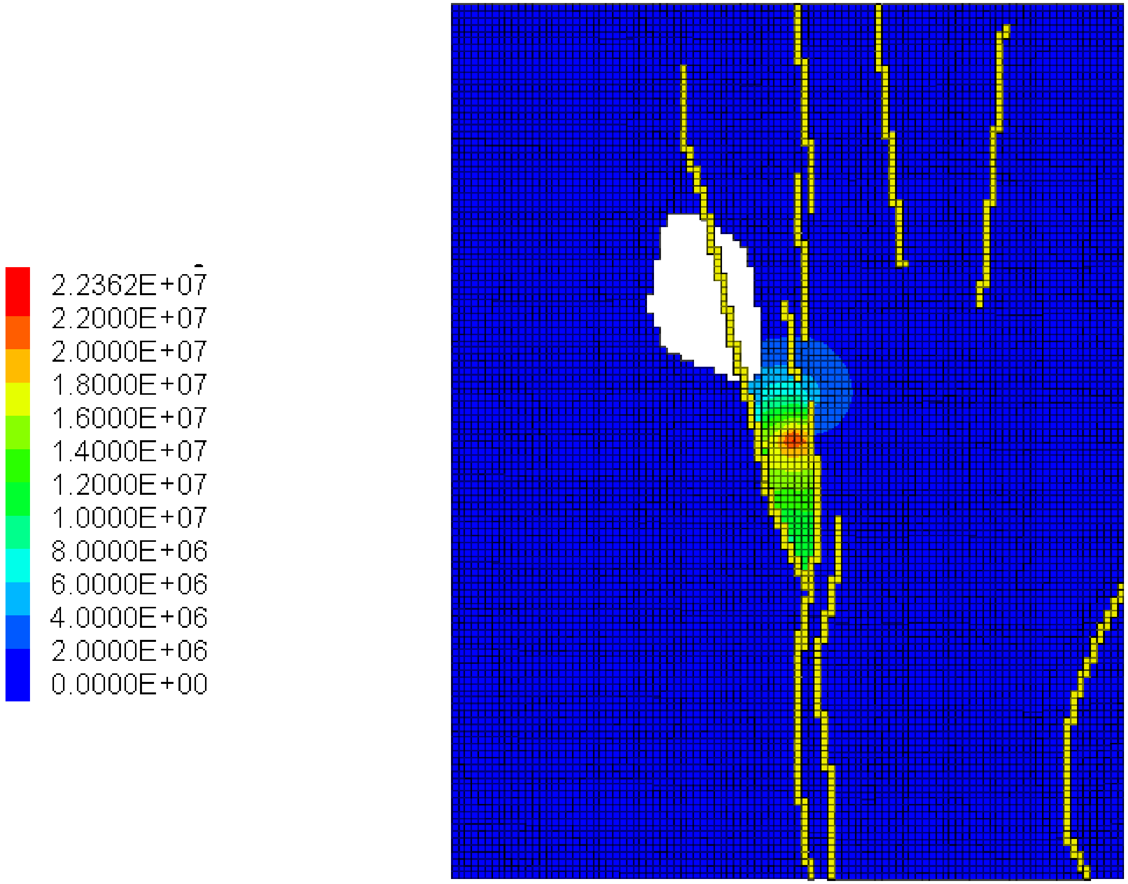
Impermeable Faults in yellow

# Model 5 – PVU1 Injection data




Wellhead pressure [Pa] versus time [sec]

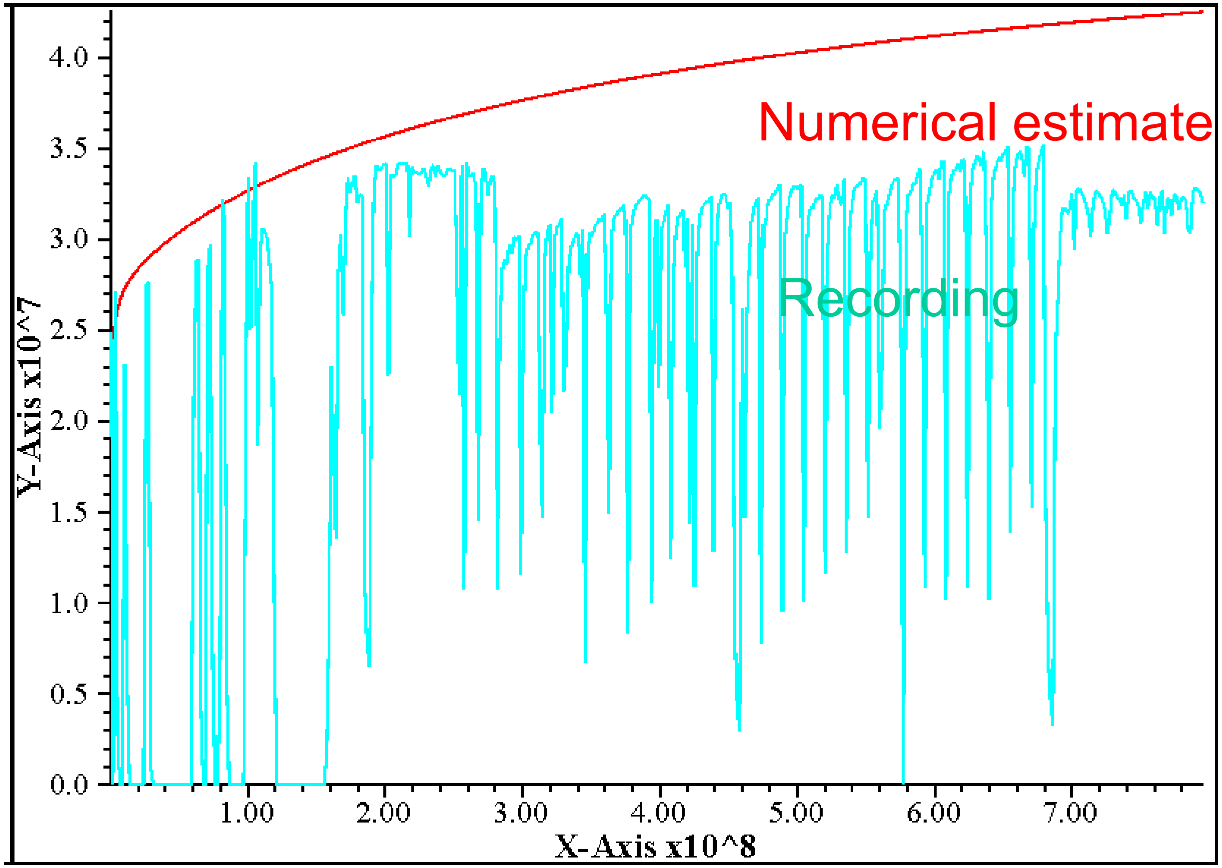
# Model 4 – PVU1 Injection data




Excess fluid pressure contours in the Leadville [Pa]

# Model 5 – constant Q

Q=0.012 m^3/sec (7000 barrels/day)




Wellhead pressure [Pa] versus time [sec]

# Calibration review

Potentially, the following two quantities could be adjusted:

Well pressure correction (radial flow hypothesis):

$$\Delta p = \alpha_{wc} \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

$$\Delta p = \alpha_{wc} [5.8\ , 28.1\ , 25.5\ , 24.0]\ \mathrm{MPa}$$

Insitu fluid pressure (already used as adjustment parameter):

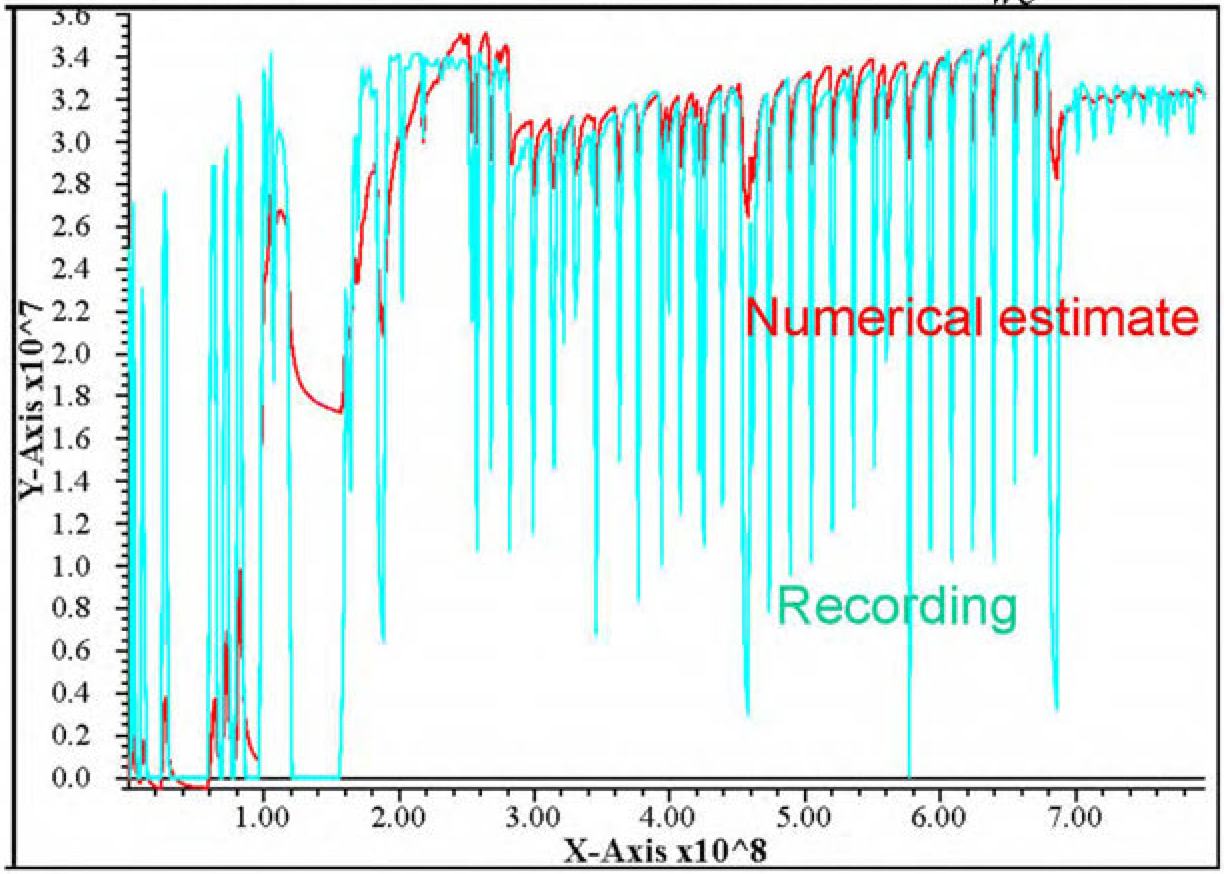
$$p_{insitu} = \alpha_{ip} 44.7\ \mathrm{MPa}\ (*)$$

So far: $\alpha_{wc} = \alpha_{ip} = 1$ ⟹ Calibration parameters?

(*) compare to 42 MPa from the map (Bremkamp &Harr) in Fig 11 of King et al., 2014

# Model 5 – adjusted well correction

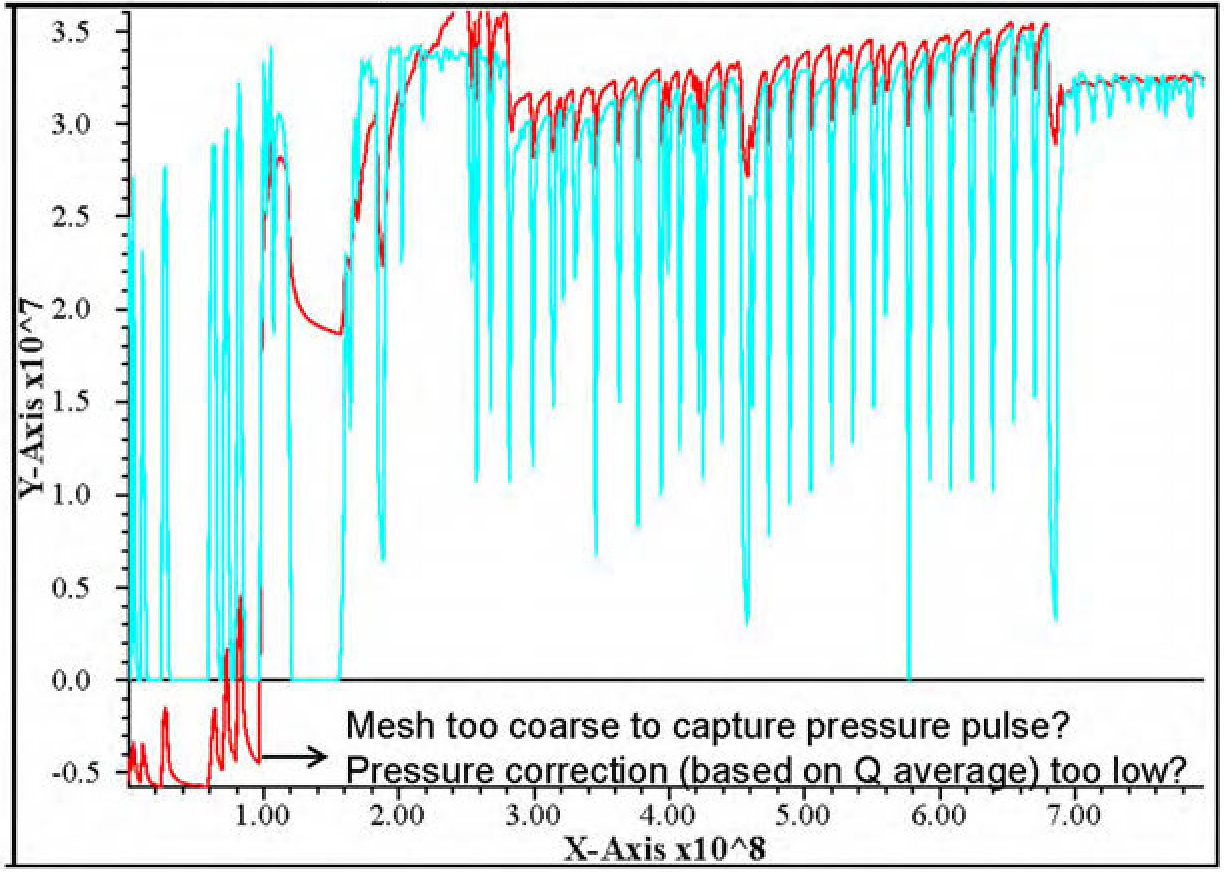
**Well pressure correction reduced to 70%:** $\alpha_{wc} = 0.7$




Wellhead pressure [Pa] versus time [sec]

# Model 5 – adjusted In-situ pressure

**Insitu pressure reduced by 7 Mpa, from 44.7 to 37.7 MPa:** $\alpha_{ip} = 0.8$ **(*)**




Wellhead pressure [Pa] versus time [sec]

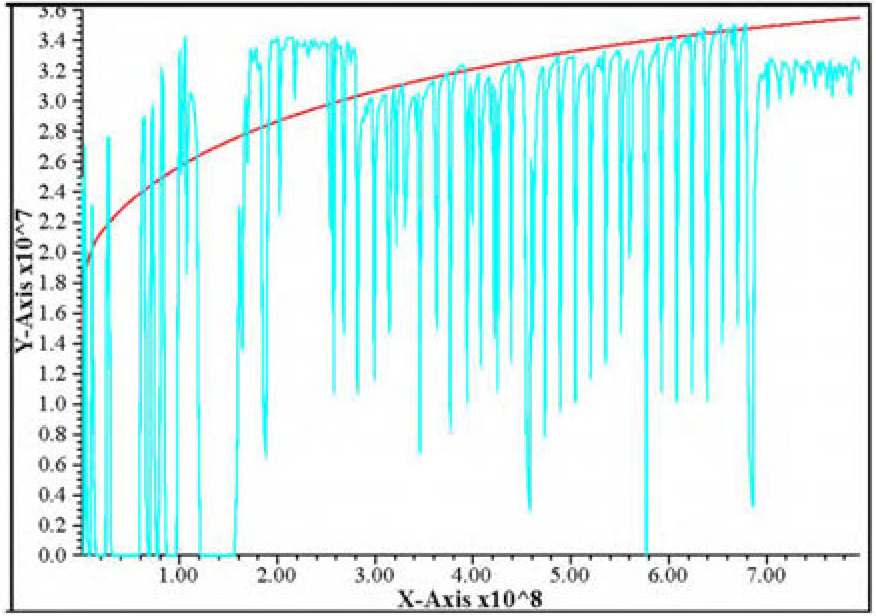
(*) compare to 42 MPa from Bremkamp &Harr

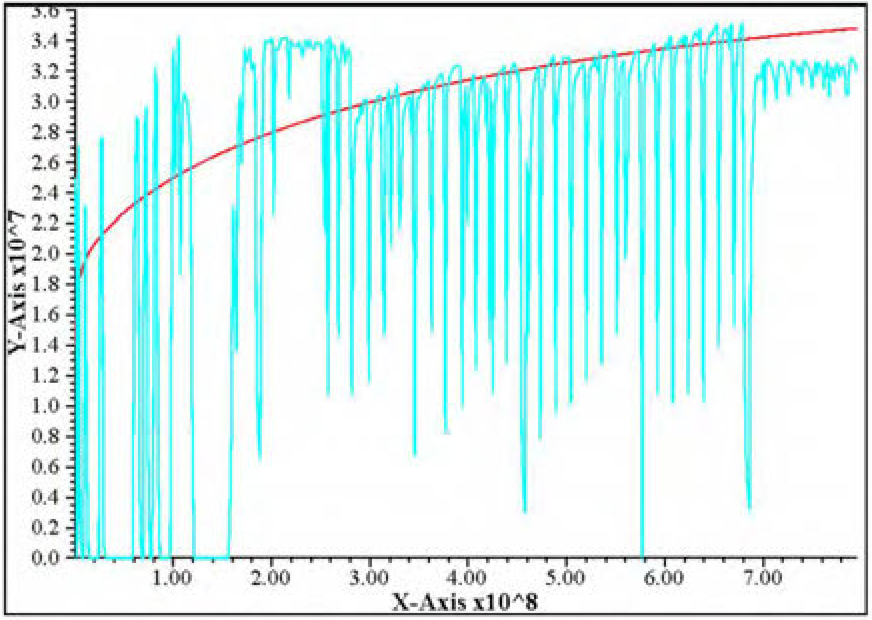
# Model 5 – adjustment - constant Q

Wellhead pressure [Pa] versus time [sec]

Numerical estimate

Recording




**Insitu pressure:** $\alpha_{ip} = 0.8$

**Well correction:** $\alpha_{wc} = 0.7$

# Summary

The comparison between wellhead pressure data and simulation results indicates that, with the FLAC3D model considered in the simulations:

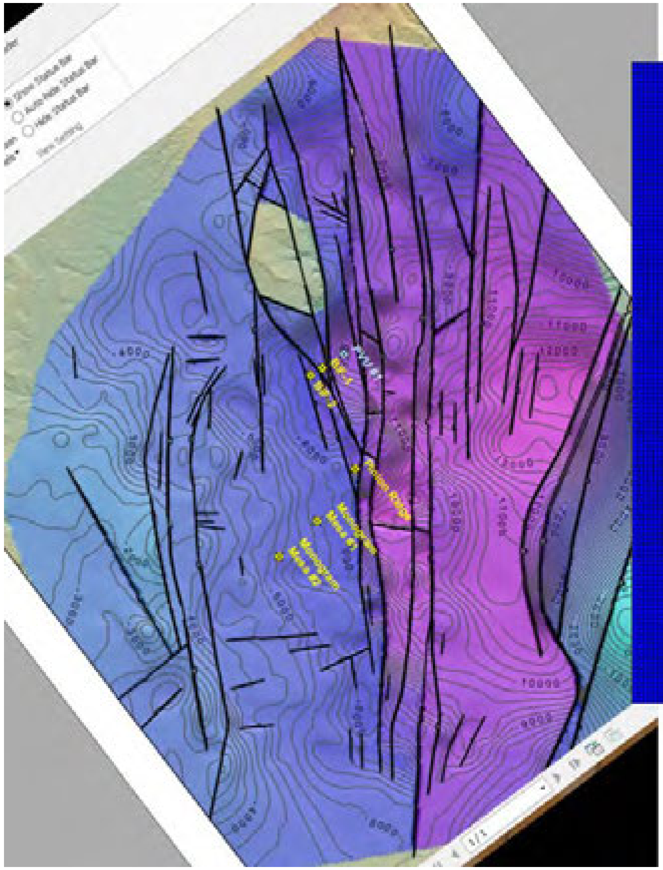
- The impact of the Salt welds is relatively small and can be noticed at 'large times' only on Slide 18

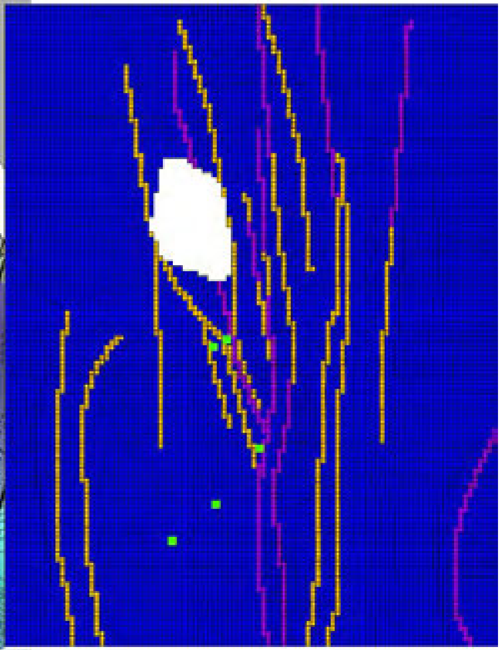
- The trend of increasing pressure during the period where an average Q=1.19 m^3/s was maintained (see slide 12) is best captured by Model 5 (with USBR impermeable Faults)

- Model 5 could be recalibrated to give a reasonable fit, from the start of that period onward, by adjusting either the in-situ pressure, or the well pressure correction, or both
  - To be discussed!

- The fit at 'early times' is not very good.

# Well locations





# THANK YOU!

# Paradox Valley Project

## Permeability model - calibration and predictions at 6 well locations

January 23, 2017

Ed Dzik, Christine Detournay
Itasca Consulting Group, Inc.

# Introduction

Fluid injection was simulated at the location of PVU#1 in a six layer *FLAC3D* model of the Paradox Valley region. The injection history reproduces more than 25 years of data at the site.
A good match *in trend* between numerical well-head pressure predictions and site data was obtained by considering that Faults with a vertical offset larger than 152 m act as barrier to the flow.
The model was further calibrated by adjusting the coefficient of the well pressure correction to best fit the predicted well-head pressure to the measurement for the 25.24 years period of injection at the site of PVU#1.

In this progress report, the calibrated model (with adjusted footprint) is used to make well-head pressure predictions, for up to 50 years of injection at the PVU # 1 site, and at 5 additional potential well sites located in the Paradox Valley.

# Planned work

1. New mesh with adjusted footprint to accommodate 5 additional wells while limiting artificial boundary effects

2. Complete PVU # 1 model calibration

3. With the updated and calibrated model:
   - resume injection up to 50 years in PVU # 1, using a constant injection rate
   - Simulate injection at constant rate, up to 50 years in the Leadville at 5 additional Well locations

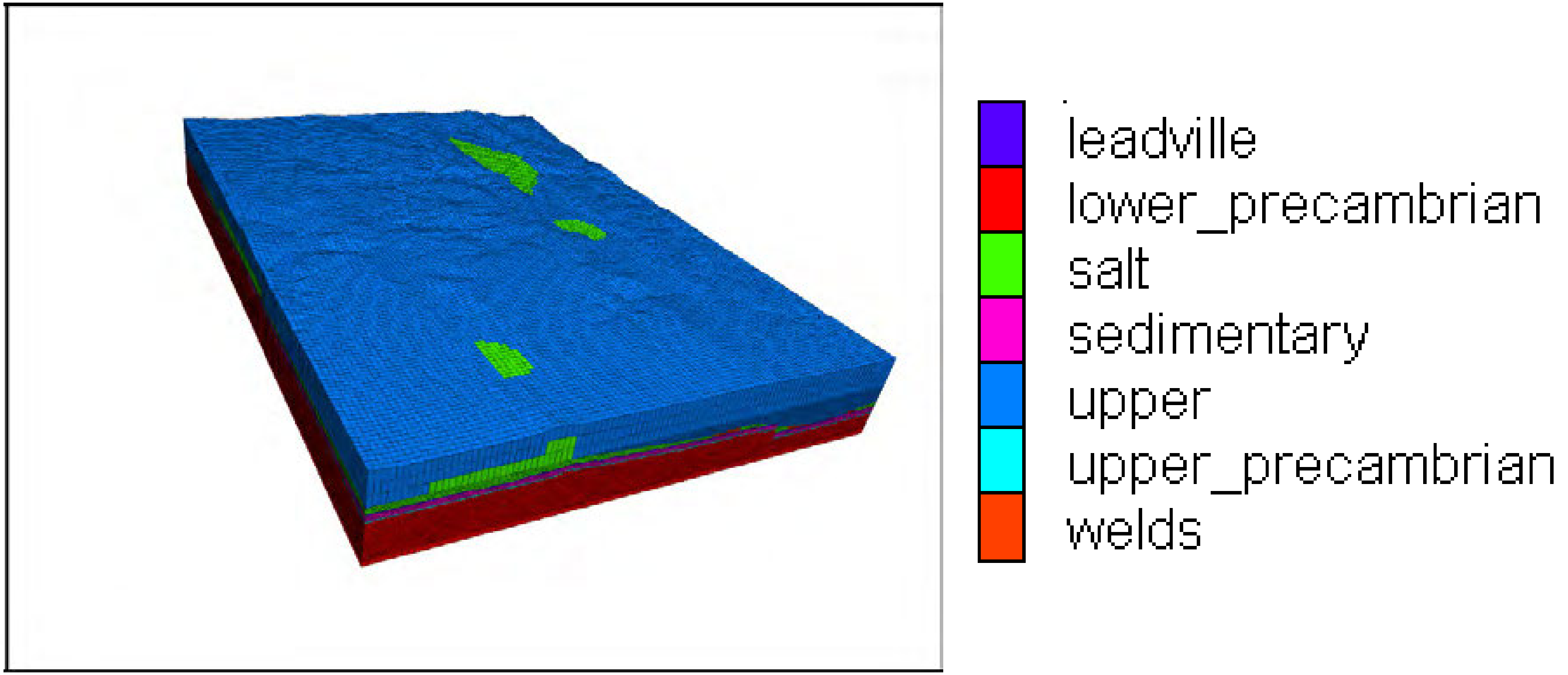
     Start with Q = 0.0227 m^3/s

     Reduce to Q = 0.0151 m^3/s if simulated wellhead pressure exceeds the 34.5 MPa target
4. Using numerical model results for wellhead pressure up to 50 years at 6 sites, predict which location is most favorable, based on the criteria that pressure level should stay below the target value.

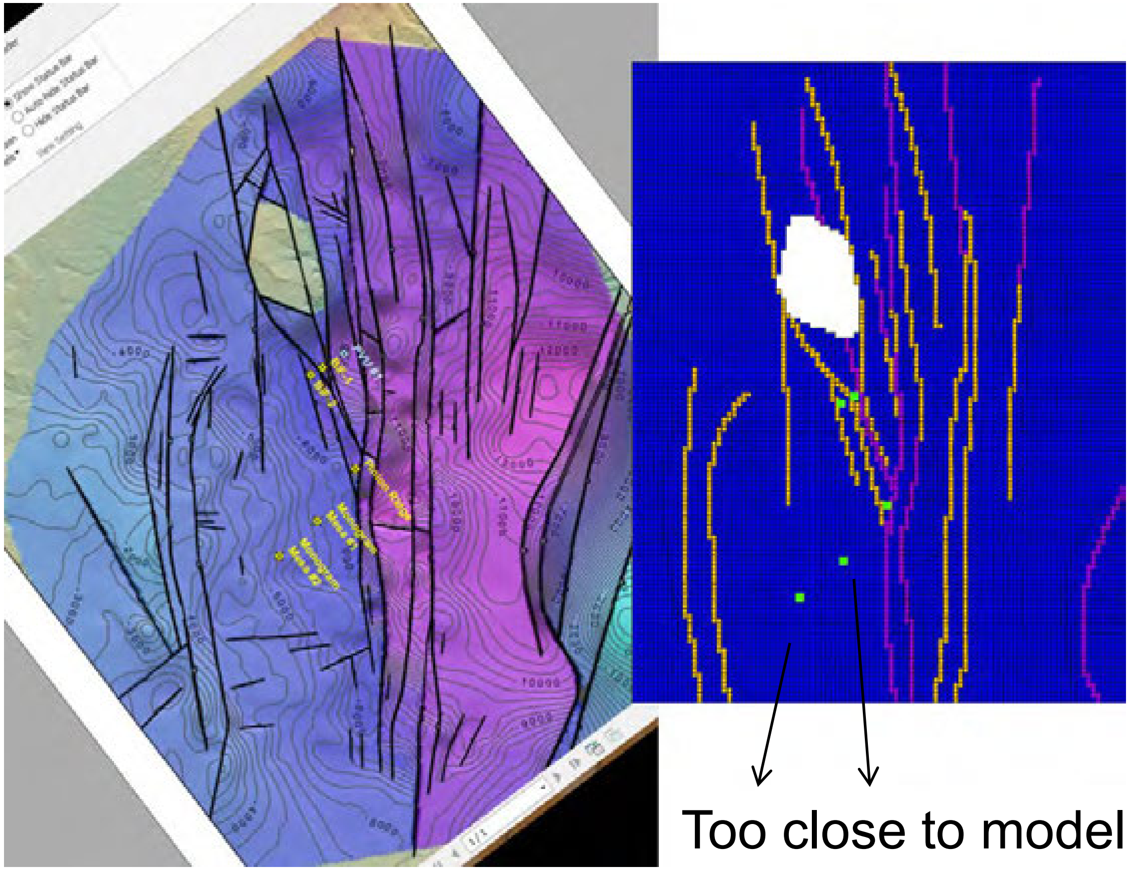
# NEW MESH

# *FLAC3D* model

- 6 Layer model + Welds + Impermeable Faults
- Updated footprint



# Well locations - previous mesh



Too close to model boundary

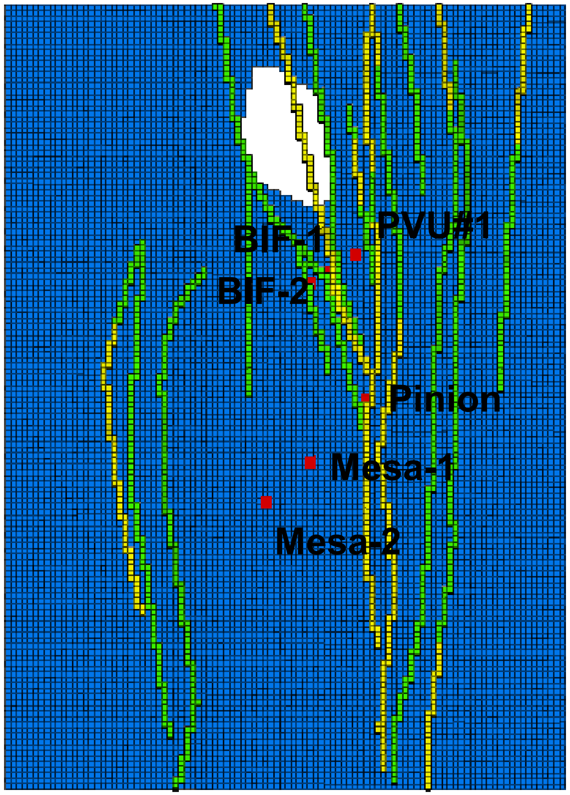
Estimated well-boundary distance to minimize boundary effects up to 50 years of injection (based on Leadville diffusivity): ~18 km

# Well locations – new mesh

Previous model:
40 km x 52 km x 7.7 km
611,000 zones – 635,088 nodes

Previous footprint

New model:
40 km x 56 km x 7.5 km
616,000 zones – 640,845 nodes




New footprint

# Model specifics

**Flow modeling assumptions**:
- Flow of one single fluid (water or brine)
- Steady-state in-situ fluid pressure

**Permeable formations**:
- Upper
- welds
- Leadville
- Sedimentary
- Upper Precambrian

**Injection**:
- in Leadville
- rate provided by USBR
- Brine viscosity: 0.001348 Pa.s
- Brine density: 1153 kg/m^3

**Layer thickness**:
- Welds → footprint provided by USBR, through salt
- Leadville → 100 m thick (90m)
- Precambrian → 100 m thick (58m)

**Zone size in Leadville**:
- 100m in vertical direction,
- 400m x 400m horizontally

# Layer Properties

| Layer | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Layer description | Formations above salt | Salt | Leadville | Sedimentary layers below Leadville | Precambrian | Lower Precambrian |
| Density | 2.53 g/cm$^3$ | 2.16 g/cm$^3$ | 2.69 g/cm$^3$ | 2.56 g/cm$^3$ | 2.65 g/cm$^3$ | 2.65 g/cm$^3$ |
| Bulk modulus | 29.8 GPa | 25.3 GPa | 64.8 GPa | 50.6 GPa | 50.1 GPa | 50.1 GPa |
| Young's modulus | 43.1 GPa | 35.8 GPa | 76.2 GPa | 66.8 GPa | 83.0 GPa | 83.0 GPa |
| Shear modulus | 17.1 GPa | 14.2 Gpa | 29.2 GPa | 26.1 GPa | 33.9 GPa | 33.9 GPa |
| Poisson's ratio | 0.260 | 0.264 | 0.304 | 0.280 | 0.224 | 0.224 |
| Permeability | 0.1 mD | 0 mD | 6 mD | 0.1 mD | 1.5 mD | 0 mD |
| Porosity | 0.06 | 0 | 0.05 | 0.01 | 0.03 | 0 |
| Diffusivity (before 1/8/02) | 0.0019 m$^2$/s | 0 m$^2$/s | 0.20 m$^2$/s | 0.0043 m$^2$/s | 0.051 m$^2$/s | 0 m$^2$/s |
| Diffusivity (after 1/8/02) | 0.0020 m$^2$/s | 0 m$^2$/s | 0.21 m$^2$/s | 0.0044 m$^2$/s | 0.053 m$^2$/s | 0 m$^2$/s |

# Flow modeling technique - a

- Injection is modelled using a volumetric source (the ‘right’ fluid volume is injected in the model).
- A flow simulation is performed in the *FLAC3D* model to calculates the excess pore pressure due to injection.
- The in-situ fluid pressure, assumed to be at steady-state (i.e. fluid pressure stays constant if no injection is made), is added to the excess pore pressure to provide the total pore pressure in the model.
  Note: A constant potentiometric surface is assumed in this PR. However, another appropriate steady-state field could be used instead.

# Flow modeling technique - b

- At the **well injection location only**:
  - a well pressure correction is made to account for the relatively large zone size, compared to well diameter in the model
  - the static brine pressure in the well is taken into account to evaluate the wellhead pressure

- It makes sense, given the one fluid restriction, to assume that the fluid considered in the model is water.

Note: the estimate of the radius of brine 'extension' in the model after 50 years of injection in the Leadville at the rate of 0.0151 m^3/s is about 1.2 km

$$r = \sqrt{\frac{Qt}{n\pi h}}$$

h = 100m height of Leadville
n = 0.05 porosity of Leadville

# Injection locations

Model based values – [m]

| Name | x | y | z | Δz |
|---|---|---|---|---|
| PVU # 1 | 0 | 200 | -2850 | --- |
| BIF-2 | -3200 | -1800 | -2050 | 800 |
| BIF-1 | -2000 | -1000 | -2050 | 800 |
| Mesa-1 | -3200 | -14600 | -1750 | 1100 |
| Mesa-2 | -6400 | -17400 | -1650 | 1200 |
| Pinion Ridge | 800 | -10200 | -2050 | 800 |

# Well pressure quantities - a

Excess pressure in injection zone: $p_e$

Well pressure correction in injection zone: $\Delta p_w$

Insitu fluid pressure at injection location: $p_{insitu}$

Brine static pressure in well: $p_{brine}$

Wellhead pressure: $p_{WH}$

$$p_{WH} = p_e + \Delta p_w + p_{insitu} - p_{brine}$$

# Well pressure quantities - b

Well pressure correction:

$$\Delta p_w = \alpha \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r} = \alpha \; 2.14 \text{ x } 10^9 \; Q \text{ [Pa]}$$

$\alpha$ → calibration parameter, chosen to fit PVU#1 Wellhead pressure data

| | |
|---|---|
| $r_0 = 200$ m | half zone lateral size |
| $r = 0.5$ m | well radius |
| $h = 100$ m | injection interval |
| $k = 4.45.10^{-12}$ m$^2$ / Pa.sec | Leadville mobility coefficient |
| $Q =$ m$^3$/sec | flow rate |

# Well pressure quantities - c

Insitu fluid pressure at injection location (*):

$$\rho_{water} = 1000 \text{ kg/m}^3$$
$$\rho_{brine} = 1153 \text{ kg/m}^3$$
$$\text{g} = 9.81 \text{ m}^2/s$$

$$p_{insitu}^{water/brine} = 42.3 \text{ MPa} - \rho_{water/brine} \cdot g \cdot \Delta z$$

| Well | $\Delta z$ [m] | $(p_{insitu}^{brine}$ [MPa]) | $p_{insitu}^{water}$ [MPa] | $p_{insitu}^{USBR}$ [MPa] |
|---|---|---|---|---|
| PVU # 1 | 0 | (42.3) | 42.3 | 42.3 |
| BIF-2 | 800 | (33.25) | 34.45 | 38.65 |
| BIF-1 | 800 | (33.25) | 34.45 | 36.47 |
| Mesa-1 | 1100 | (29.86) | 31.51 | 35.82 |
| Mesa-2 | 1200 | (28.73) | 30.53 | 36.08 |
| Pinion Ridge | 800 | (33.25) | 34.45 | 39.12 |
| | | | | |

(*) relative to PVU # 1

# Well pressure quantities - d

Brine static pressure :

$$p_{brine} = \rho_{brine} \cdot g \cdot \mathrm{d}_{inj}$$

$\rho_{brine} = 1153\ \mathrm{kg/m^3}$
$\mathrm{g} = 9.81\ \mathrm{m^2}/s$
$d_{inj}$ = injection depth (*)

| Well | $\mathrm{d}_{inj}$ [km] | |
|---|---|---|
| PVU # 1 | 4.40 | 49.7 |
| BIF-2 | 4.02 | 45.5 |
| BIF-1 | 3.73 | 42.2 |
| Mesa-1 | 3.66 | 41.4 |
| Mesa-2 | 3.73 | 42.2 |
| Pinion Ridge | 3.96 | 44.7 |
| | | |

(*) from model surface

# MODEL CALIBRATION RESULTS

# Model calibration

1. PVU#1 location:

$$p_{WH} = p_e + \Delta p_w + p_{insitu} - p_{brine}$$

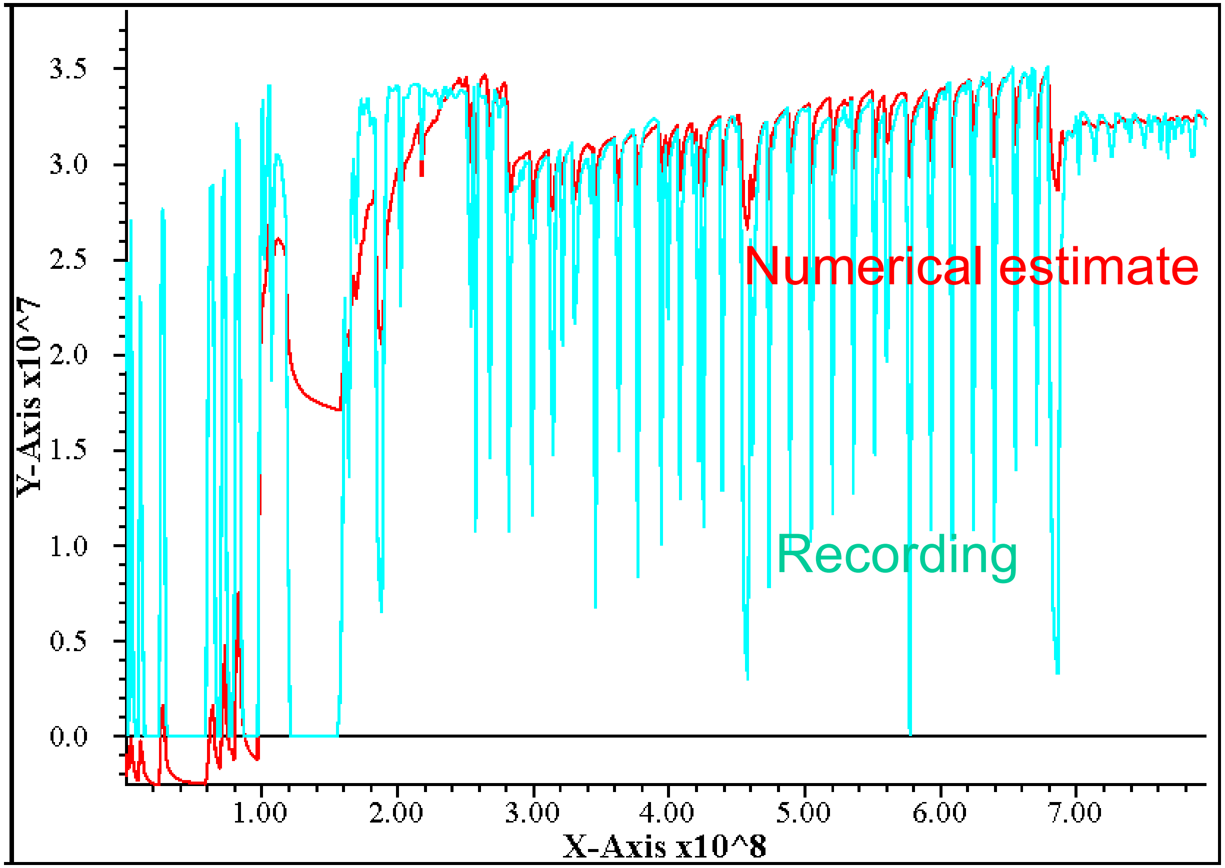
$$\Downarrow$$

$$\alpha = 0.78$$

2. Faults with large vertical offset (>150m), made impermeable (Chris Wood , email of 5 January, 2017)

# Wellhead pressure - PVU#1

Comparison between data and calibrated model simulation results:




Wellhead pressure [Pa] versus time [sec]

# FLOW SIMULATION RESULTS

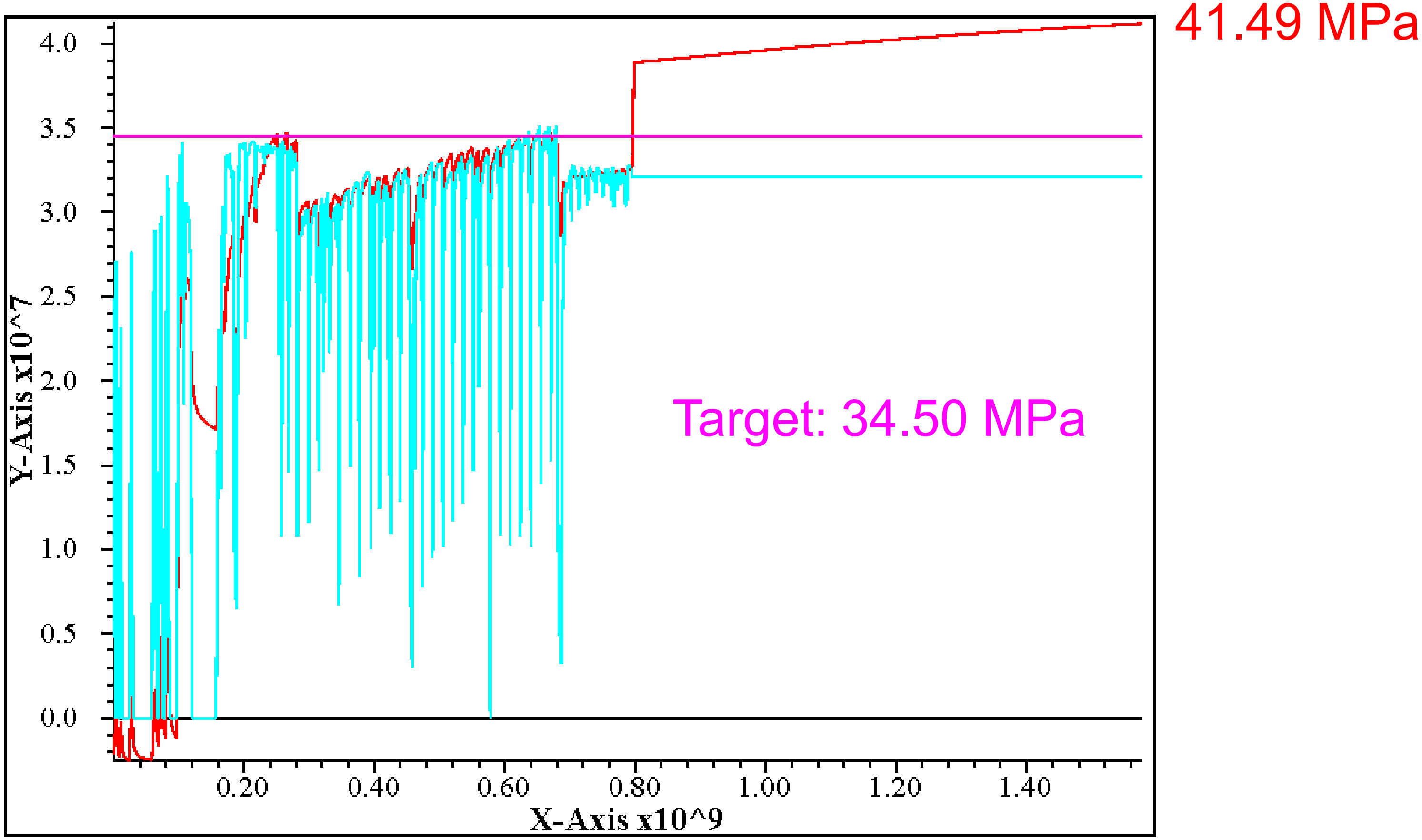
# PVU # 1

Actual injection rate is used up to 25.24 year, and the following constant rate after that:

a) 0.0151 m^3/s – as specified by USBR

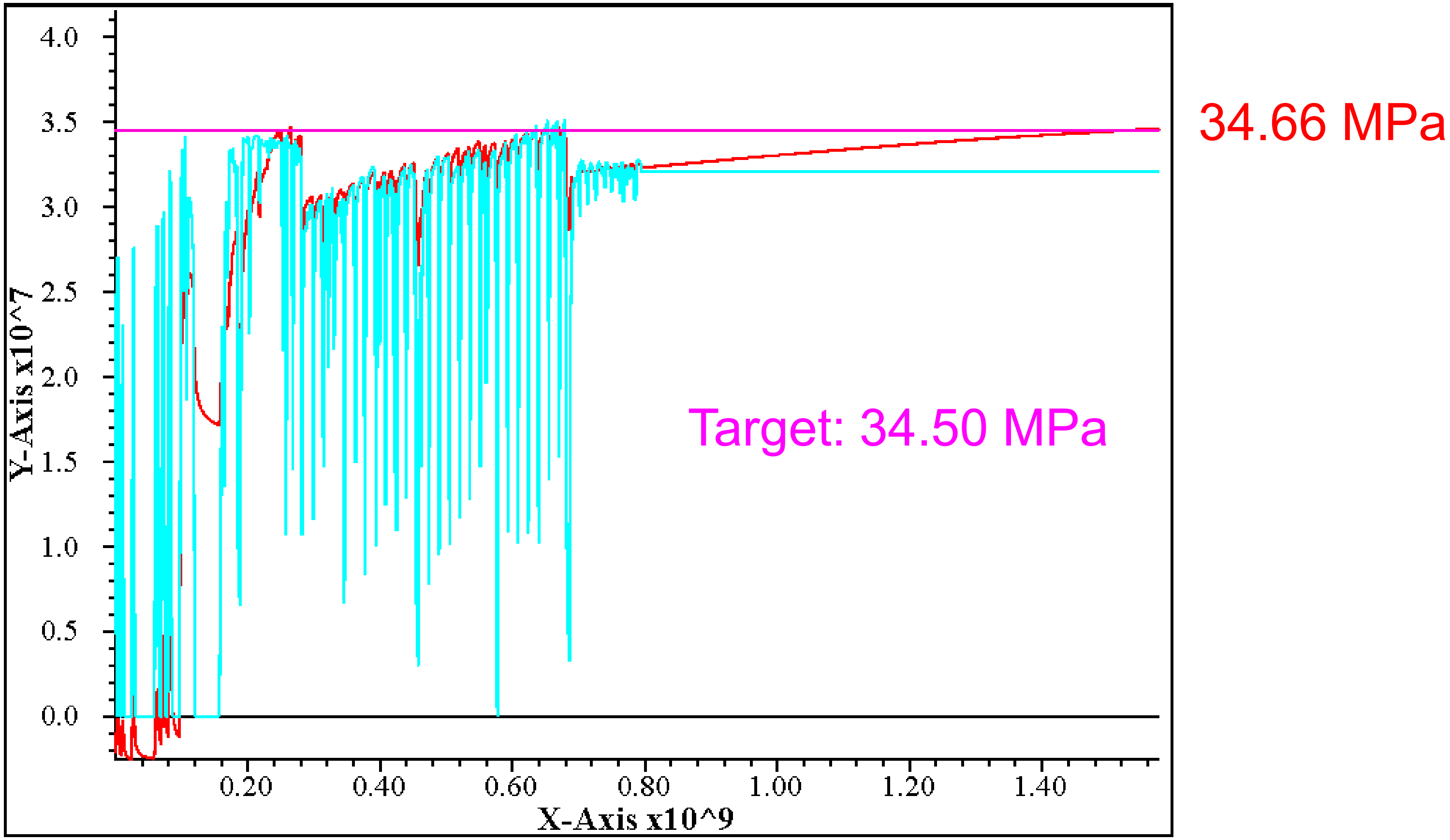
b) 0.0112 m^3/s – average daily rate in the last actual injection period

# PVU # 1 : Q = 0.0151 m^3/s




Well-head pressure [Pa] vs time [sec]

# PVU # 1 : Q = 0.0112 m^3/s

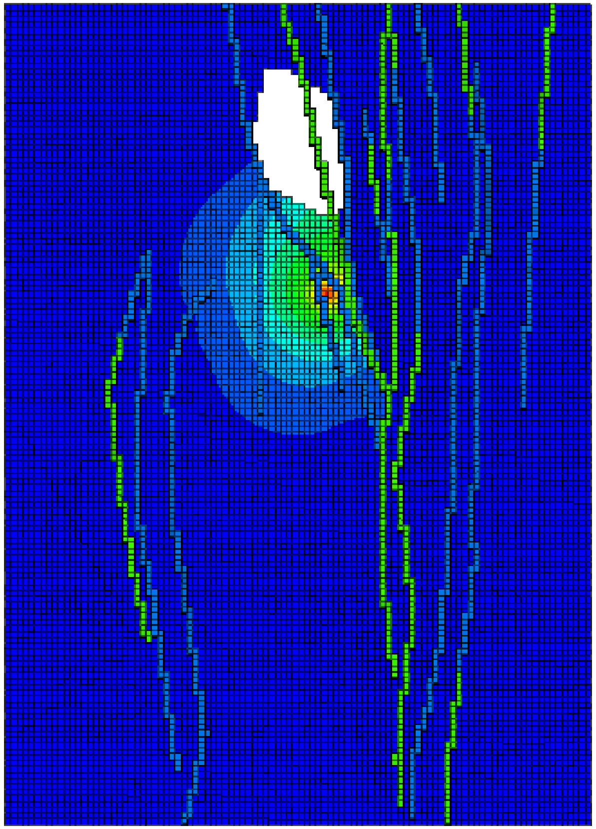



Well-head pressure [Pa] vs time [sec]

$$Q = 0.0151\ m^3/s$$

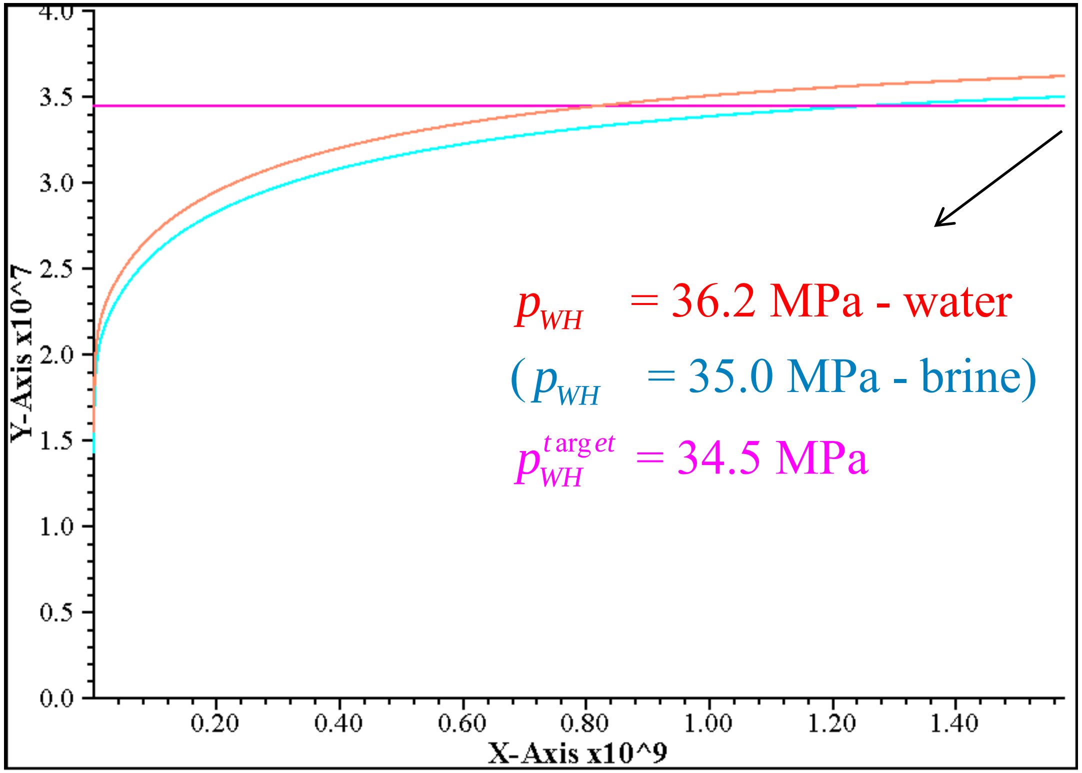
# BIF # 2

**Time = 50 year**



Excess pp contours in Leadville [Pa]

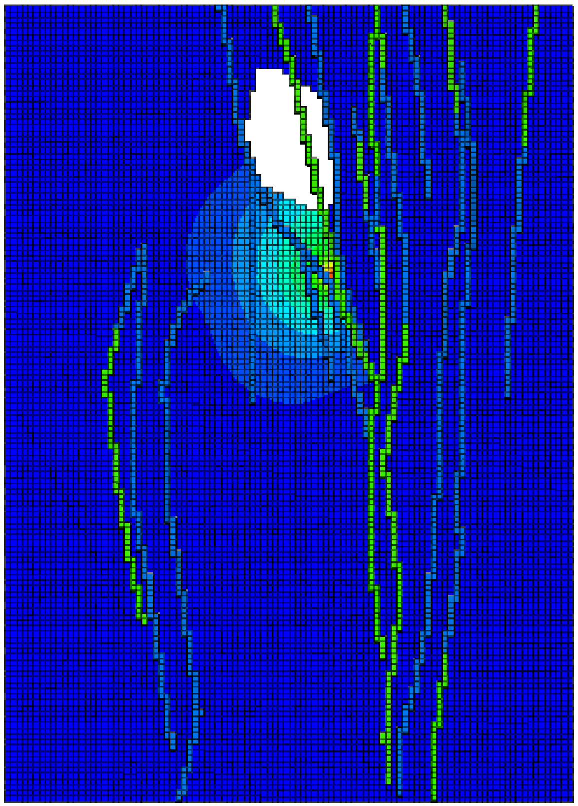
**Final time = 50 year**




Wellhead pressure [Pa] versus time [sec]

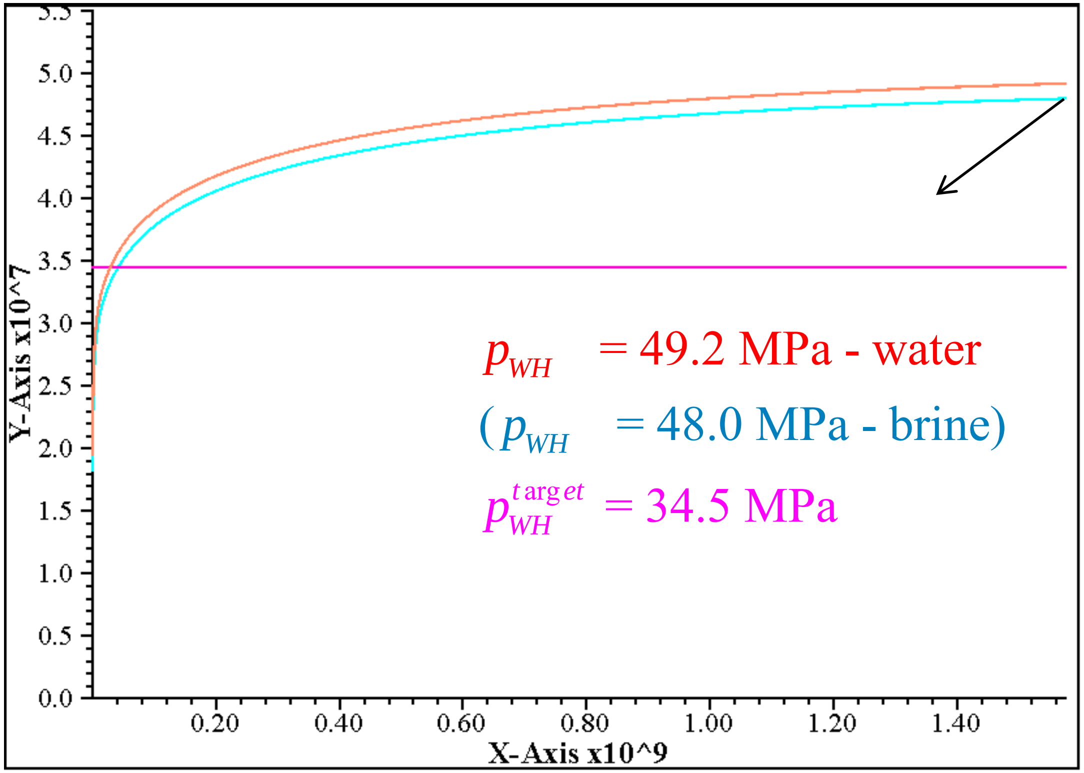
# BIF # 1

**Time = 50 year**



Excess pp contours in Leadville [Pa]

**Final time = 50 year**

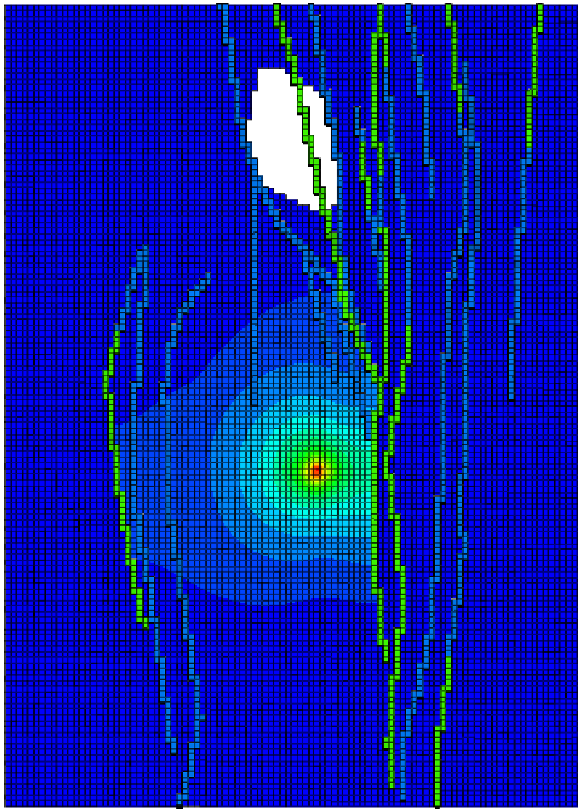


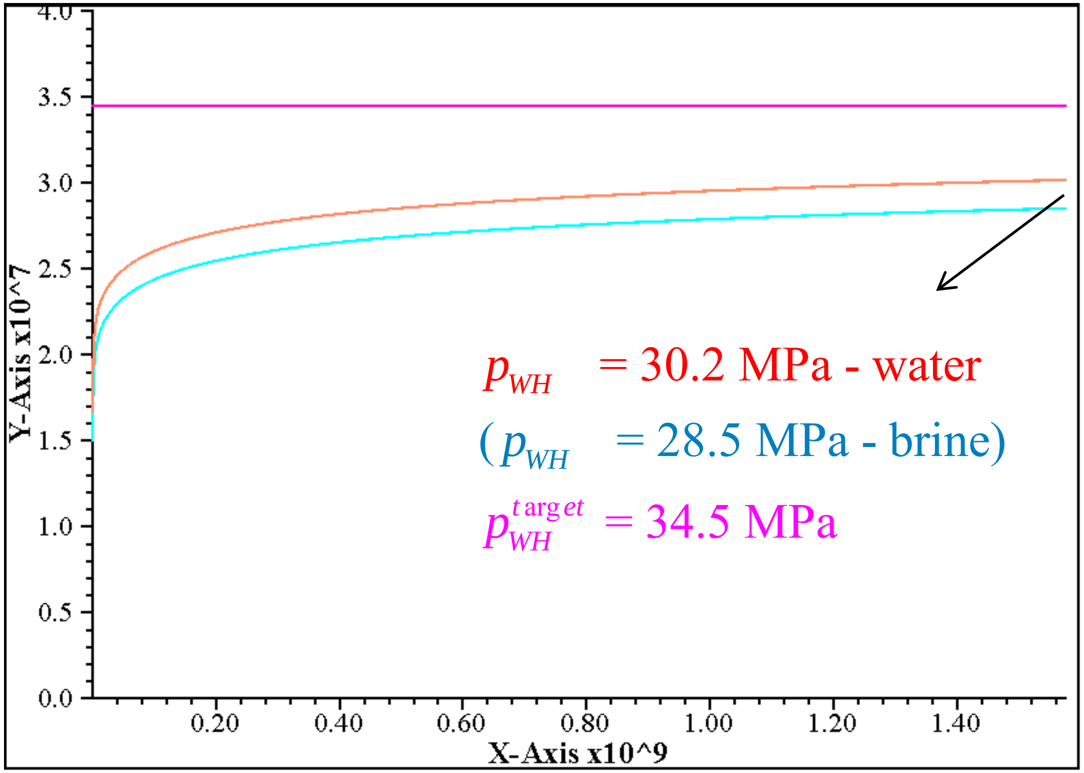

Wellhead pressure [Pa] versus time [sec]

# Mesa # 1

**Time = 50 year**

**Final time = 50 year**





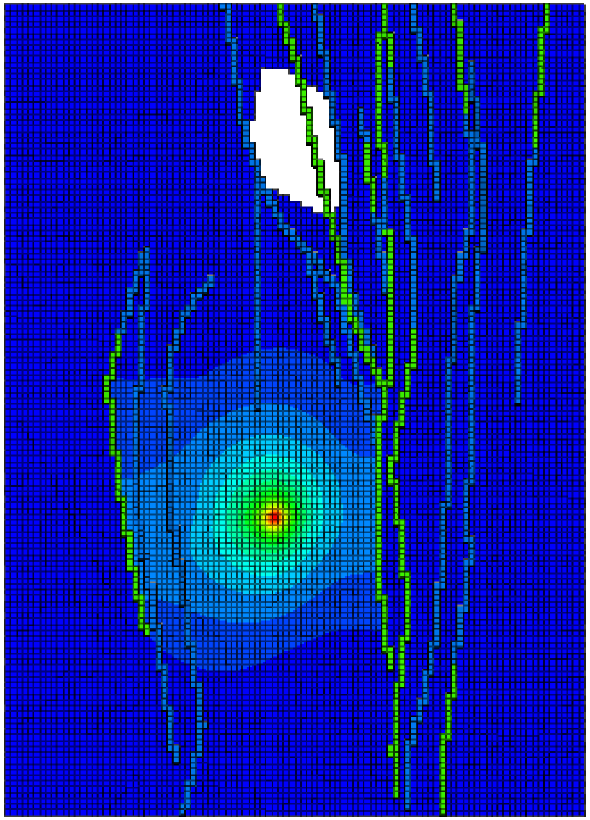

Excess pp contours in Leadville [Pa]

Wellhead pressure [Pa] versus time [sec]

ITASCA

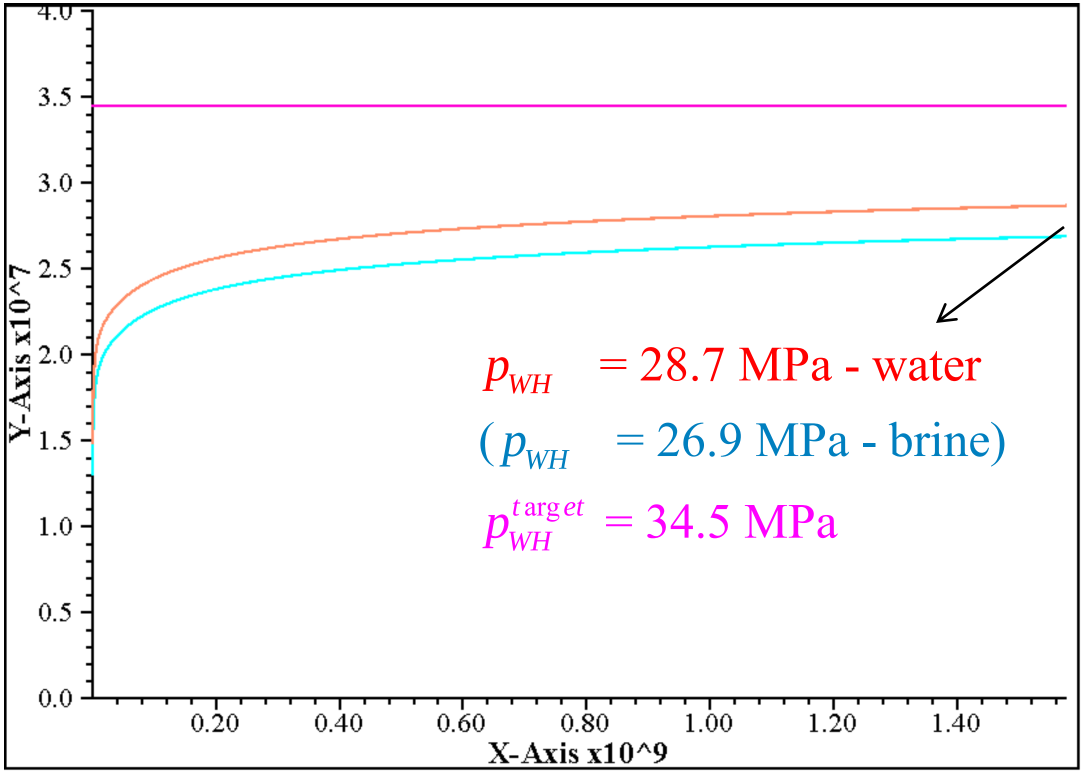
# Mesa # 2

**Time = 50 year**



Excess pp contours in Leadville [Pa]

**Final time = 50 year**

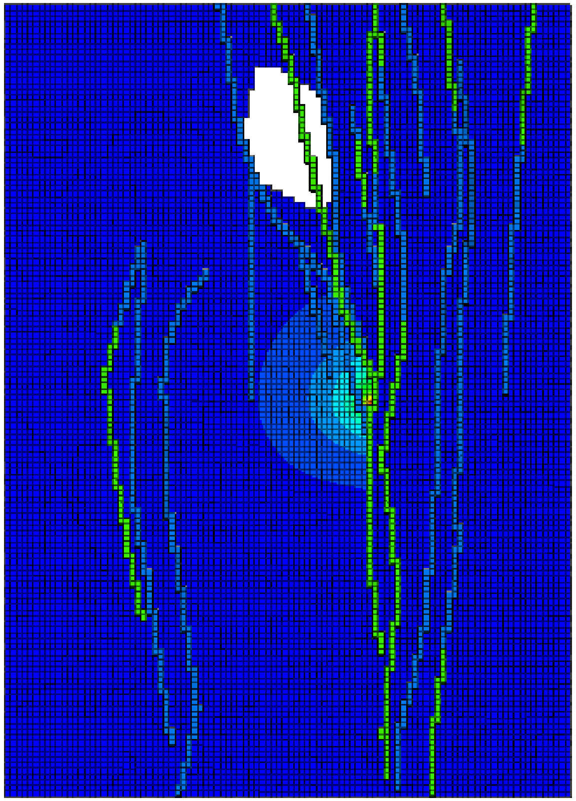


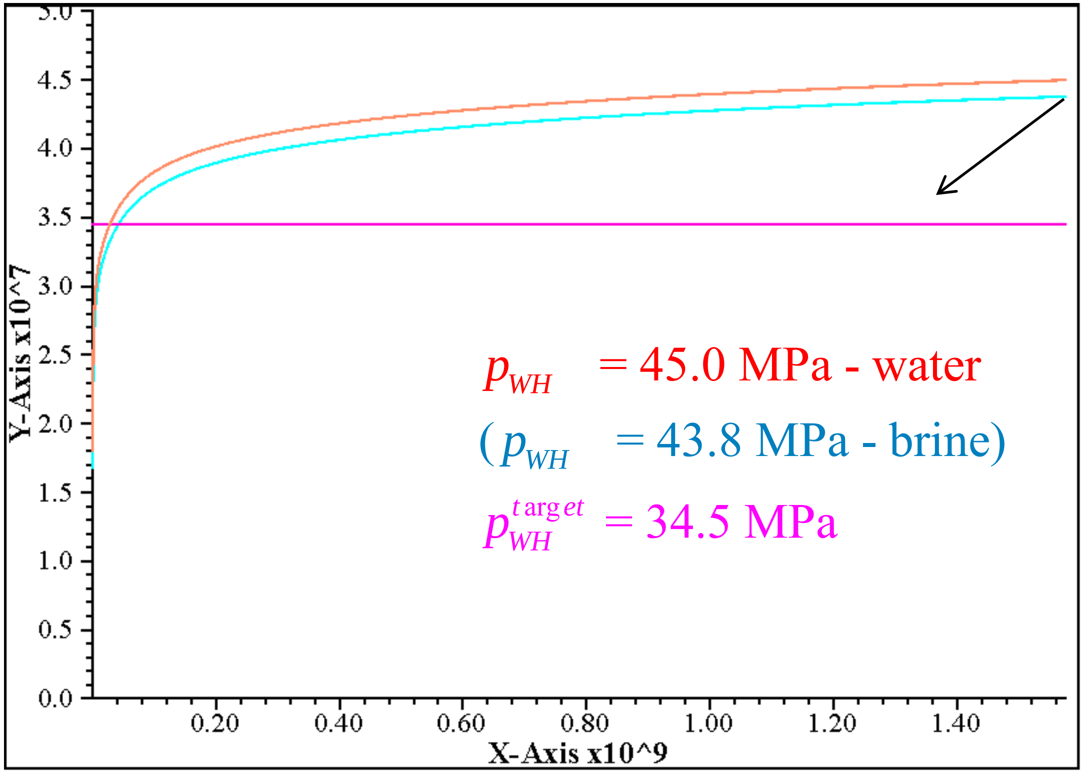

Wellhead pressure [Pa] versus time [sec]

# Pinion Ridge

**Time = 50 year**

**Final time = 50 year**





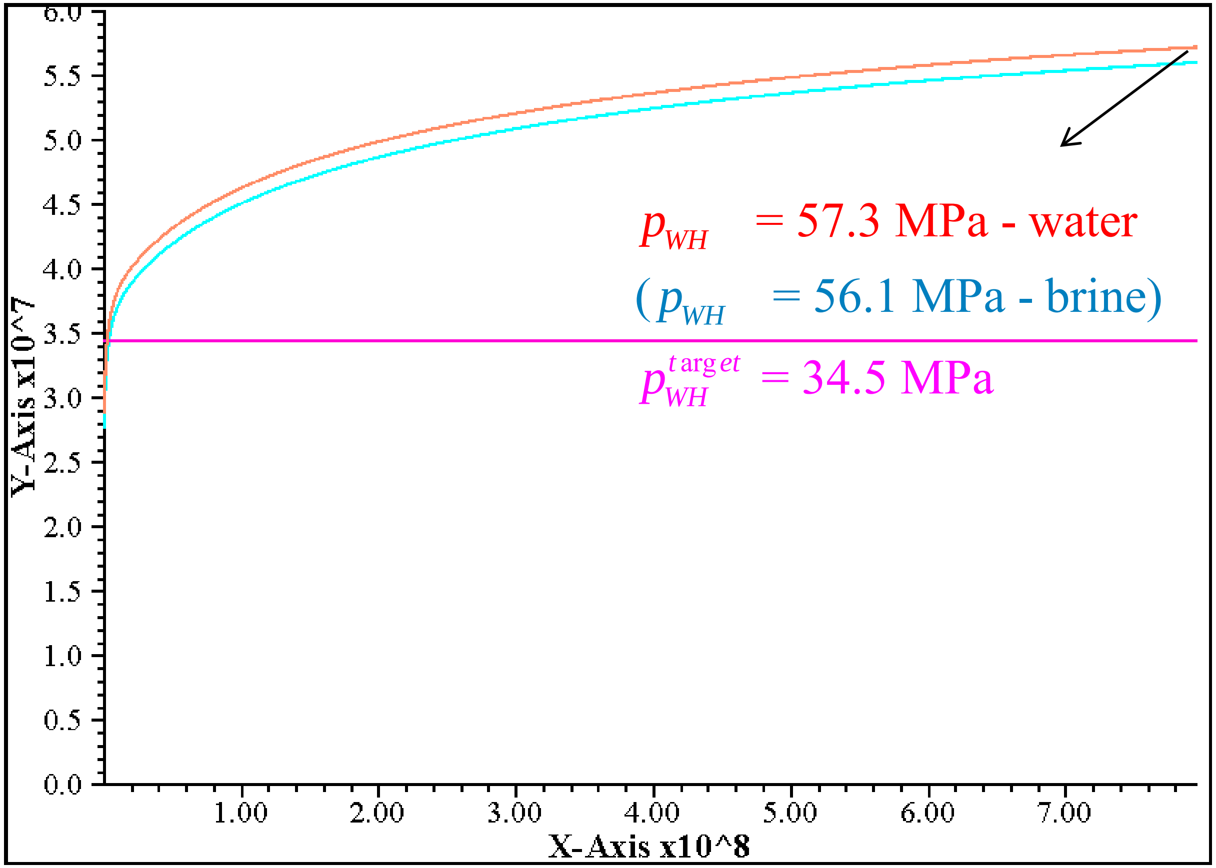

Excess pp contours in Leadville [Pa]

Wellhead pressure [Pa] versus time [sec]

$$Q = 0.0227\ m^3/s$$

# BIF # 2

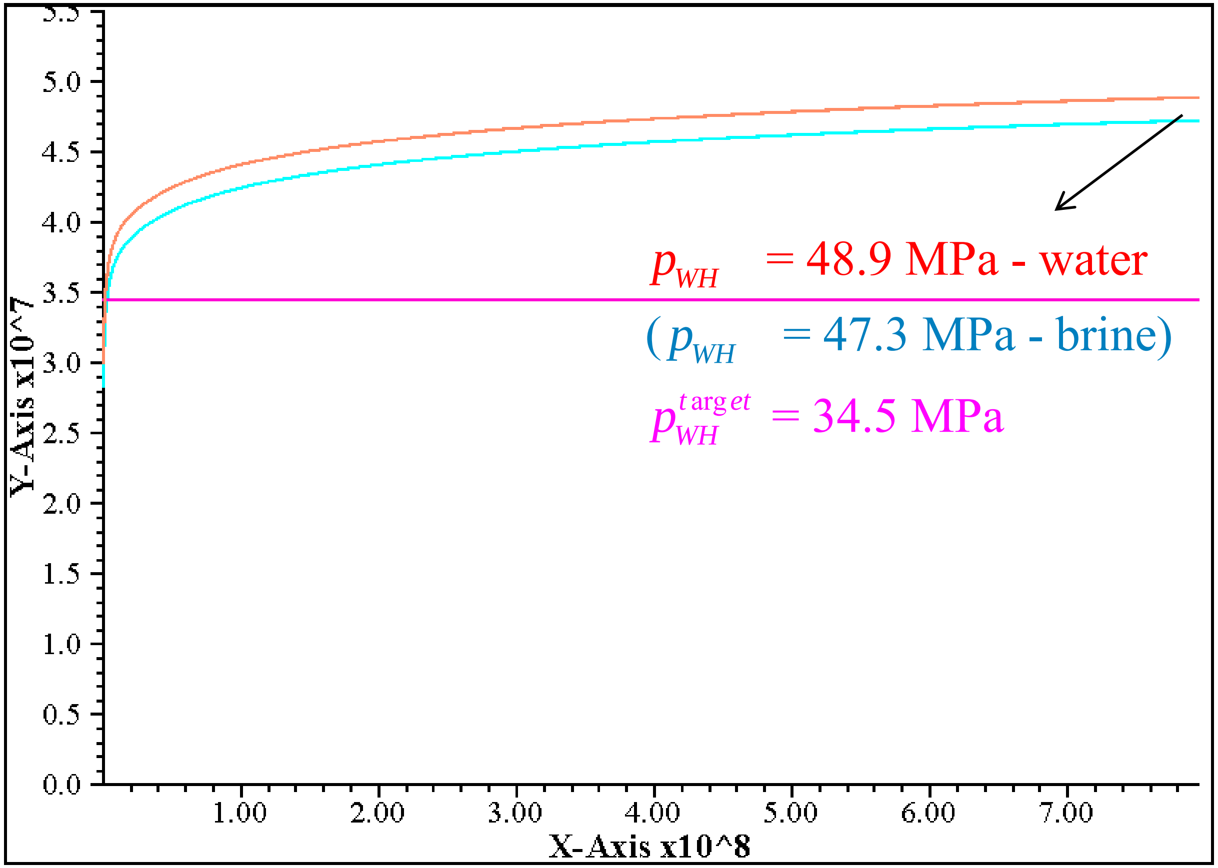
**Final time = 25.24 year**




Wellhead pressure [Pa] versus time [sec]

# Mesa # 1

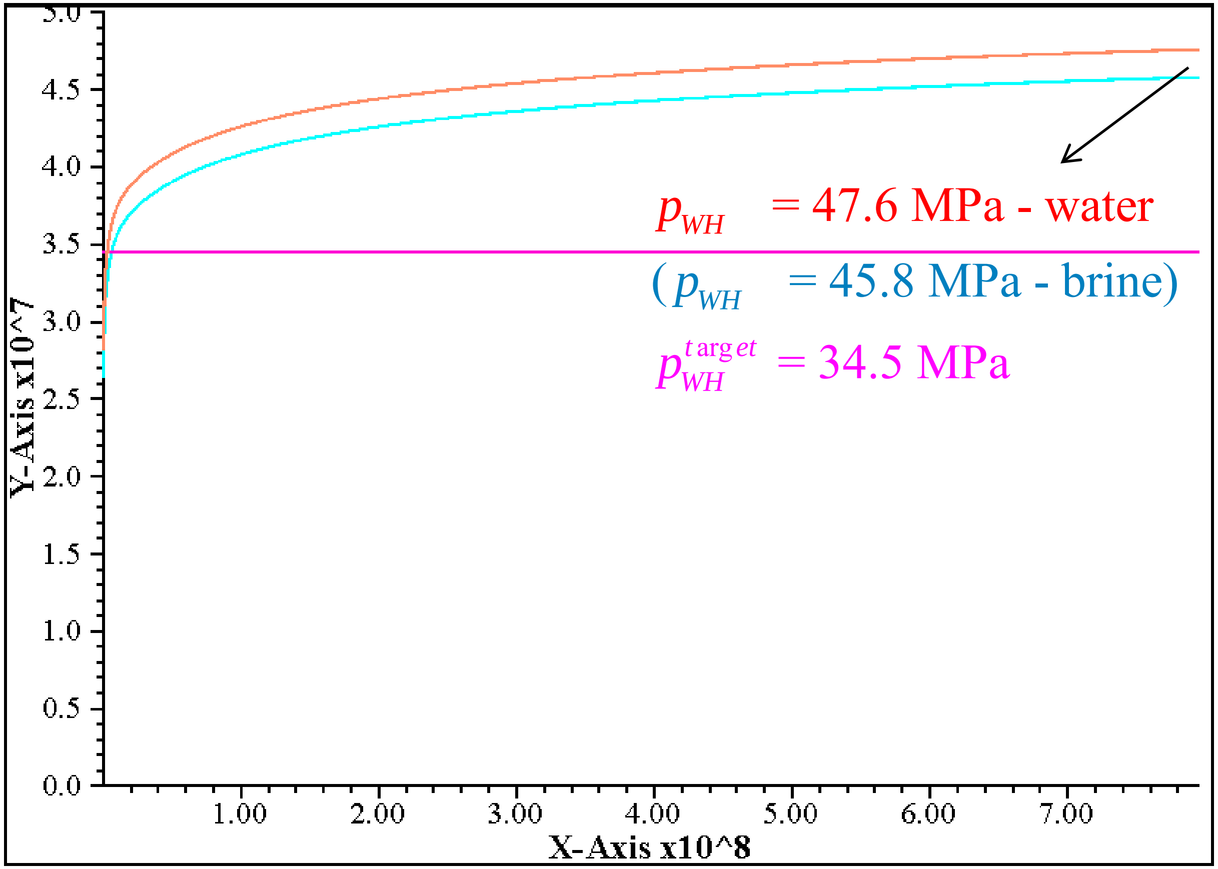
**Time = 25.24 year**




Wellhead pressure [Pa] versus time [sec]

# Mesa # 2

**Time = 25.24 year**




Wellhead pressure [Pa] versus time [sec]

# Summary - a

**Wellhead pressure estimate - [Mpa] Q=0.0151 m^3/s – 50years**

$p_{WH}^{target} = 34.5\ \text{MPa}$

| Well | water | (brine) | USBR |
|---|---|---|---|
| PVU#1 | | | |
| BIF-2 | 36.23 | (35.03) | 40.43 |
| BIF-1 | 49.22 | (48.02) | 51.24 |
| Mesa-1 | 30.19 | (28.54) | 34.50 |
| Mesa-2 | 28.70 | (26.90) | 34.25 |
| Pinion Ridge | 45.00 | (43.80) | 49.67 |

# Summary - b

**Wellhead pressure estimate - [Mpa] Q=0.0227 m^3/s – 25.24years**

$p_{WH}^{t\arg et} = 34.5$ MPa

| Well | water | (brine) | USBR |
|---|---|---|---|
| BIF-2 | 57.26 | (56.06) | 61.46 |
| BIF-1 | | | |
| Mesa-1 | 48.92 | (47.27) | 53.23 |
| Mesa-2 | 47.61 | (45.81) | 53.16 |
| Pinion Ridge | | | |

# Observations

With the calibrated *FLAC3D* model and hypotheses used for the simulations:

- For PVU#1: a wellhead pressure of 34.7MPa is predicted after injection is resumed for up to 50 years at a constant rate of 0.0112 m^3/s

- For each of the 5 additional wells: the predicted wellhead pressure at 25.24 years of injection at the rate of 0.0227 m^3/s is predicted to be at least 10MPa higher than the target pressure of 34.5 MPa

- If injection at the rate of 0.0151 m^3/s is used: Mesa 1 and Mesa 2 are the only two locations where the wellhead pressure is predicted to stay below the target value after 50 years
  Note: These are also the most shallow Injection sites
  (3.66 km, and 3.73 km, respectively, see slide 17).

# THANK YOU!

# Paradox Valley Project

## Permeability model - Appendix

January 24, 2017

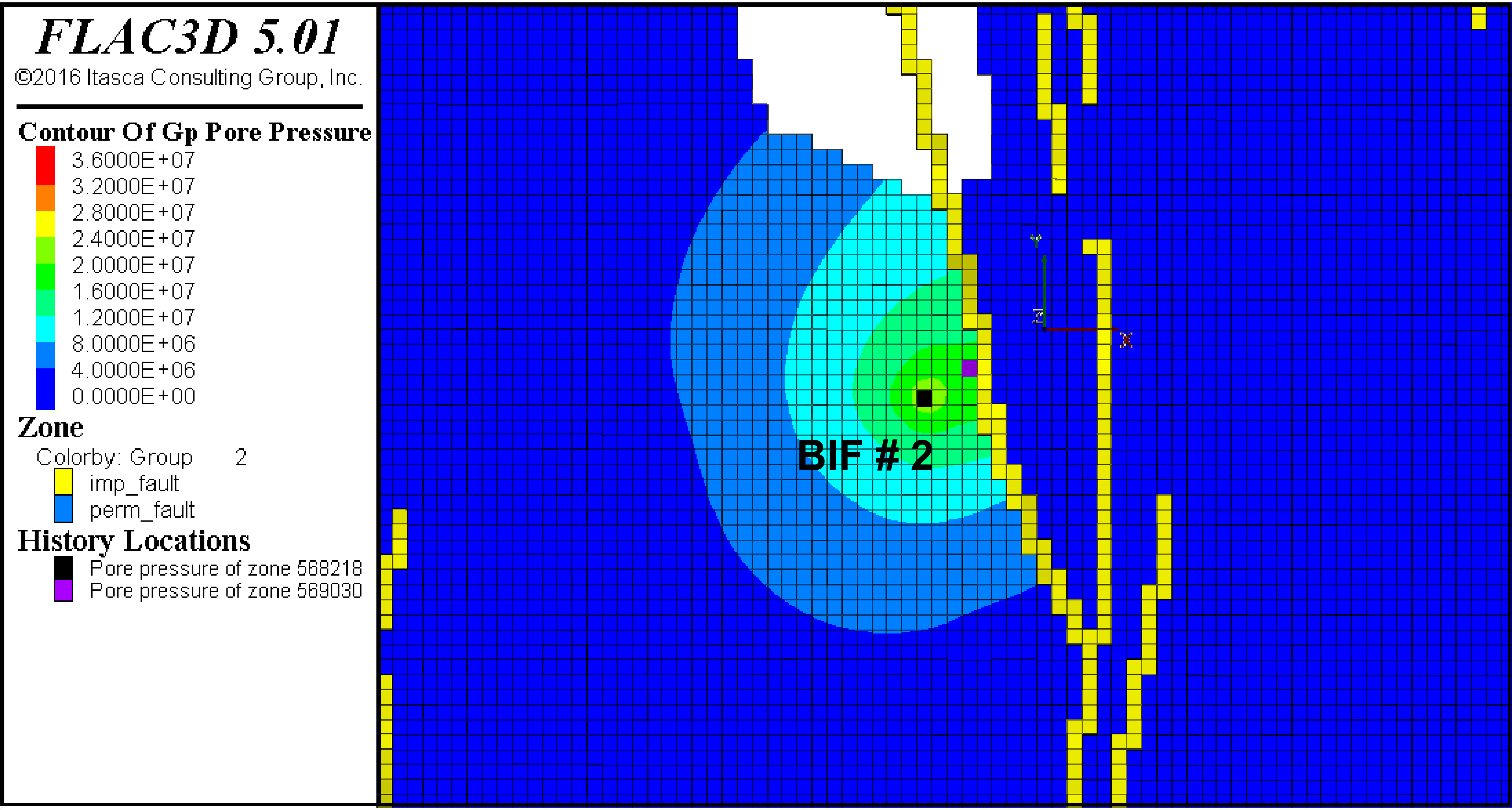
Christine Detournay
Itasca Consulting Group, Inc.

# BIF # 2 and BIF # 1

For BIF # 2 and BIF # 1:
the numerical wellhead pressure predictions after 50 years of continuous injection at the rate of 0.0151 m^3/s differ by about 13 Mpa
The difference appears surprisingly large, given the relative proximity of the two wells.
The following is noted:

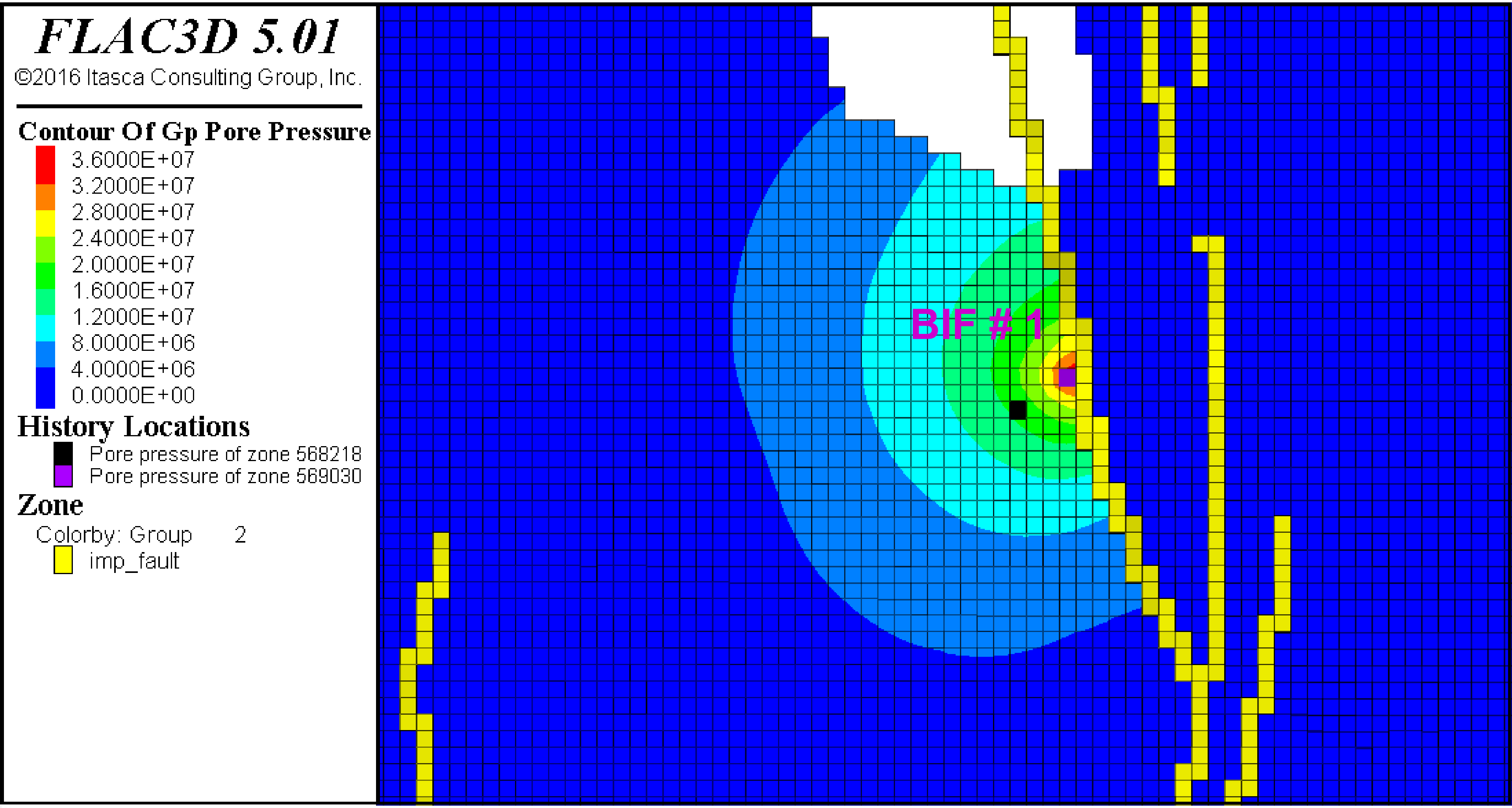
- the horizontal distance between the two wells in the model is about 1.4 km
- injection is performed at the same global model elevation
- the injection depth from the model surface differs by about 0.3 km. This implies a difference in brine pressure at the injection location of about 3.3MPa (larger value is for BIF # 2)

# BIF # 2 – Q = 0.0151 m^3/s




Well location (BIF # 1, in magenta) and excess fluid pressure contours at 50 Y

# BIF # 1 – Q = 0.0151 m^3/s




Well location (BIF #2 in black) and excess fluid pressure contours at 50 Y

# Impact of proximity to impermeable fault

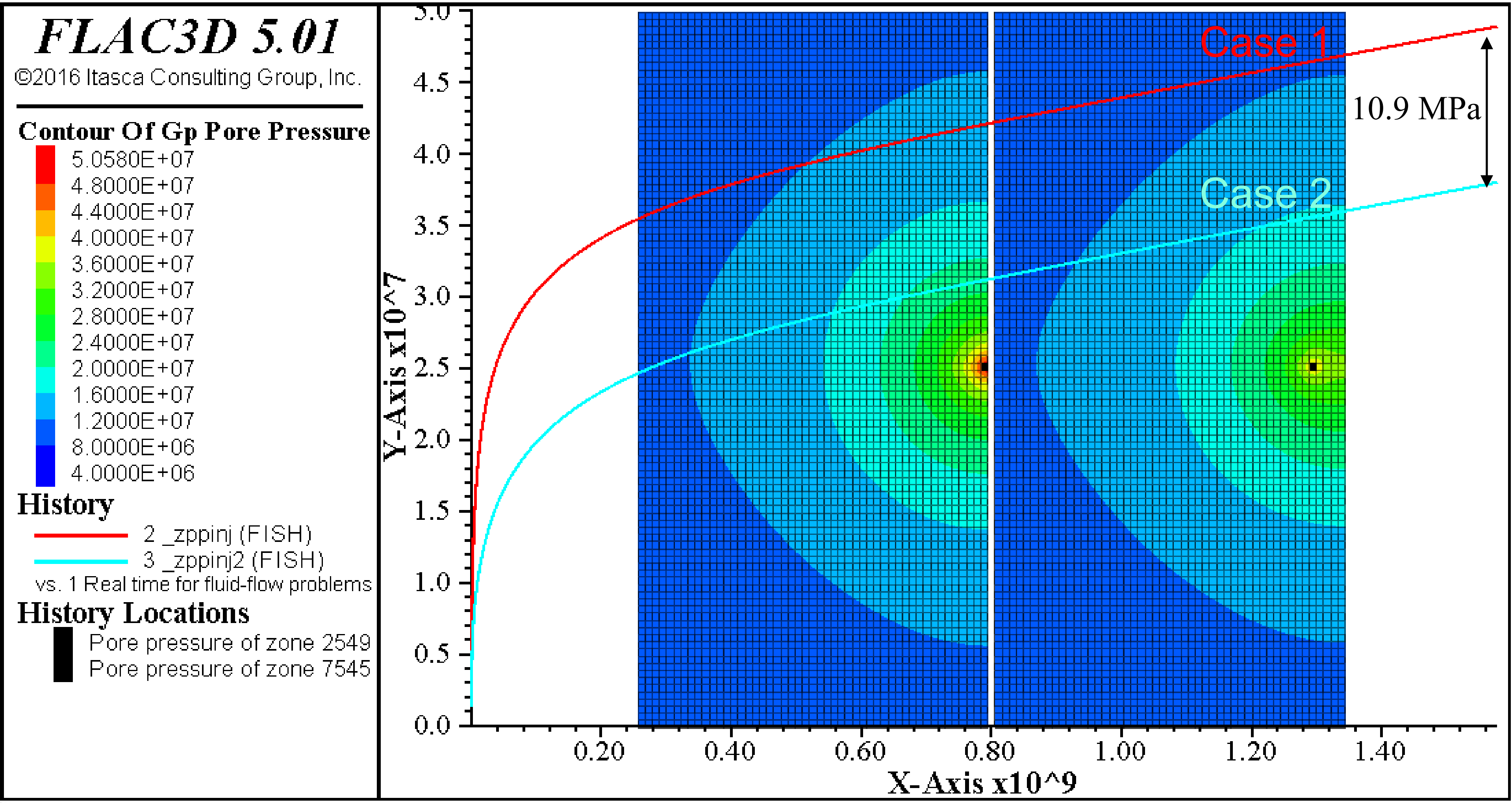
The main difference between the situation at the two wells appears to be the different proximity to the closest Impermeable fault.

To study the effect, we consider the simple case of constant injection in a horizontal Leadville layer of thickness 100m (same zone size, properties and injection rate as in the Paradox Valley model).
The model boundaries are impermeable.

We consider two cases:
- Injection in a zone adjacent to a model boundary
- Injection in a zone located 1.2 km away from the first one

The excess pressure prediction at the injection locations over 50 years of injection at the rate of 0.0151 m^3/s are compared in the next slide.

# Excess zone pressure predictions




Excess pressure contours for Case 1 (left) and case 2 (right), and
Excess zone pressure at injection location [Pa] vs time [sec]

# Observation

After 50 years of injection, the difference in **excess** pore pressure prediction in the injection **zone** for the simple models is about 10.9 MPa.

The value is in the same order of magnitude as the difference (9.7 MPa) in **zone excess** pressure (*) for BIF # 1 and BIF # 2, using the Paradox Valley model.

This result implies that the difference in BIF # 1 and BIF # 2 wellhead pressures predicted by the Paradox Valley model could be attributed to the difference in well proximity from the closest impermeable fault.

(*) see PR4: formula on slide 13, BIF pressure values on slides 14-16, and 25-26.

# Paradox Valley Project

## Permeability model – Simultaneous injections and well location investigations

February 2, 2017

Christine Detournay
Itasca Consulting Group, Inc.

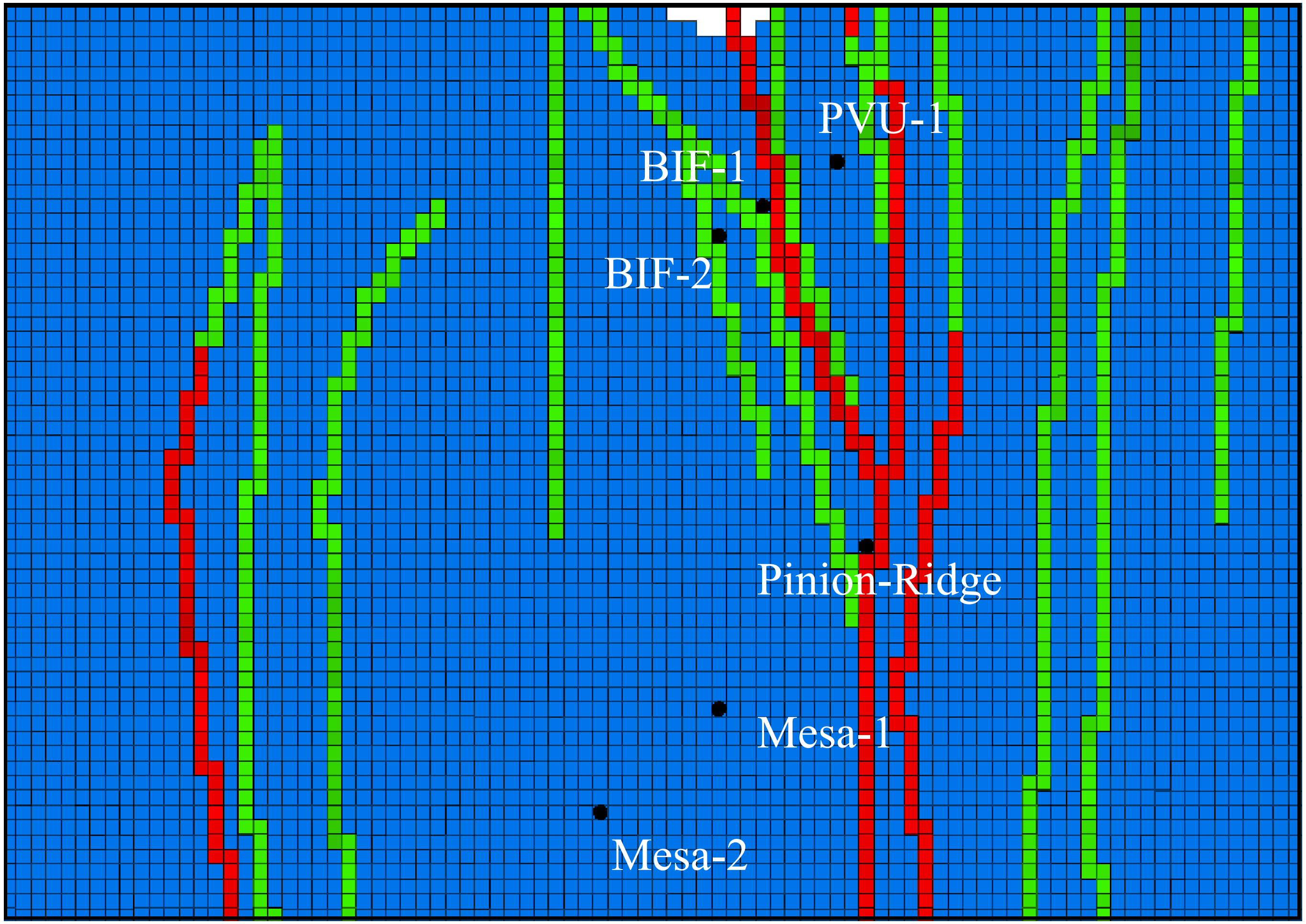
# SIMULTANEOUS INJECTIONS

# Framework

Two sets of simulations are conducted at the request of USBR to investigate if, In the Paradox Valley model, the PVU-1 injection activity influences the wellhead pressure behavior at BIF-1 and BIF-2.

Note: no significant influence is expected because BIF-1 and BIF-2 are separated from PVU-1 by an impermeable Fault in the model.

# *FLAC3D* Wells and Faults location




Impermeable Faults shown in red

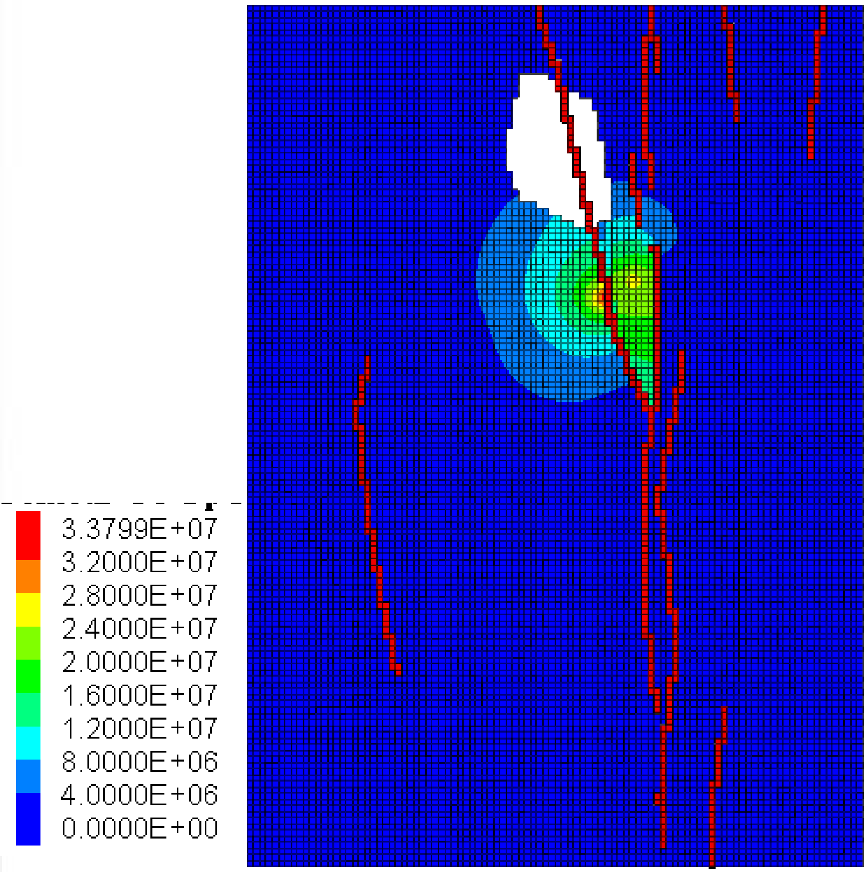
# Injection scenario

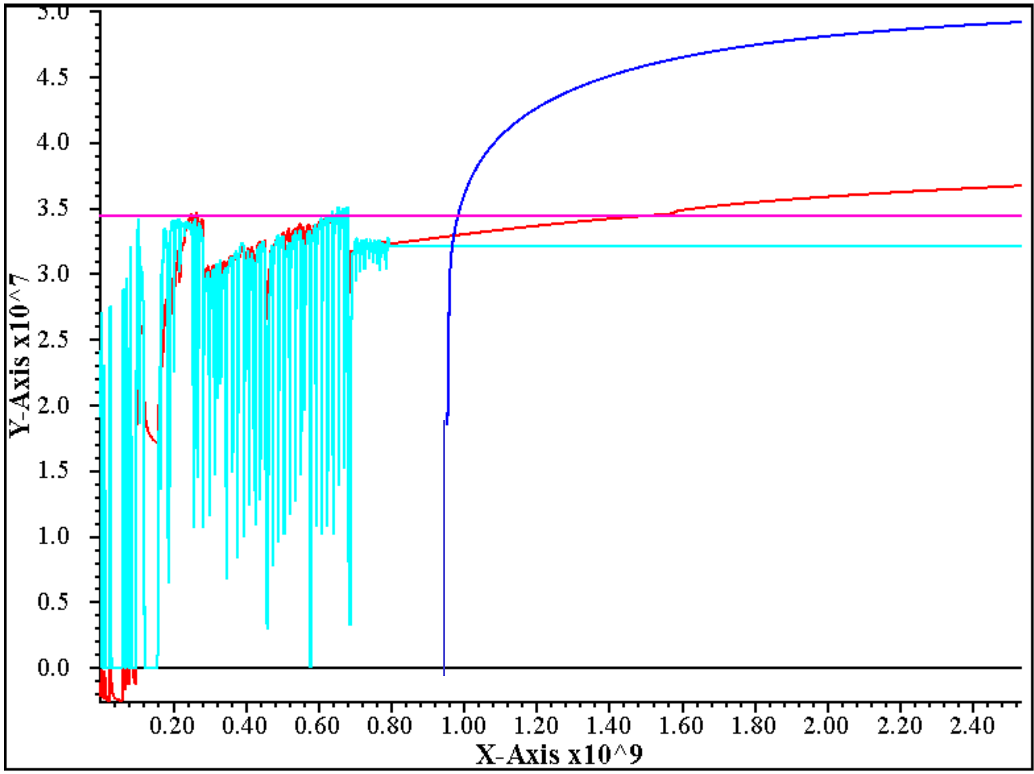
With the calibrated FLAC3D Paradox Valley model:

1. Simulate injection in PVU-1 for 25.24 years plus 5 years after that
2. Start injection in BIF-1 (BIF-2)
3. Run simultaneous injections in PVU-1 and BIF-1 (BIF-2) for 50 additional years

- for PVU-1, use injection data up to 25.24 year, and Q=0.012 m^3/s after that
- for BIF-1 and BIF-2, use Q=0.0151 m^3/s

# Simulation results: PVU-1and BIF-1

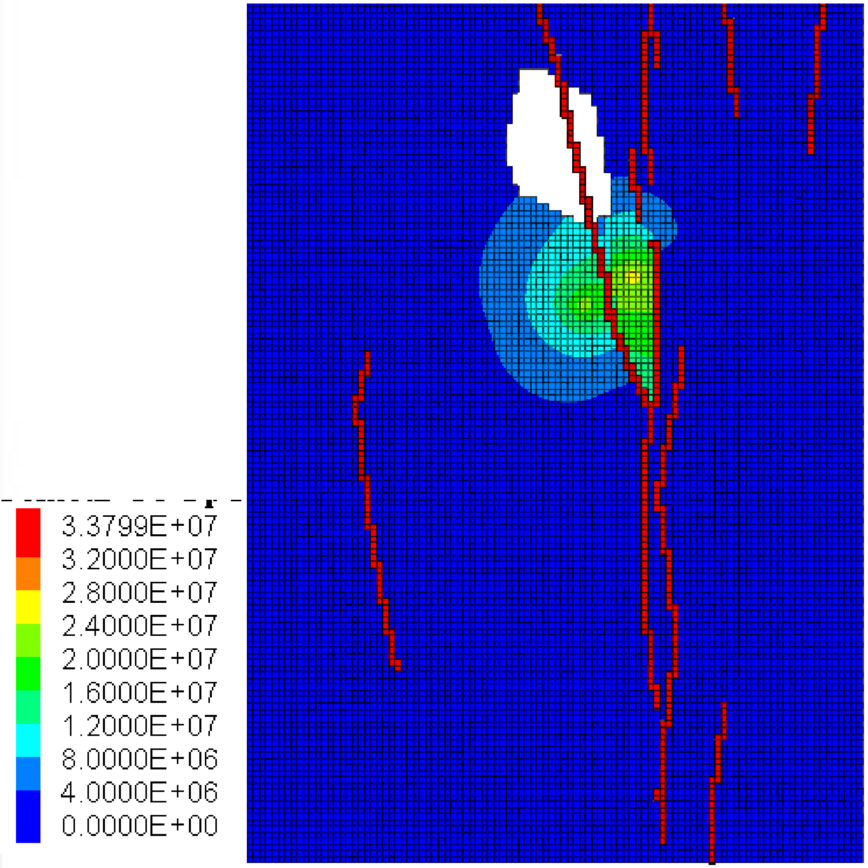


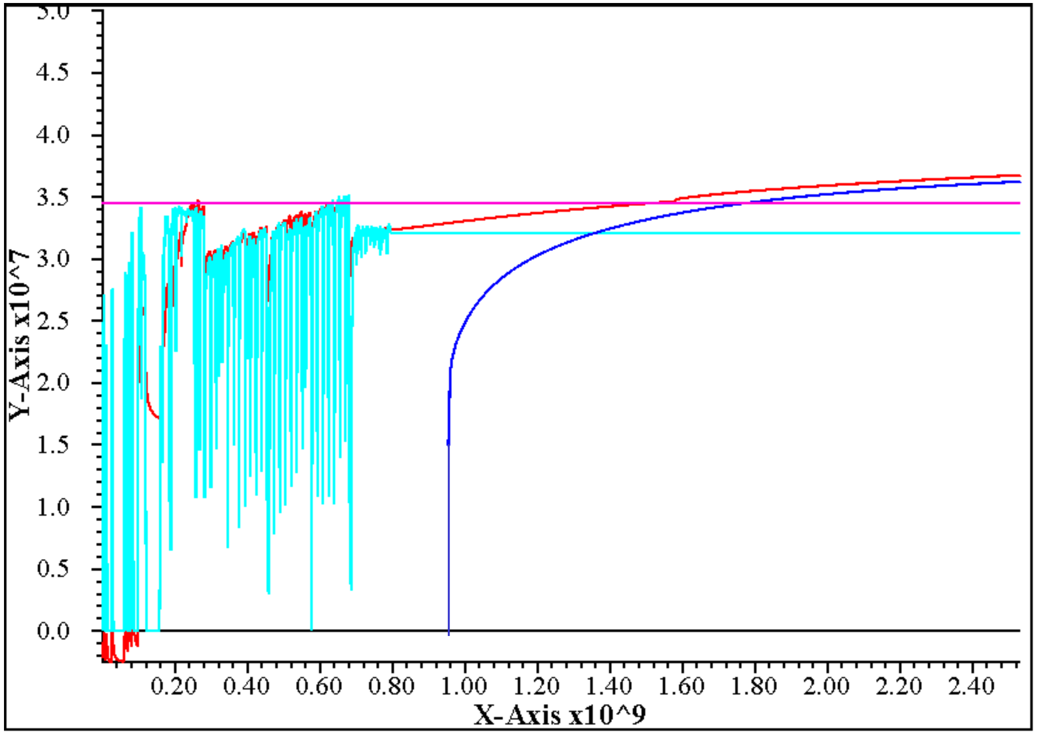

Excess pp contours [Pa] at 80.24 years

Wellhead pressure [Pa] versus time [sec]

# Simulation results: PVU-1and BIF-2

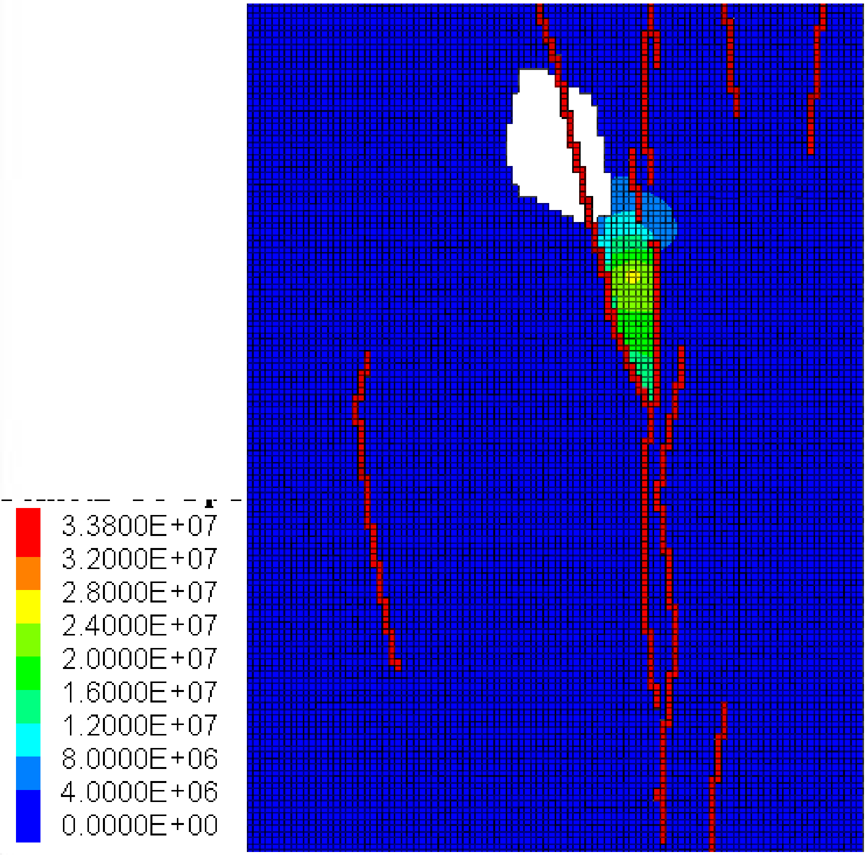


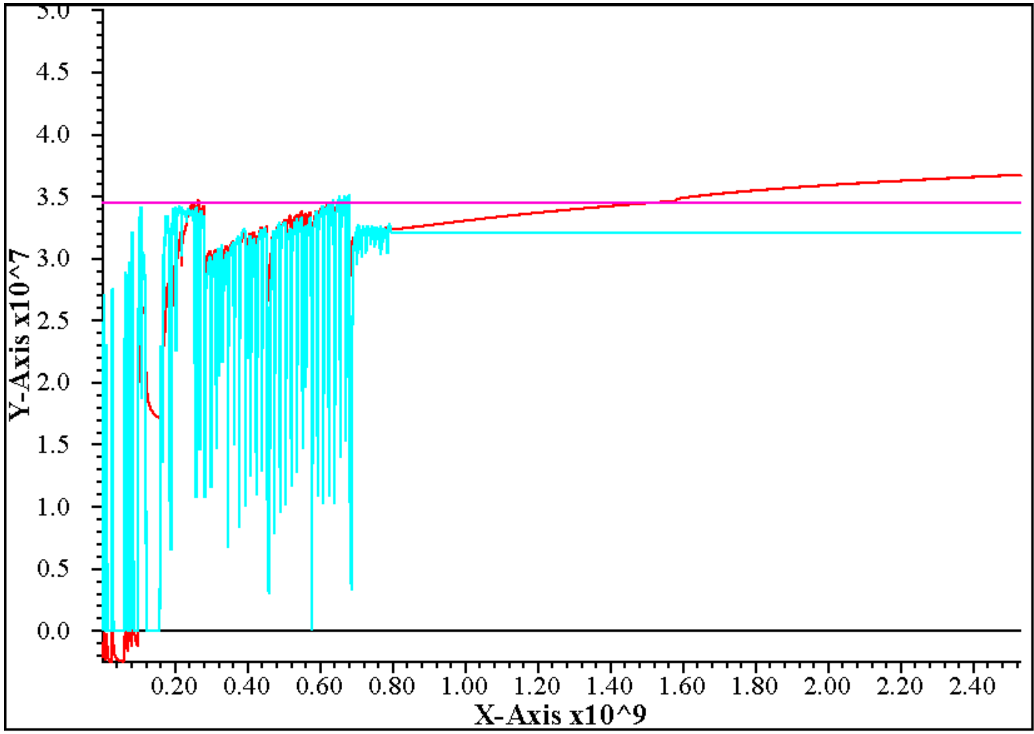

Excess pp contours [Pa] at 80.24 years




Wellhead pressure [Pa] versus time [sec]

# Simulation results: PVU-1 alone




Excess pp contours [Pa] at 80.24 years

Wellhead pressure [Pa] versus time [sec]

# Summary

No cross-influence detected between wells across the impermeable fault in the *FLAC3D* model at the end of the simulation:

| Well | water |
|---|---|
| PVU-1 | 36.75 |
| PVU-1 and BIF-2 | 36.75 |
| PVU-1 and BIF-1 | 36.75 |

| Well | water |
|---|---|
| BIF-1 | 49.22 |
| BIF-1 and PVU-1 | 49.22 |
| BIF-2 | 36.23 |
| BIF-2 and PVU-1 | 36.23 |

**Wellhead pressure estimate - [Mpa] Q=0.0151 m^3/s – 80.24years**

# WELL LOCATION INVESTIGATION

# BIF-1 vs BIF-2

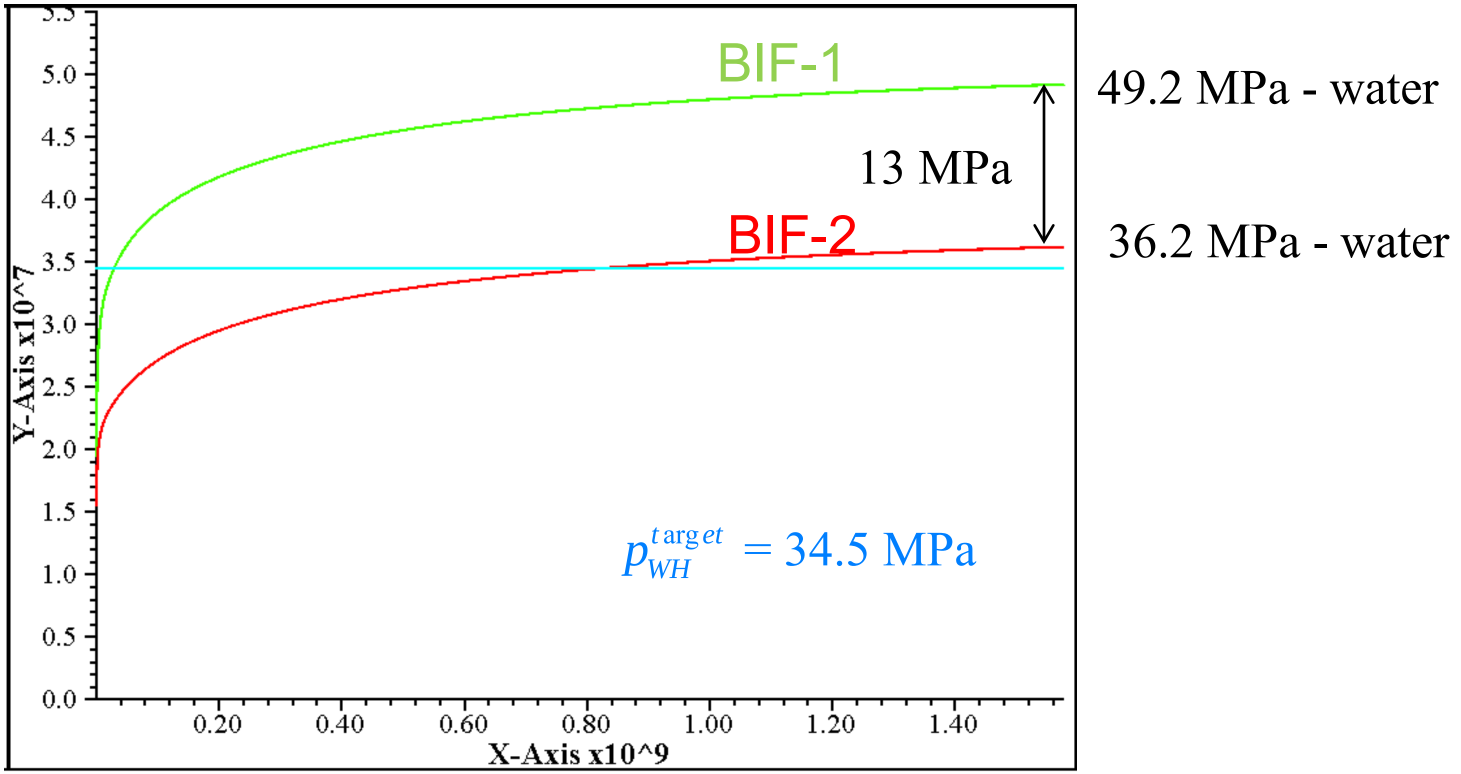
With the calibrated *FLAC3D* Paradox Valley model:

the numerical wellhead pressure predictions after 50 years of continuous injection at the rate of 0.0151 m^3/s differ by about 13 MPa (higher value for BIF # 1)

The difference appears surprisingly large, given the relative proximity of the two wells.

# Wellhead pressure predictions

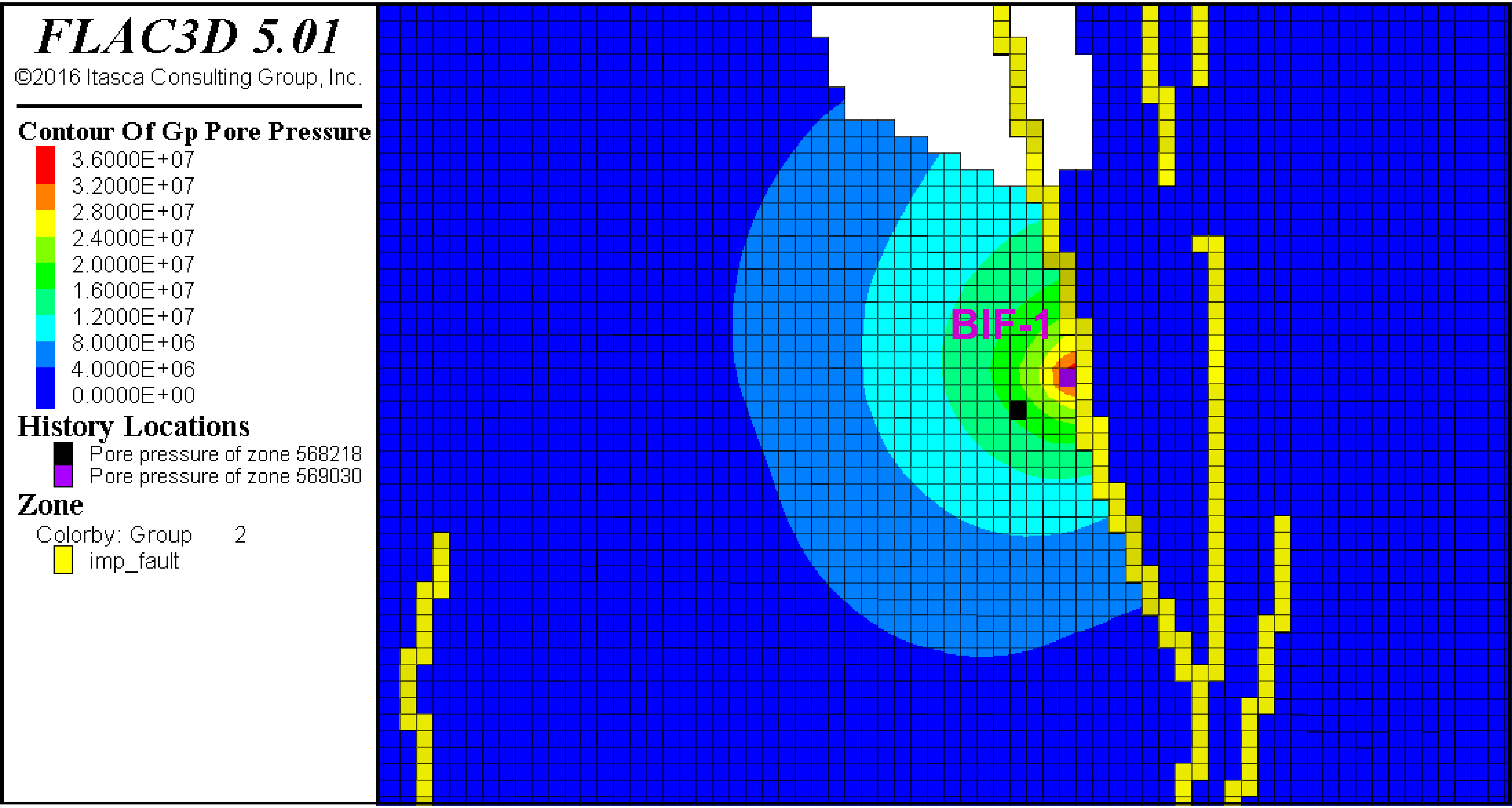
**Q=0.0151 m^3/s - Final time = 50 year**




Wellhead pressure [Pa] versus time [sec]

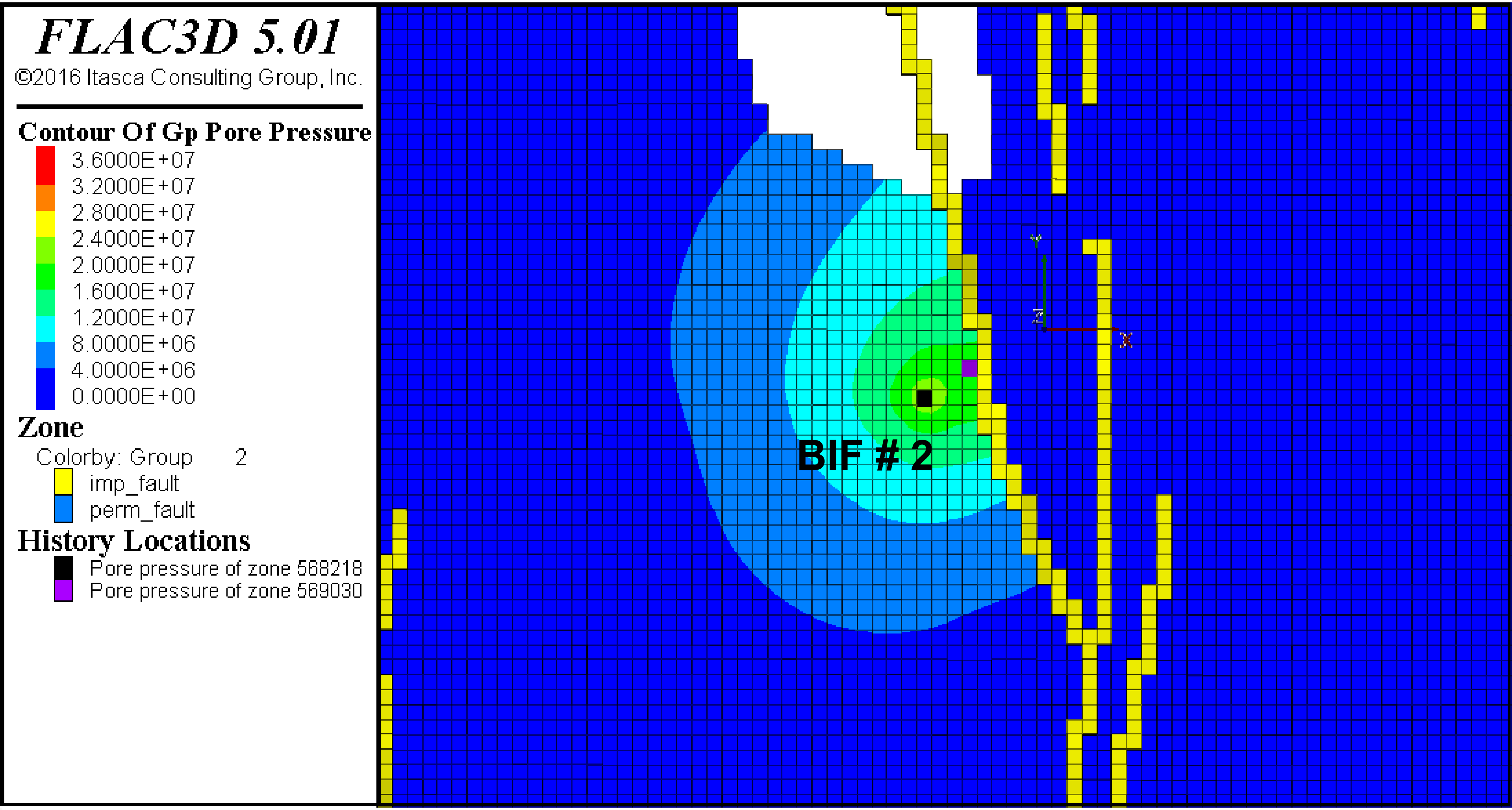
# *FLAC3D* WELL LOCATIONS

# BIF-1 – Q = 0.0151 m^3/s




BIF-1 location (BIF-2 in black) and excess fluid pressure contours at 50 Y

# BIF-2 – Q = 0.0151 m^3/s




BIF-2 location (BIF-1, in magenta) and excess fluid pressure contours at 50 Y

# Well data – (a)

Injection location in *FLAC3D* model – [m]

| Well | x | y | z | $\Delta z$ |
|---|---|---|---|---|
| BIF-2 | -3200 | -1800 | -2050 | 800 |
| BIF-1 | -2000 | -1000 | -2050 | 800 |

Insitu fluid pressure at injection location – [MPa]

| Well | $p_{insitu}^{water}$ | $p_{insitu}^{USBR}$ |
|---|---|---|
| BIF-2 | 34.45 | 38.65 |
| BIF-1 | 34.45 | 36.47 |

Brine static pressure – [MPa]

| Well | $p_{brine}$ |
|---|---|
| BIF-2 | 45.5 |
| BIF-1 | 42.2 |

# Well data – (b)

The following is noted:

- BIF-1 is adjacent to an Impermeable Fault
- the horizontal distance between the two wells in the model is about 1.2 km
- injection is performed at the same global model elevation → Same insitu pressure
- the injection depth from the model surface differs by about 0.3 km. This implies a difference in brine pressure at the injection location of about 3.3MPa (larger value is for BIF # 2)
- The well pressure correction is the same for the two wells
- Note:

$$p_{WH} = p_e + \Delta p_w + p_{insitu} - p_{brine}$$

$$\Rightarrow \quad p_e^{BIF-1} - p_e^{BIF-2} = \left( p_{WH}^{BIF-1} - p_{WH}^{BIF-2} \right) - 3.3 \text{ MPa} \approx 9.7 \text{ MPa}$$

# Impact of proximity to impermeable Fault

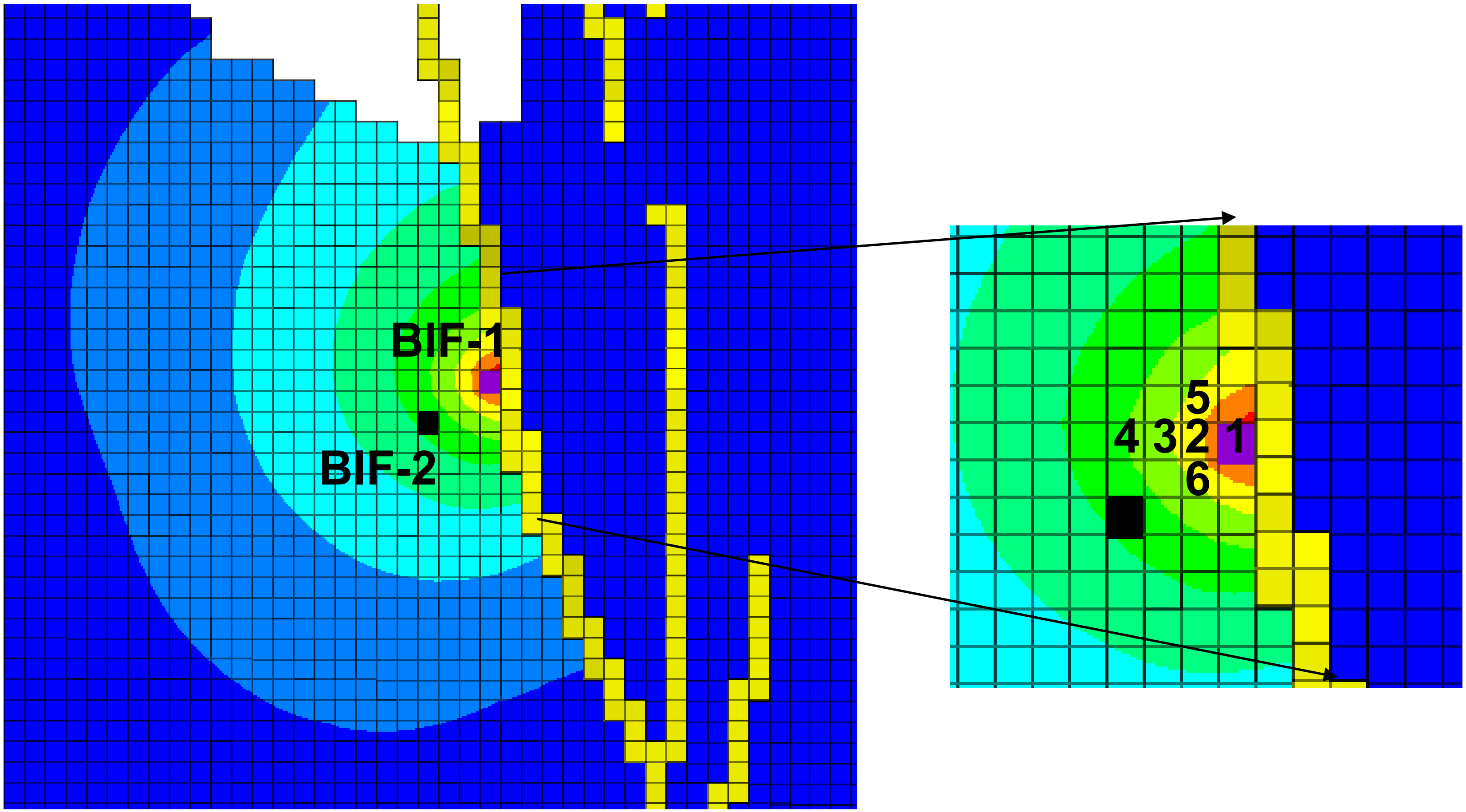
The main difference between the status at the two wells appears to be the different proximity to the closest impermeable Fault.

We recall that the zone dimensions are 400mx400mx100m.

To study the effect of the well location relative to the impermeable Fault, we repeat the BIF-1 simulation, after moving the well location 1 to 3 zones (or 400m to 1200m) away in the Paradox Valley model.

The cases investigated are sketched on the following slide.

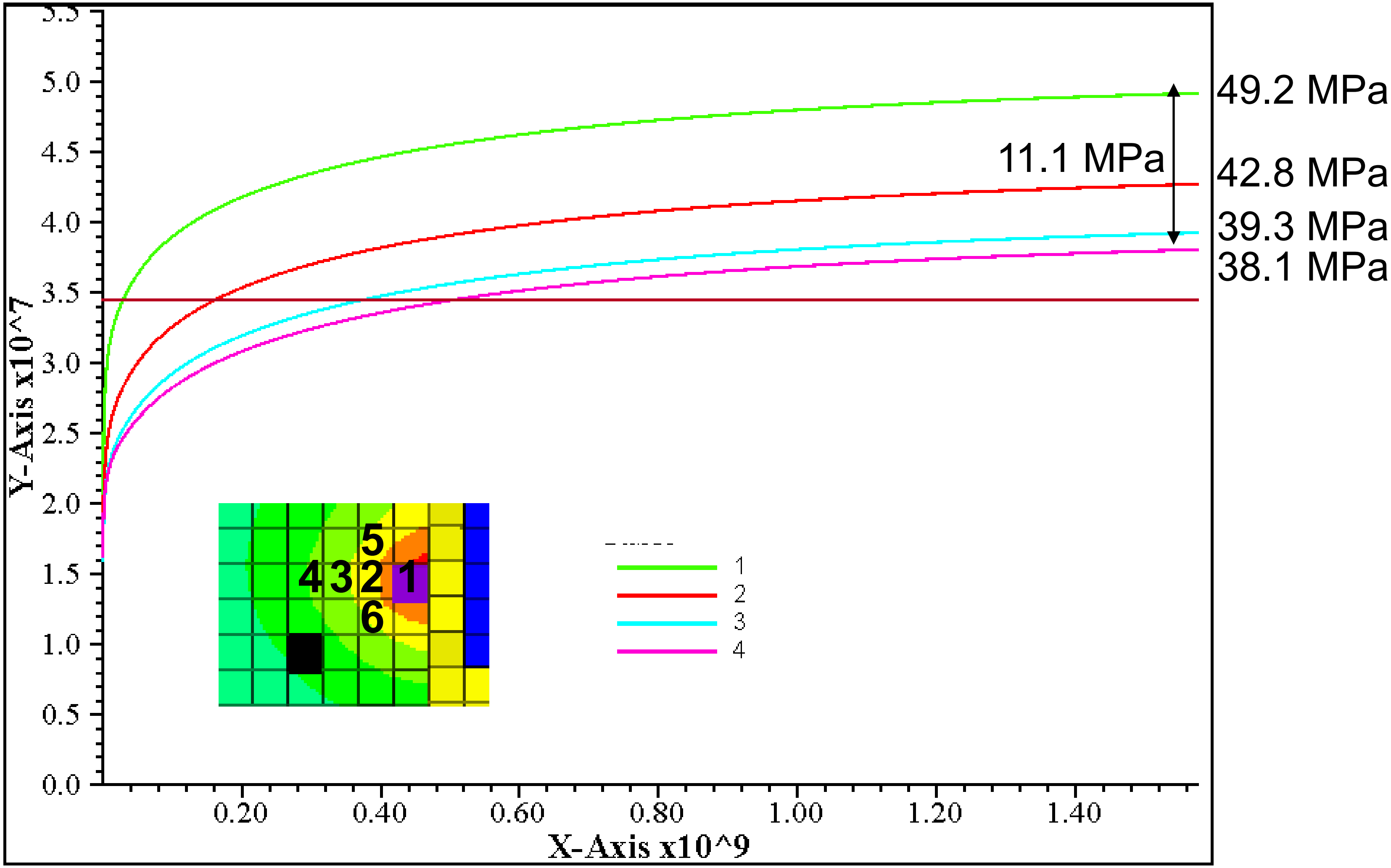
# BIF-1: Alternative injection locations




1: original location, 2-6: locations used in the investigation

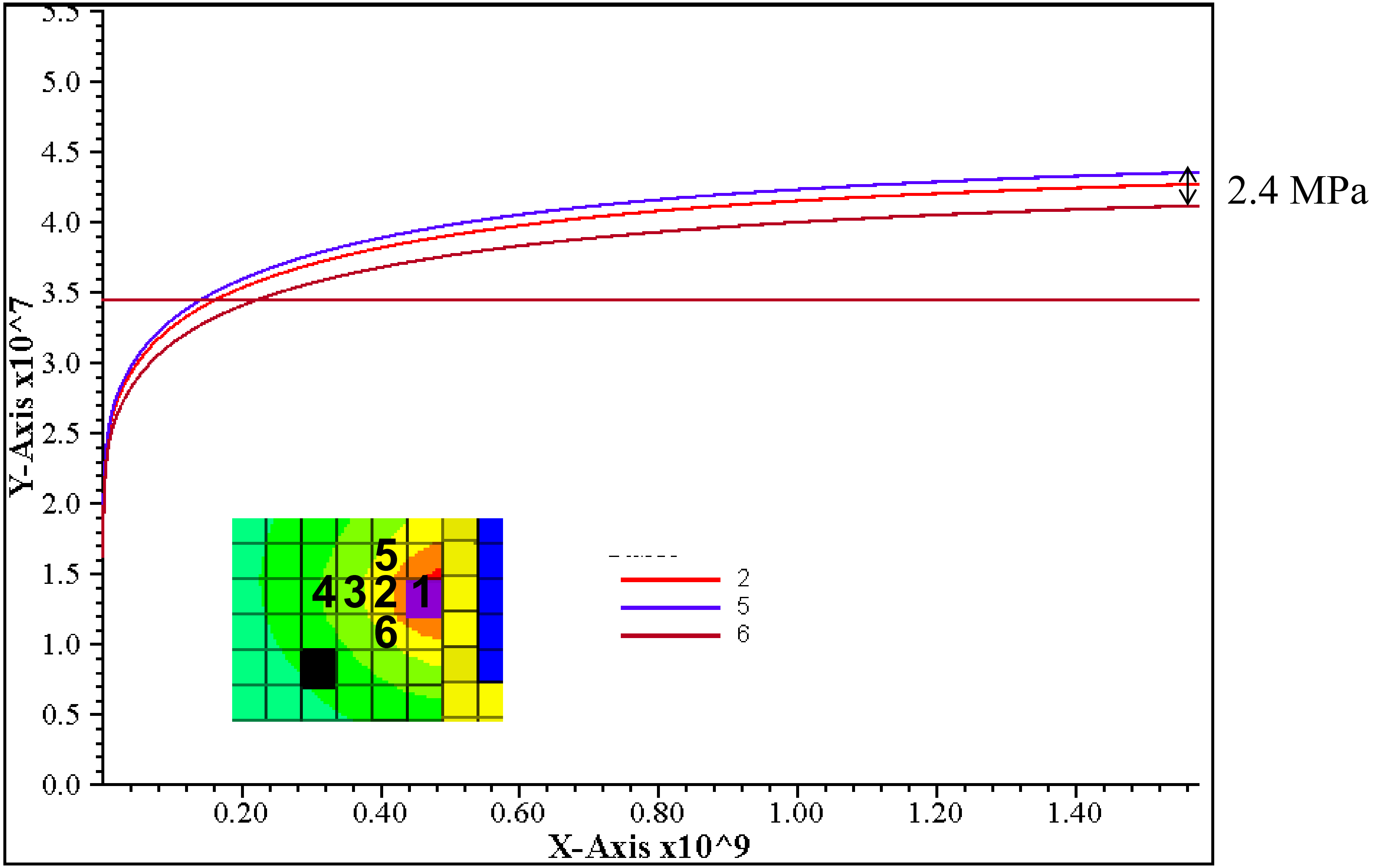
# SIMULATION RESULTS – CASE 1-6

# BIF-1: shift left 400m, 800m, 1200m




Wellhead pressure [Pa] vs time [sec] for BIF#1 locations 1 to 4

# BIF-1: shift 400m left-up-down 400m




Wellhead pressure [Pa] vs time [sec] for BIF#1 locations 2, 5, and 6

# Observations

The reduction in wellhead pressure obtained after moving BIF-1 1200m to the left of its original location in the model, away from the Impermeable Fault, is about 11.1 MPa.

The variation in wellhead pressure evaluated after moving BIF-1 400m to the left, and 400m up versus down from that position is less than 2.4 MPa (lower value down).

Note that the insitu pressures and brine pressures are not always the same at the different locations investigated. The data is summarized in the next slide.

# Summary

Q=0.0151 m^3/s – 50 y    Units: [Mpa], [m]

| | BIF-1 | 400m-left | 800m-left | 1200m-left | 400m-left 400m-up | 400m-left 400mdown |
|---|---|---|---|---|---|---|
| Wellhead pressure | 49.2 | 42.8 | 39.3 | 38.1 | 43.6 | 41.2 |
| Brine Pressure | 42.2 | 44.0 | 45.0 | 44.7 | 44.0 | 44.7 |
| In-situ pressure | 33.3 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 |
| Injection depth | 3731.6 | 3888.5 | 3979.0 | 3953.0 | 3889.1 | 3953.1 |
| Zone excess pressure | 31.8 | 27.1 | 24.6 | 23.1 | 27.9 | 26.3 |

# PARADOX MODEL – VERIFICATION TESTS

# Outline

Two injection tests are simulated in a simplified one-layer, constant thickness model, with same zone size (400mx400mx100m), same rate and same volumetric injection procedure as used in the Paradox Valley model.
The objectives are:

1. to investigate in a simple context the impact of the distance between a well and an impermeable barrier on predicted wellhead pressure, and confirm the findings obtained with The Paradox Valley model

2. to test the capability of the *FLAC3D* mesh to reproduce the pressures predicted by Theis analytical solution

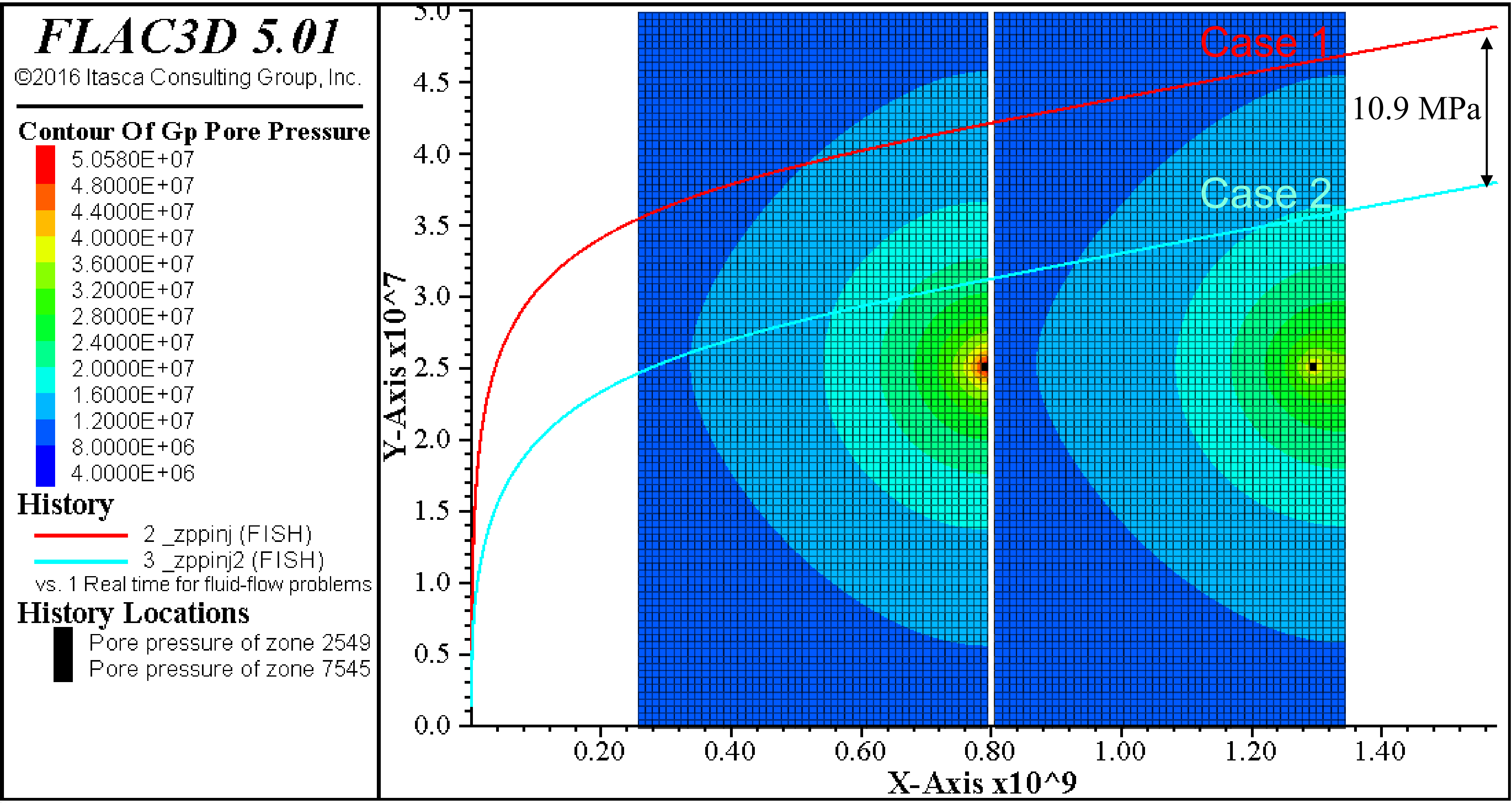
# Test 1: Wellhead pressure prediction close to an impermeable barrier

Constant injection in a horizontal Leadville layer of thickness 100m is simulated for up to 50 years, at a rate of 0.0151 m^3/s . We use the same zone size, and properties as in the Paradox Valley model. The model boundaries are impermeable.

We consider two cases:
- Injection in a zone adjacent to a model boundary
- Injection in a zone located 1.2 km away from the first one

The excess pressure prediction at the injection locations are compared in the next slide.

# Excess zone pressure predictions




Excess pressure contours for Case 1 (left) and case 2 (right), and Excess zone pressure at injection location [Pa] vs time [sec]

# Observations

After 50 years of injection, the difference in excess pore pressure prediction in the injection zone for the simple models is about 10.9 MPa.

The value is in the same order as the difference (9.7 MPa) in excess pressure for BIF # 1 and BIF # 2, using the Paradox Valley model (see slide 8) .

This result suggests that the difference in BIF # 1 and BIF # 2 wellhead pressures predicted by the Paradox Valley model can mainly be attributed to the difference in well proximity of the two wells to the closest impermeable Fault.

# Test 2: Comparison of fluid pressure prediction with analytical solution

Constant injection in a horizontal Leadville layer of thickness 100m is simulated for up to 50 years, at a rate of 0.0151 m^3/s . Again, we use the same zone size, and properties as in the Paradox Valley model. The pore pressure is fixed at zero on the model boundaries.

The pore pressure is monitored at grid points located 600m, 1000m, 1400m, 2200m, 4200m, 6200m, and 8200m from the center of the injection zone. The values are compared to Theis analytical solution:

# Theis analytical solution

$$p_{ana} = \frac{Q}{4\pi k^{Flac} h} E_1(u) + p_0$$

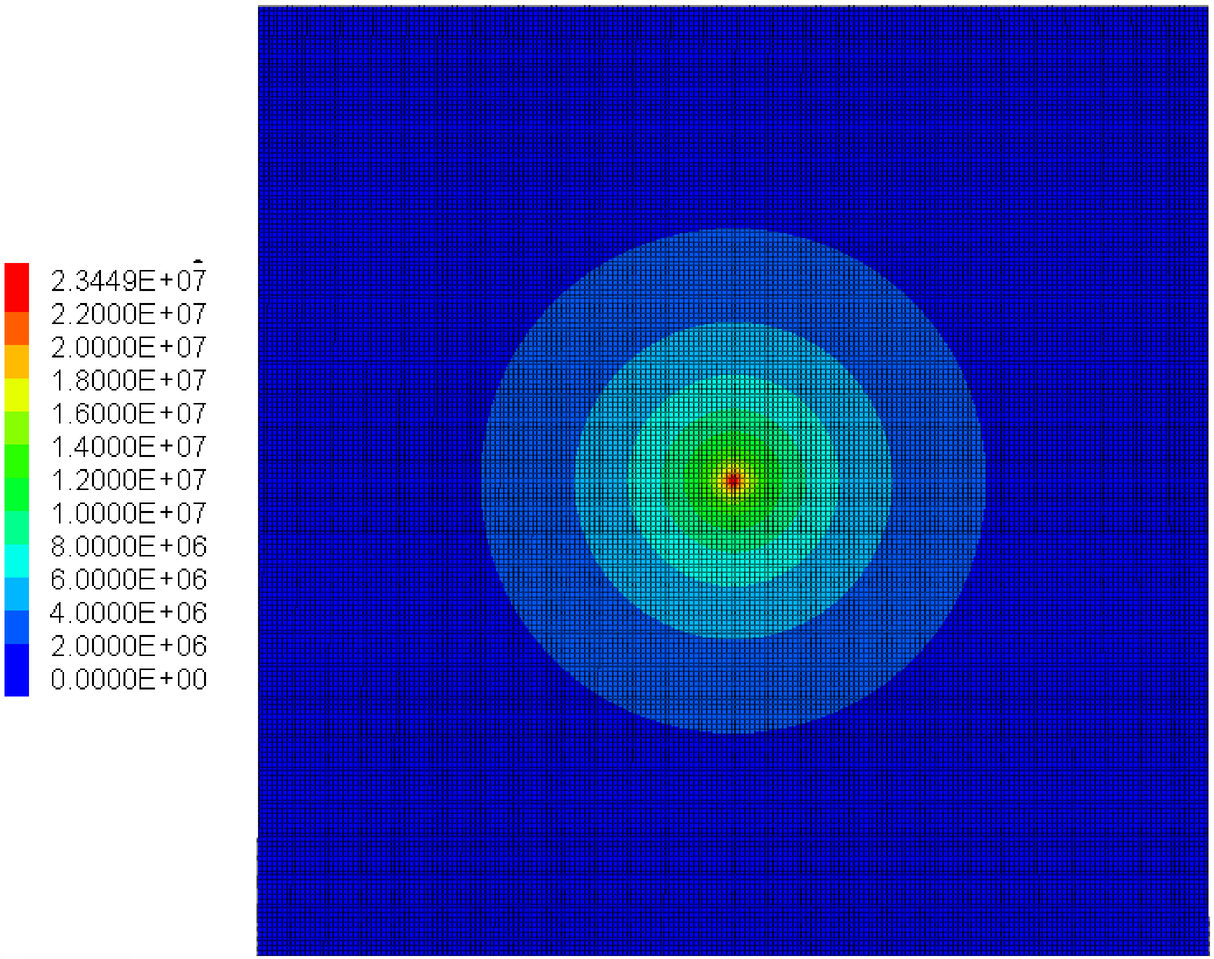
$$u = \frac{r^2}{4ct}$$

$E_1$ : Exponential Integral

Leadville quantities:

| | |
|---|---|
| $r$ [m] | radial distance from well axis |
| $c = 0.21\ \mathrm{m^2/s}$ | diffusivity |
| $t$ [sec] | time |
| $Q =\ 0.0151\ \mathrm{m^3/sec}$ | flow rate |
| $k = 4.45.10^{-12}\ \mathrm{m^2/Pa.sec}$ | mobility coefficient |
| $h = 100$ m | layer thickness |
| $(p_0 = 0$ Pa | far field pressure ) |

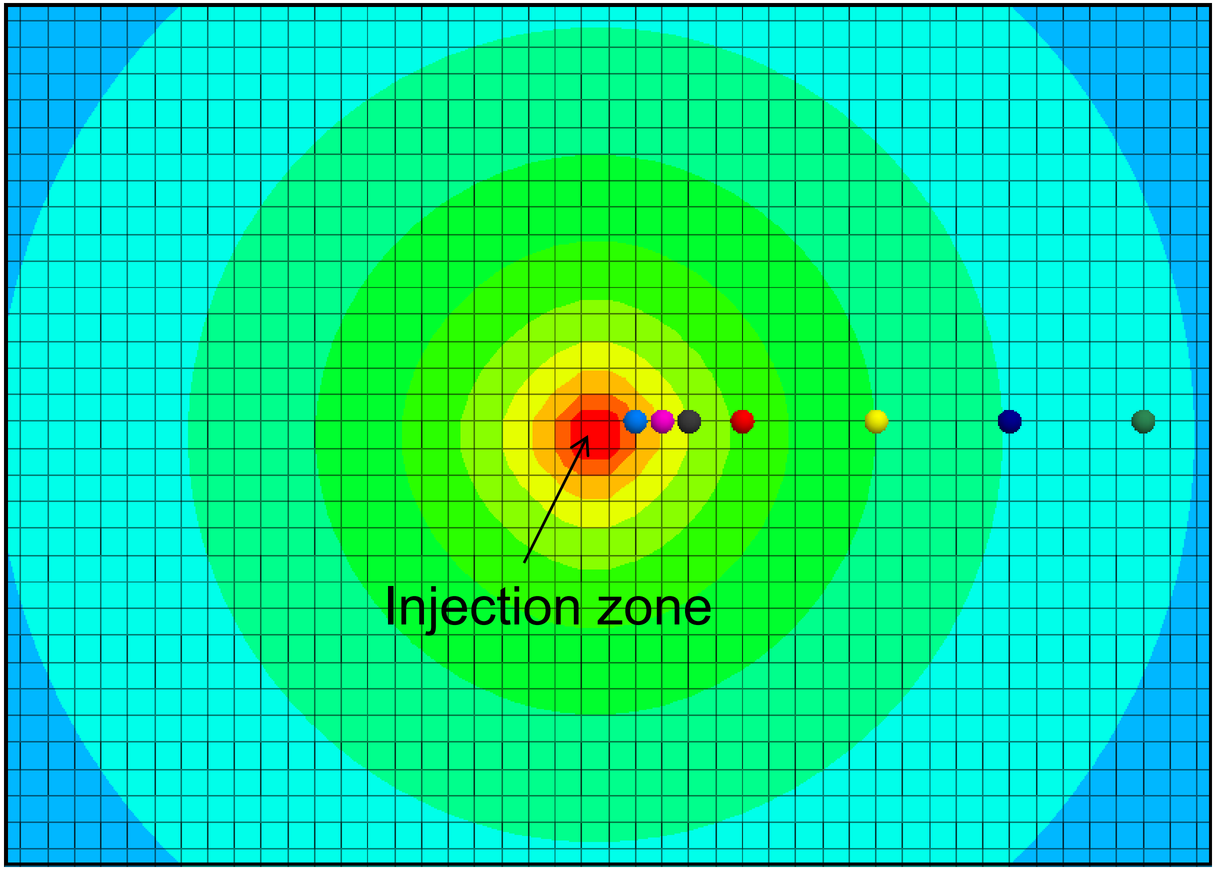
# Pore pressure contours at 50 years




80kmx80kmx0.1km

Plan view of FLAC3D model, and excess pore pressure contours [Pa] at 50 years.

# Location of pressure monitoring points

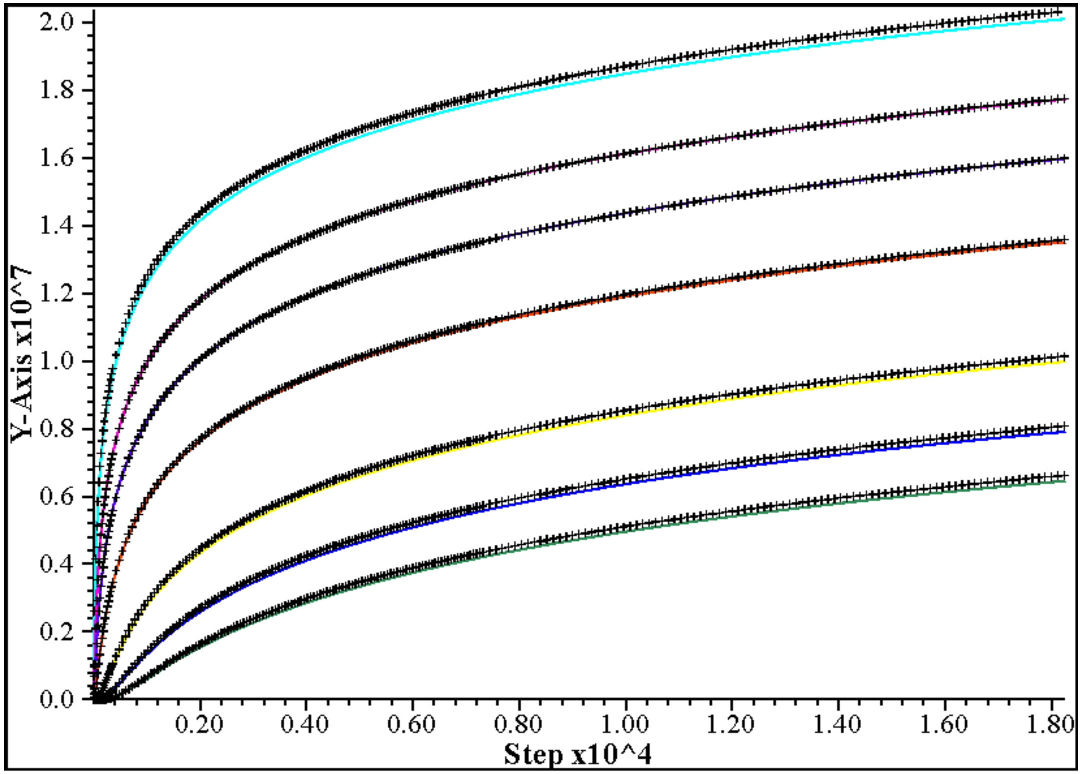



Close up view of FLAC3D model near the well, and location of monitoring points.

# Comparison between numerical pressure predictions and Theis solution

Numerical:

Analytical:
++++++




Excess pore pressure [Pa] versus time [sec] at 7 monitoring points.

# Well pressure prediction and Theis solution

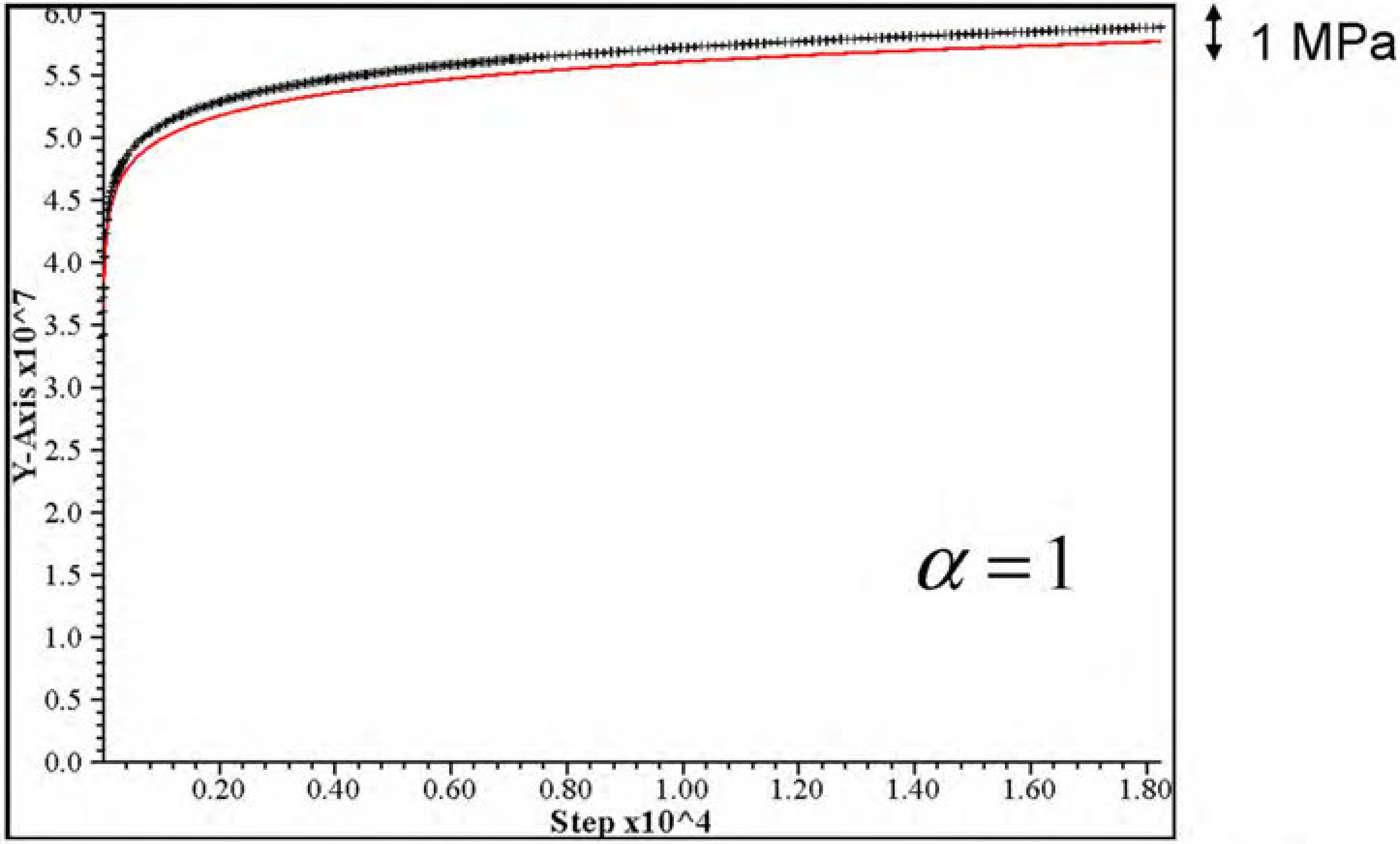
In the paradox Valley model, the excess pressure at the well is evaluated as the sum of the zone pressure at the injection location and a well pressure correction (to account for the relatively large zone size compared to well radius).
The well pressure correction is defined as:

$$\Delta p_w = \alpha \frac{Q}{2\pi k^{Flac} h} \ln \frac{r_0}{r}$$

| | |
|---|---|
| $r_0 = \sqrt{2.*200^2 + 50^2}$ m | distance between injection zone center and its nodes |
| $r = 0.5$ m | assumed well radius |
| $h = 100$ m | injection interval |
| $k = 4.45.10^{-12}$ m$^2$ / Pa.sec | Leadville mobility coefficient |
| $Q = 0.0151$ m$^3$/sec | flow rate |
| $\alpha$ | calibration parameter |

# Comparison between well pressure prediction and Theis solution

Numerical:
--------
Analytical:
+++++




Numerical well pressure prediction and Theis solution [Pa] versus time [sec]

# Observations

As may be seen from the results of the comparison between numerical predictions and Theis solution on the previous slides:

- a good match between numerical and analytical pressure values at the monitoring points is obtained, over the 50 years injection period, even at nodes close to the injection zone.

- The well pressure (zone pressure with applied well correction) is also captured reasonably well in the model: for a well radius of 0.5m, the relative discrepancy with Theis solution is less than 2%.

# THANK YOU!

# Paradox Valley Project

## Fluid-Mechanical injection simulations with the Paradox Valley model
## - Preliminary results -

February 21, 2017

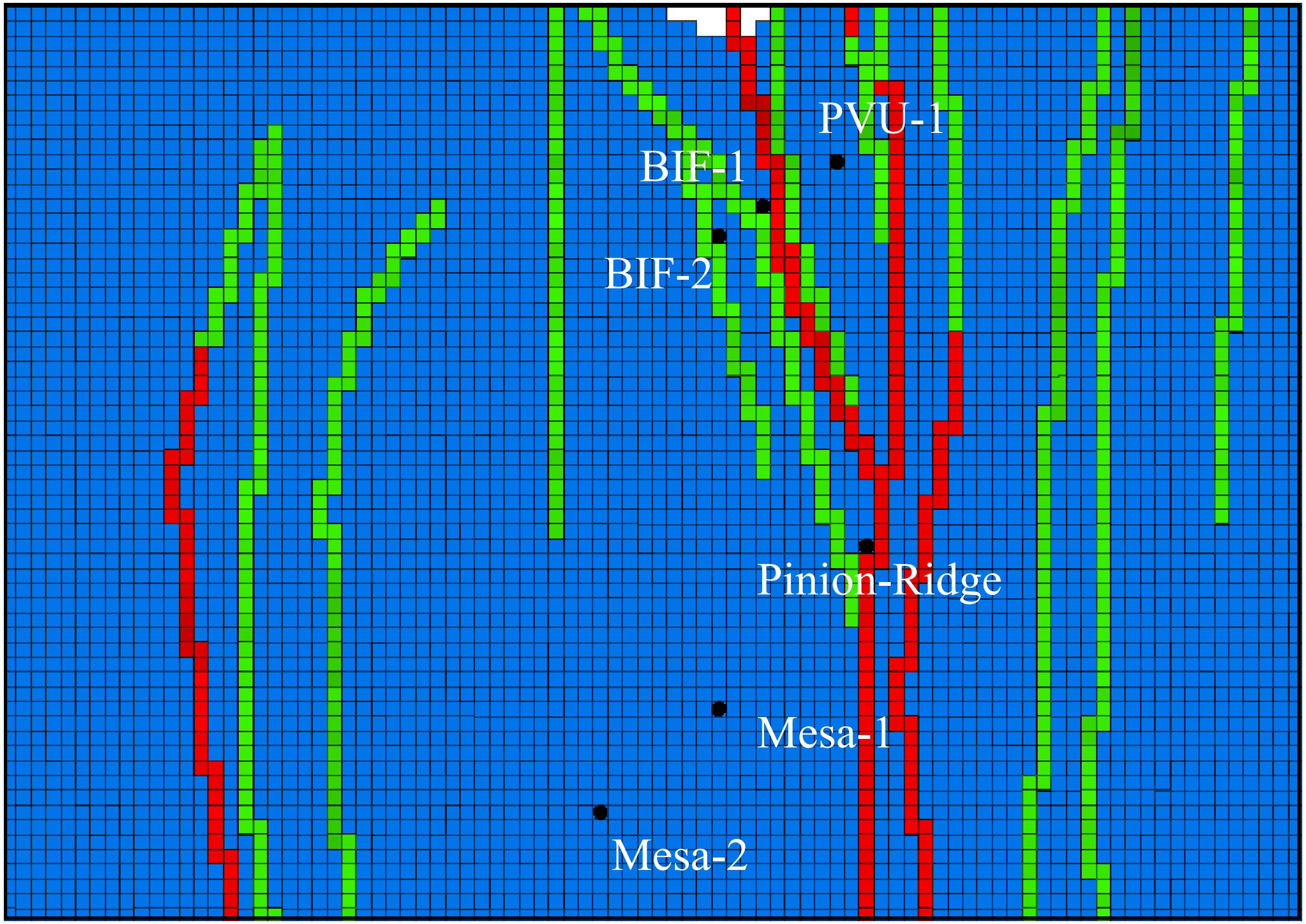
Christine Detournay
Itasca Consulting Group, Inc.

# Outline

Fluid-mechanical injection simulations are carried out at 6 well locations using the calibrated Paradox Valley model. The induced surface heave is evaluated and a simplified approach (based on elastic stress state) is used to predict possible location of increased potential for slip in the model.

Each well is considered individually, using the current site selection in the model, and injection is simulated for up to 50 years. The USBR rate data is used to simulate injection at PVU-1 for the first 25.24 years, and a rate of 0.0112 m^3/s is used after that. A constant injection rate of 0.0151 m^3/s is used for BIF-1, BIF-2, Mesa-1, Mesa-2 and Pinion Ridge.

# *FLAC3D* Wells and Faults location




Impermeable Faults shown in red

# Modeling technique

The fluid mechanical simulations are carried out as follows:

1. The Biot elastic framework is assumed for the simulations
2. The initial stress state is established, assuming elastic material properties.
3. The fluid pressures induced by the brine injection are computed.
4. The elastic deformations induced by the fluid pressure changes are evaluated, and the new equilibrium stress state is calculated.
5. The total elastic effective stresses (assuming initial horizontal water table) are used locally to evaluate the value of a frictional Mohr-Coulomb criterion, and to estimate the potential for slip.

# Initial stress state

The initial stress state is calculated using the following procedure:

1. The USBR elastic properties for the Upper, Welds, Salt, Leadville, Sedimentary, Upper Precambrian, and Lower Precambrian are assigned in the model
2. The mechanical boundary conditions are prescribed (fixity at the base, roller boundary along the lateral sides), gravity is specified. A low shear modulus is specified for the Salt, and the model is cycled to equilibrium
3. An in-situ water table is assumed that matches the 42.3 MPa In-situ pressure at the injection location in PVU-1 (USBR data). The horizontal effective stress in the model
    - in y-direction is taken equal to the vertical effective stress,
    - in x-direction is taken equal to 0.32 times the vertical effective stress.

   Total horizontal stresses are assigned to all zones in the model, except in the Salt, consistent with the effective stresses and fluid pressures.
4. The model is cycled to elastic equilibrium, the realistic salt shear modulus is reassigned, and the displacements are reset to zero.

# Coulomb stress criterion

A cohesionless frictional Coulomb yield function is considered for post-processing of the stresses:

$$F = \sigma_1' - \sigma_3' N_\phi$$

$$N_\phi = \frac{1+\sin\phi}{1-\sin\phi} = \left[\sqrt{1+\tan^2\phi}+\tan\phi\right]^2 = \tan^2\left(\frac{\pi}{4}+\frac{\phi}{2}\right)$$

Yield is predicted to occur (based on an elastic stress distribution) if :

$$F \leq 0$$

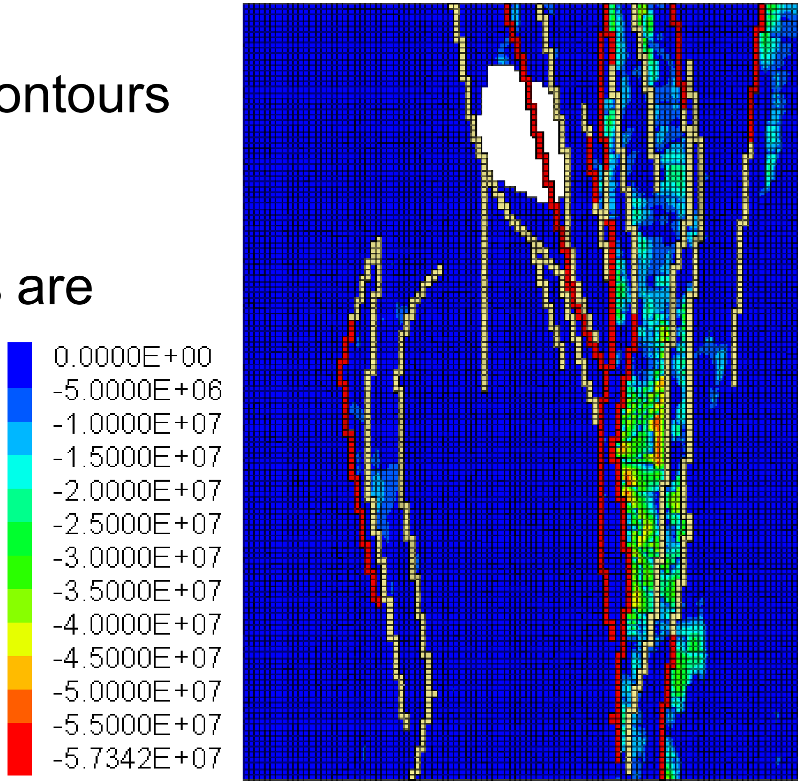
Friction is assumed to be 40 degrees for the simulations.

# *F* contours - In-situ stress state

For the in-situ stress state:
Yield is predicted based on negative F contours in the Leadville using 40 degree friction.

The larger than expected shear stresses are attributed to the following factors:

- non-horizontal layers with offsets
- Isotropic stress state in the salt
- Anisotropic stresses elsewhere




F_ini [Pa] in Leadville

# Yield indicator?

The difference in F value between the current and the initial elastic stress state, if negative, is taken as an indicator of possible yield increase in the model.

However, the prediction using this technique may be misleading because elasto-plastic readjustments would modify the initial stress-state in the model and make the indicator unreliable.

# Biot Parameters

It is assumed that the diffusivity is a (measured) field quantity in the simulations: the same value is used independent of the value of Biot coefficient, $\alpha$ .

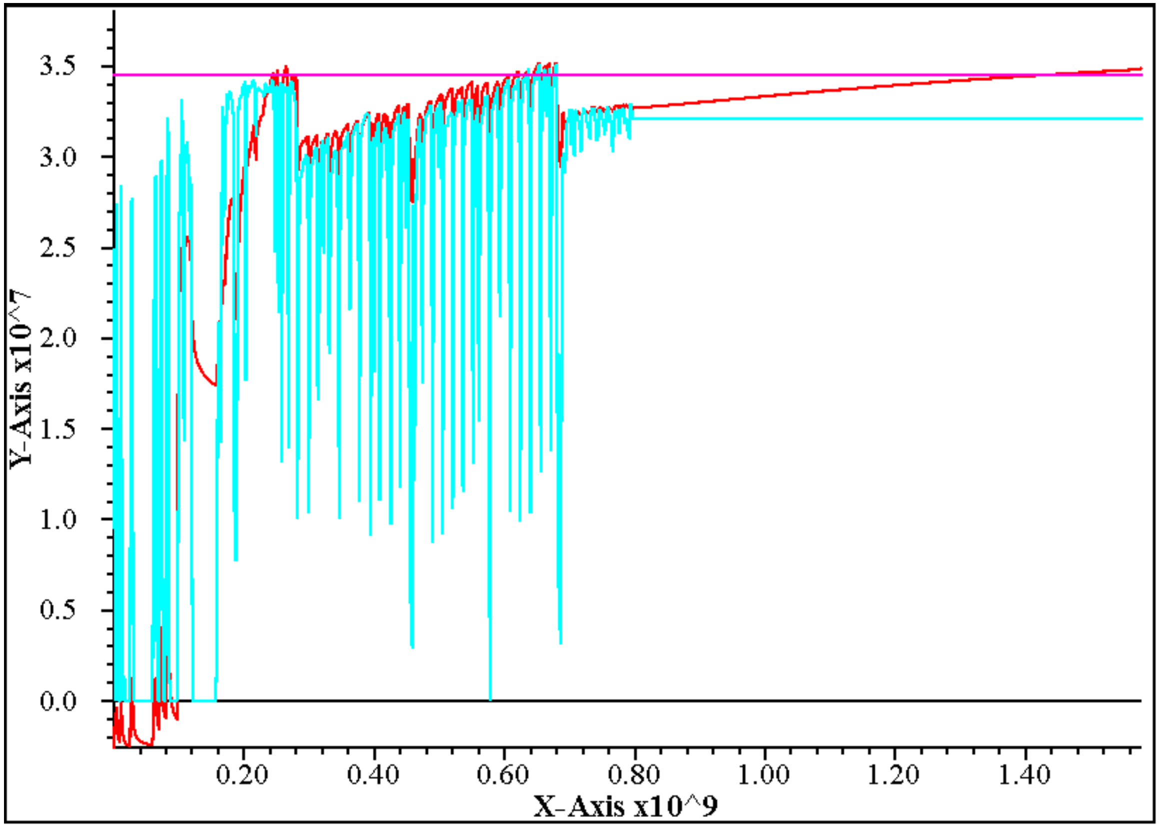
This implies that the Specific storage remains unchanged. Thus the numerical fluid pressure predictions are the same, independent of the assumed value of Biot coefficient.

Note that a reduction of Biot modulus is expected to produce a reduction in maximum surface heave in the elastic simulations.

We report the simulation results obtained using alpha=1 for the 6 wells. For PVU-1, results obtained using more realistic values for alpha are also reported.

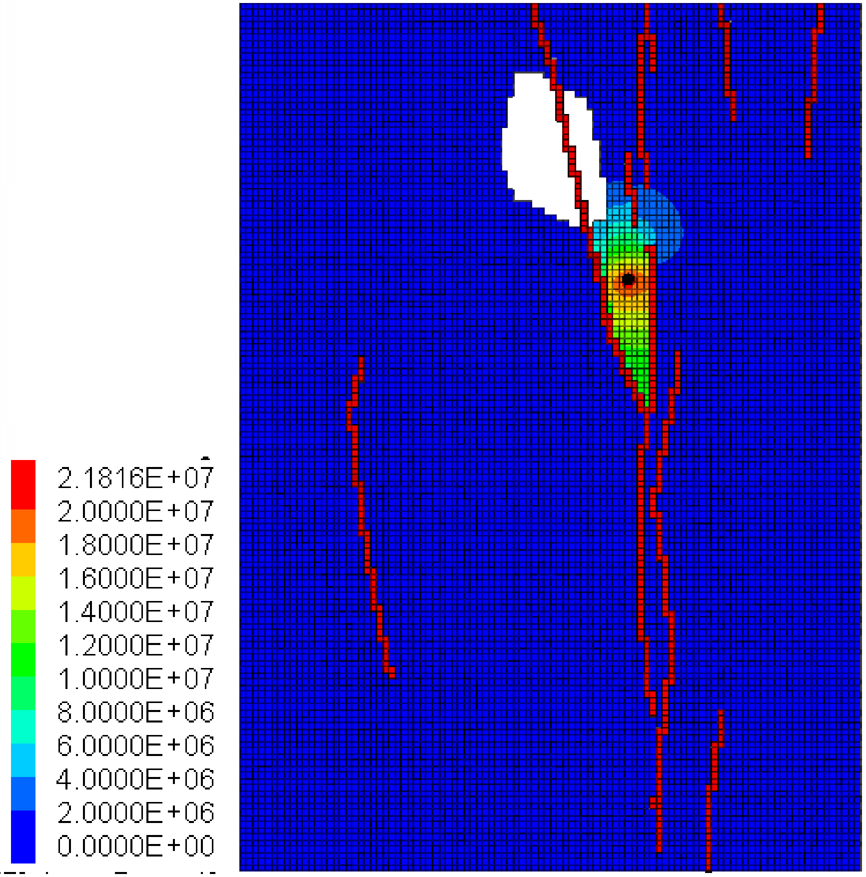
# SIMULATION RESULTS – $\alpha = 1$

# PVU-1

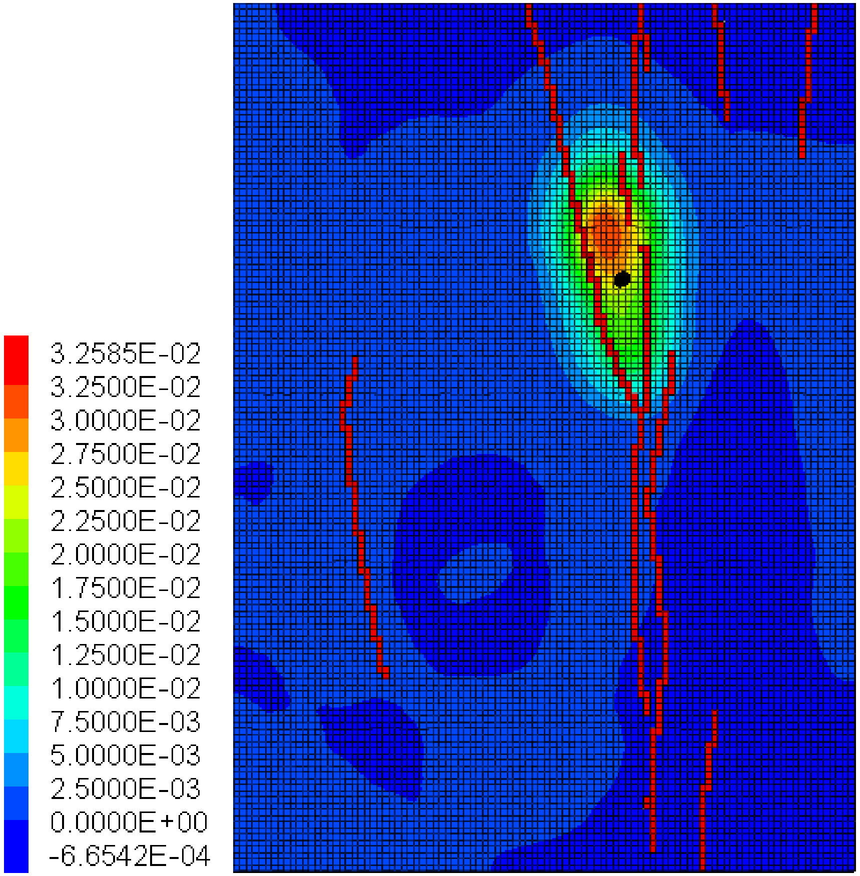



Wellhead pressure [Pa] vs time [sec]

# PVU-1 – 25.24 year

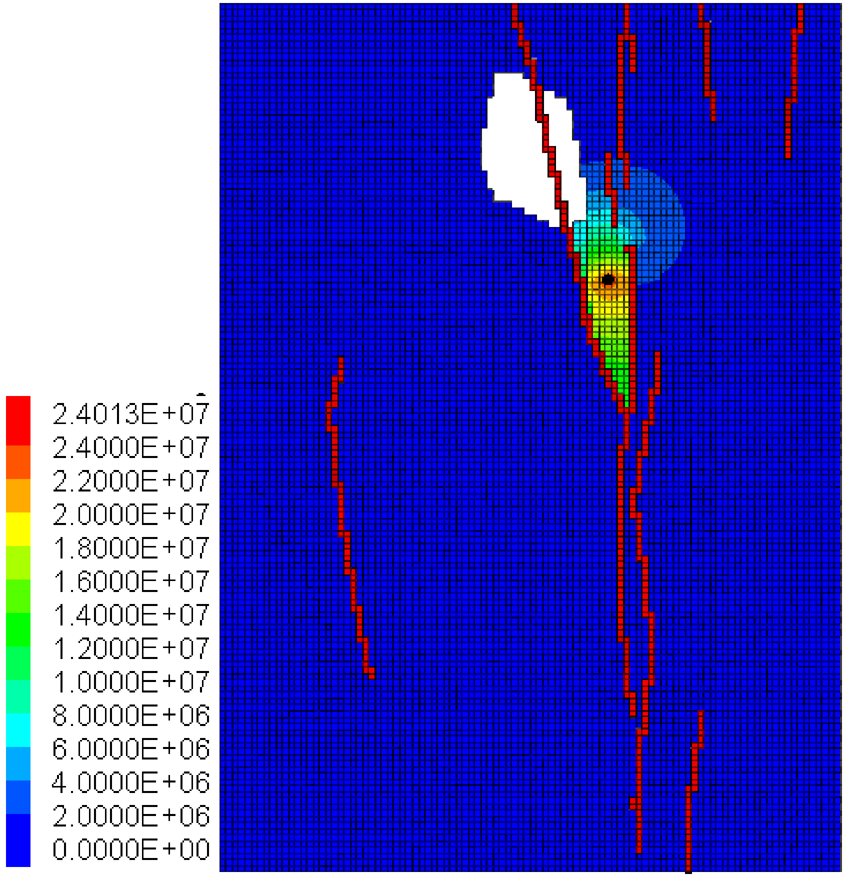



Excess pp contours [Pa] in Leadville

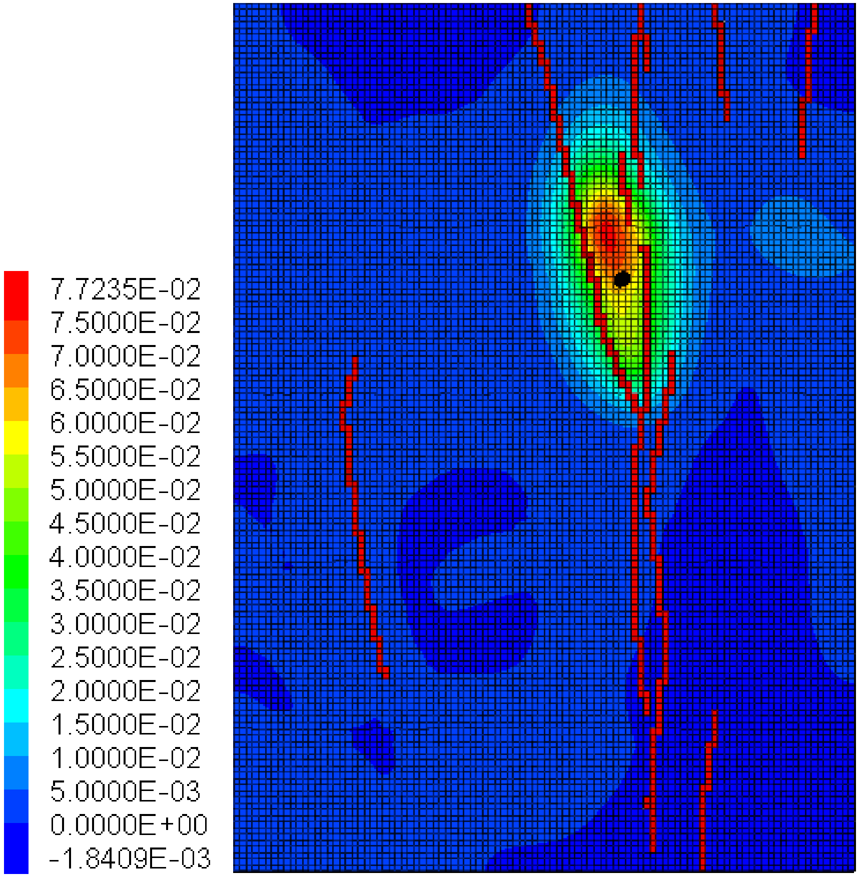



Contours of surface heave [m]

# PVU-1 – 50 year

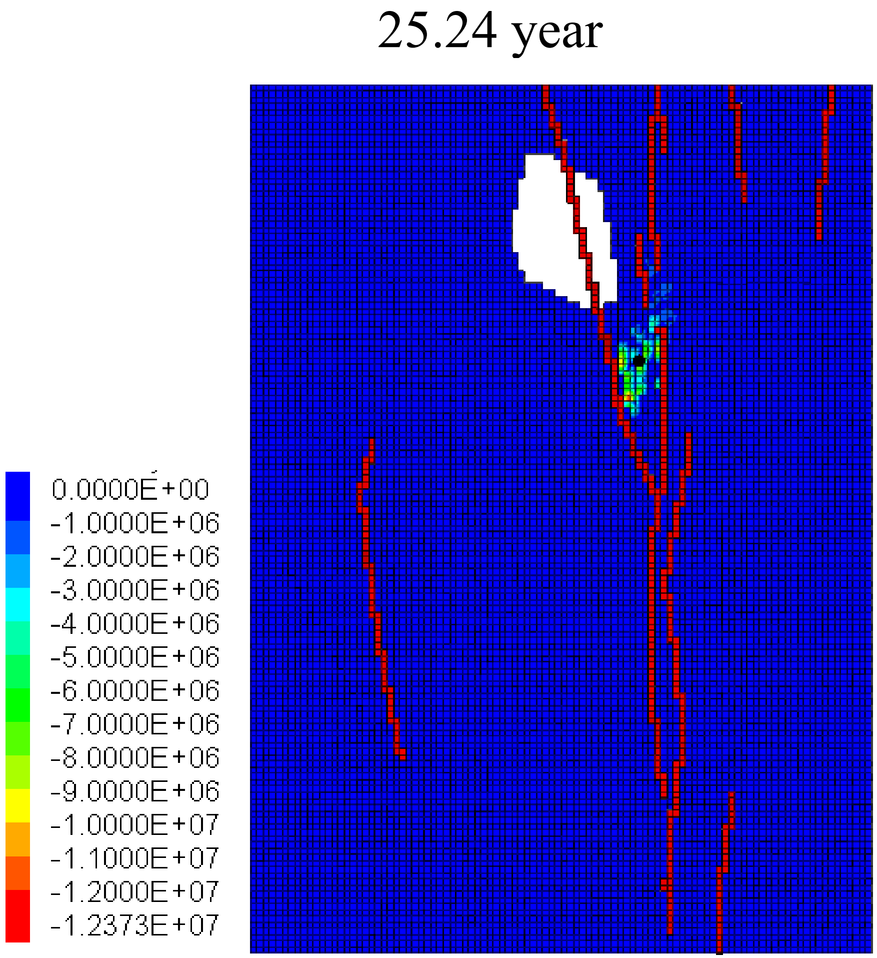


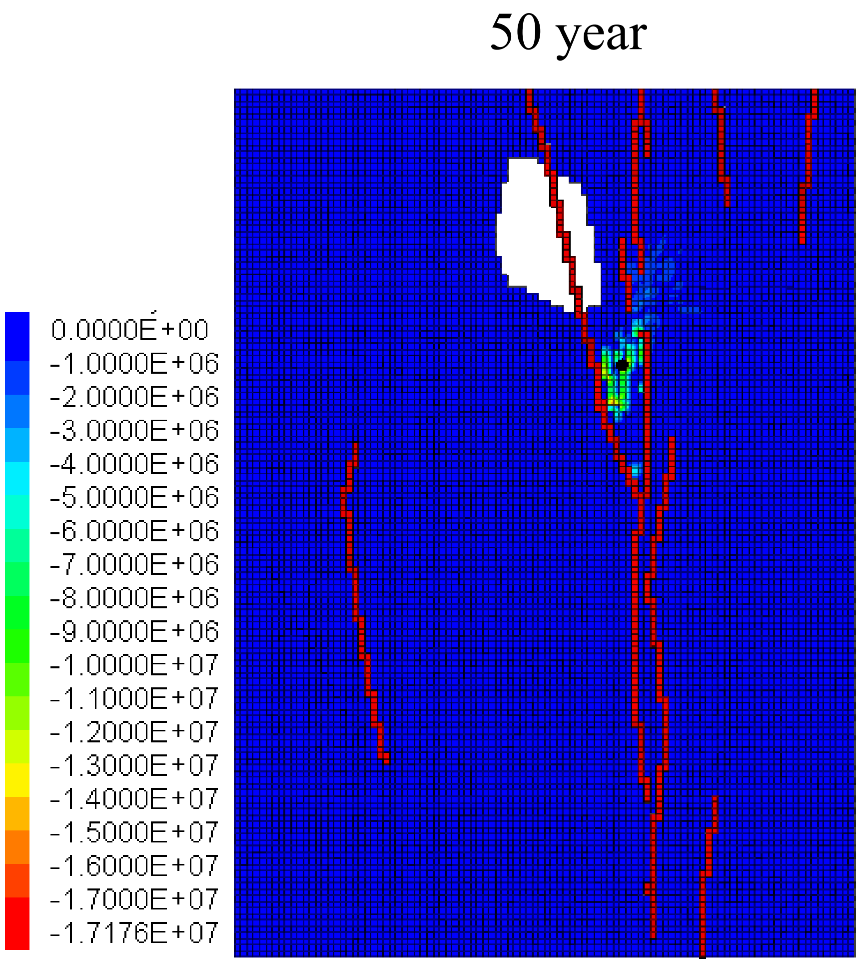

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# PVU-1



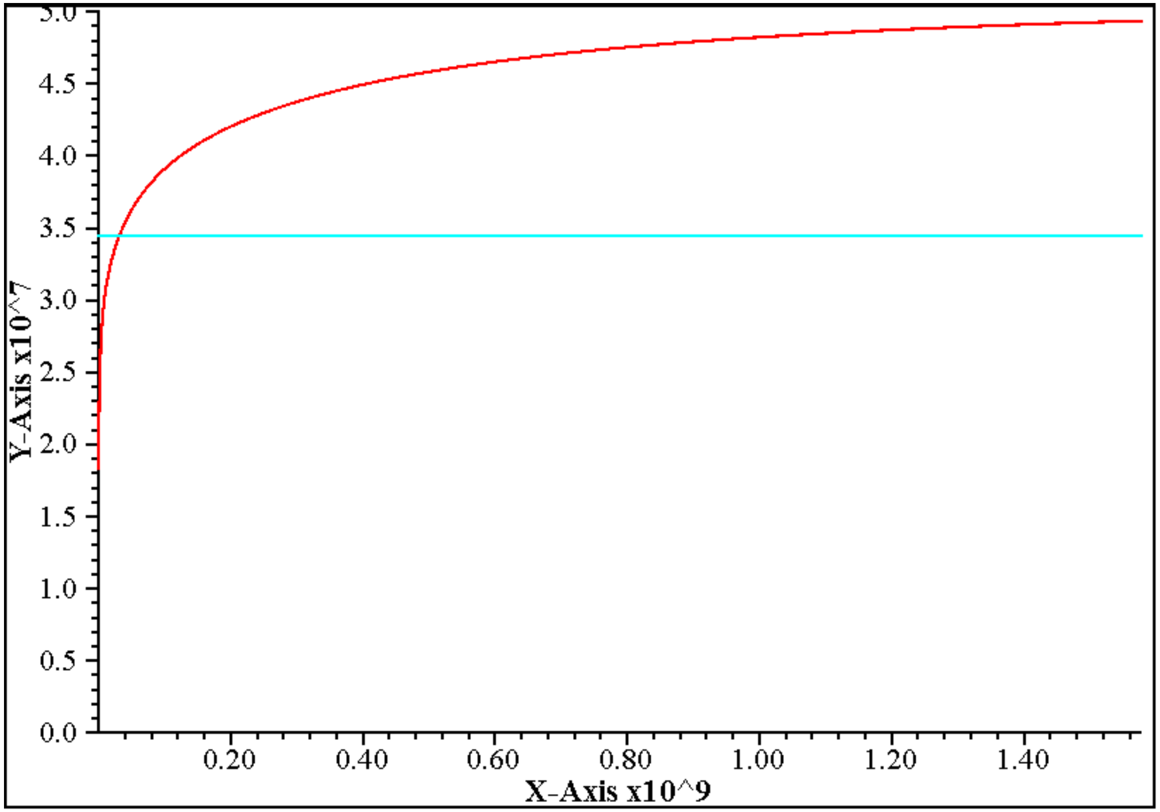

Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| PVU-1 | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| 25.24 year | 32.69 | 3.26 |
| 50 year | 34.85 | 7.72 |
| | | |

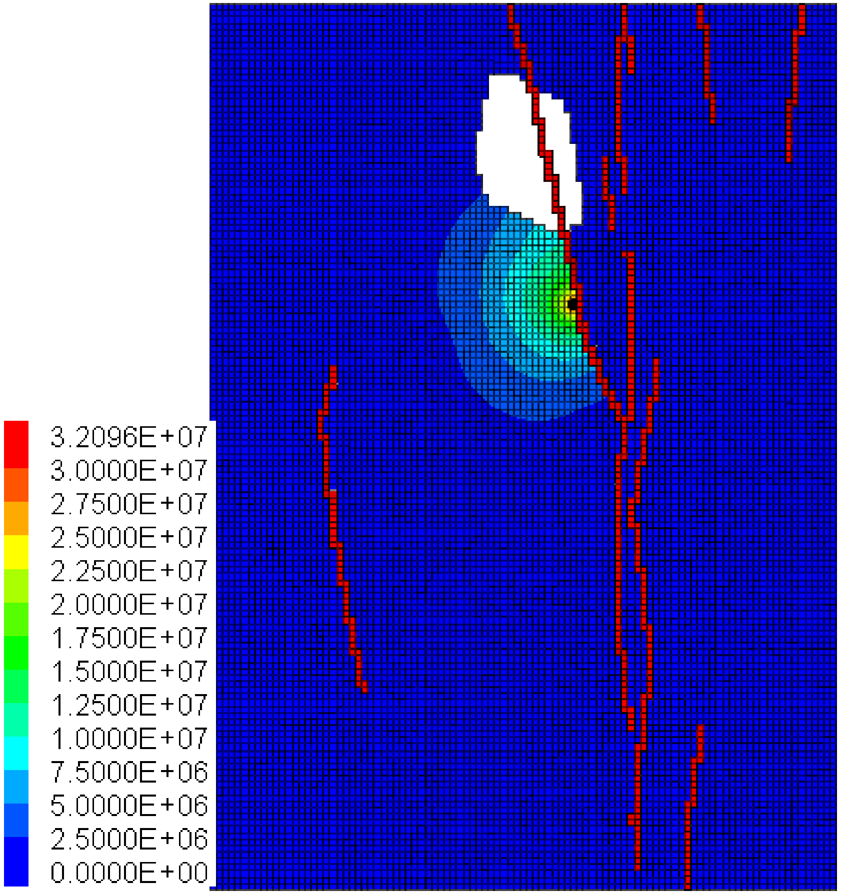
Slip is predicted to occur,
based on elastic stress state in the model.

# BIF-1

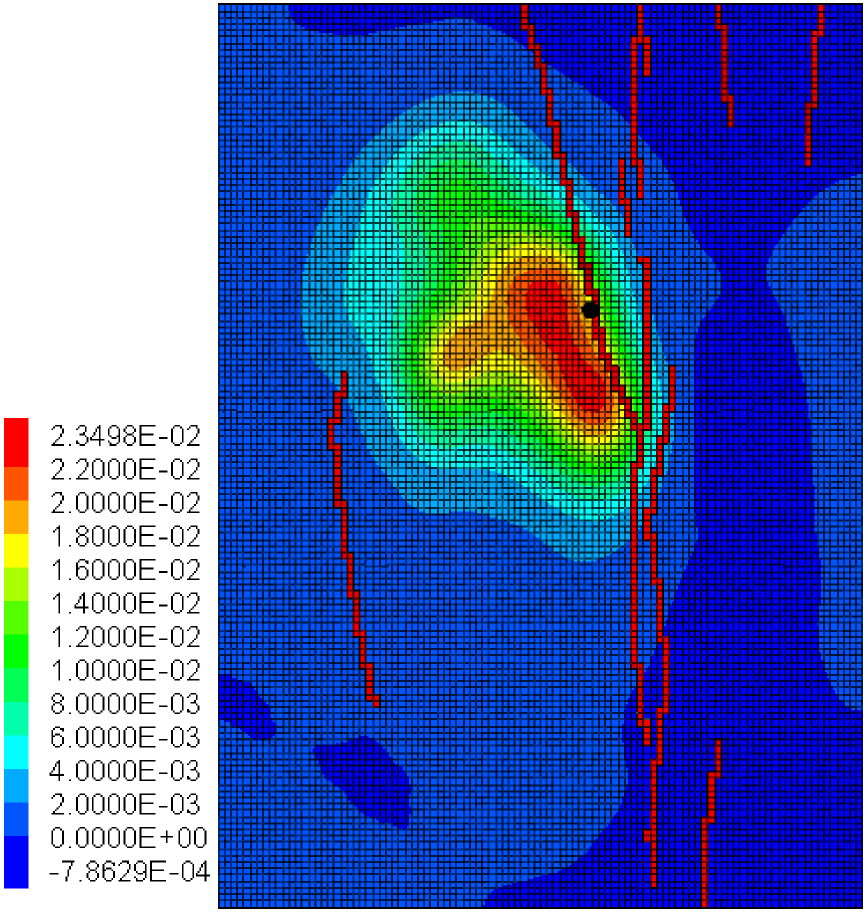



Wellhead pressure [Pa] vs time [sec]

# BIF-1 – 25.24 year

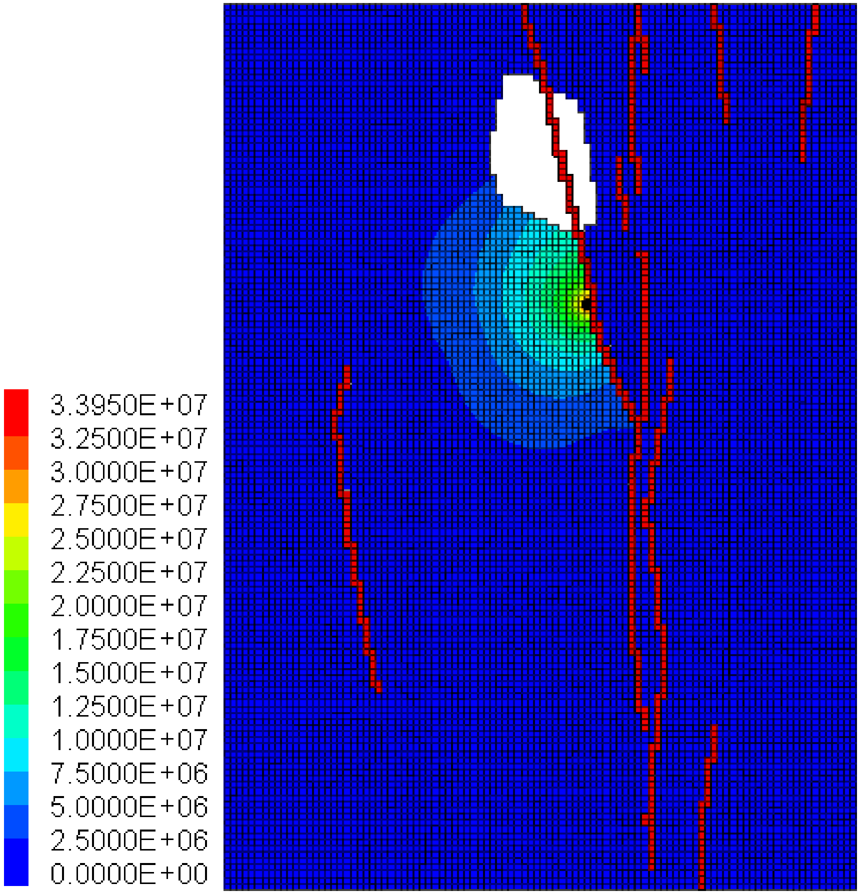



Excess pp contours [Pa] in Leadville

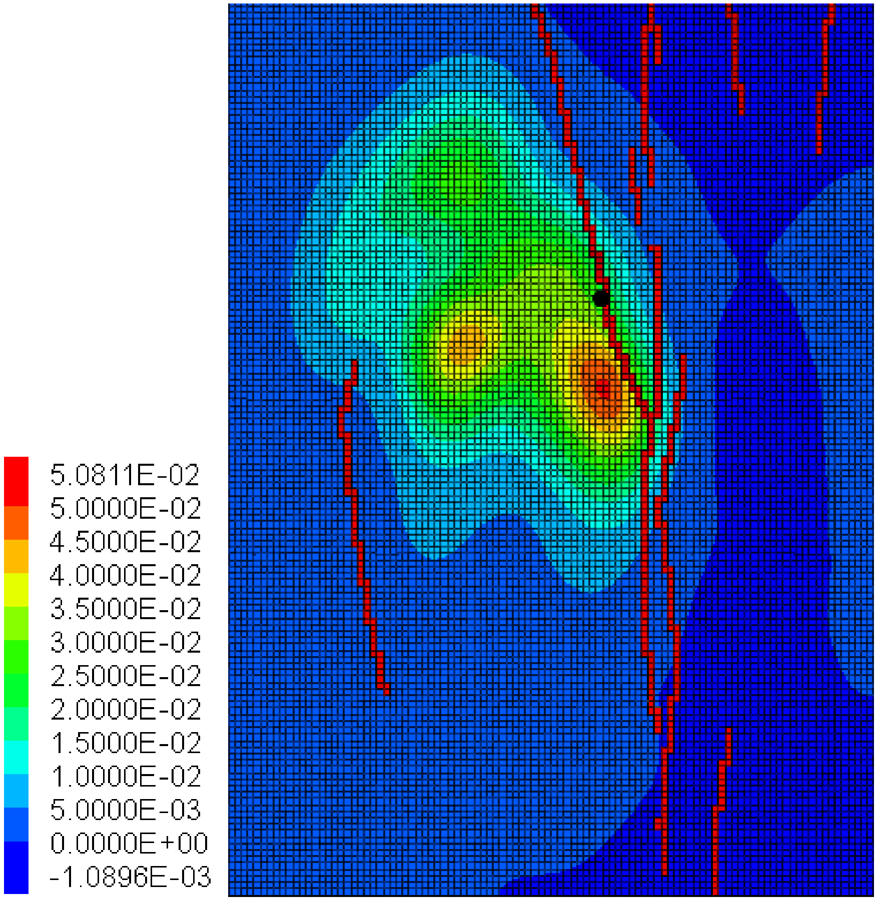



Contours of surface heave [m]

# BIF-1 – 50 year

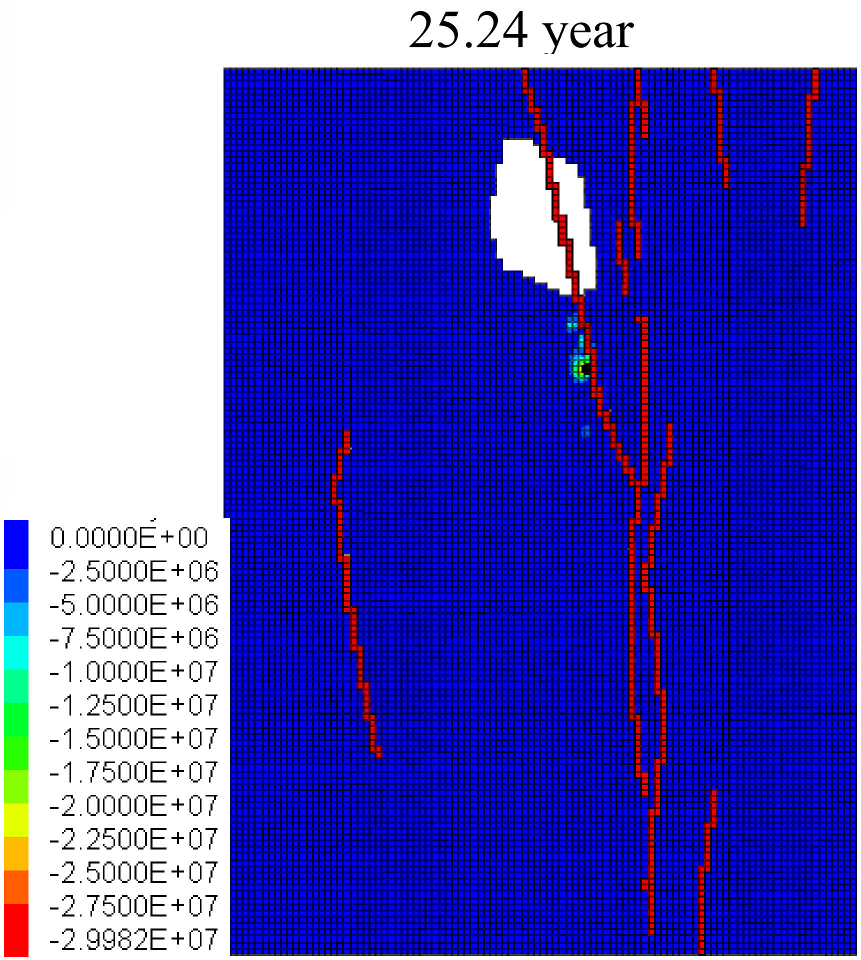


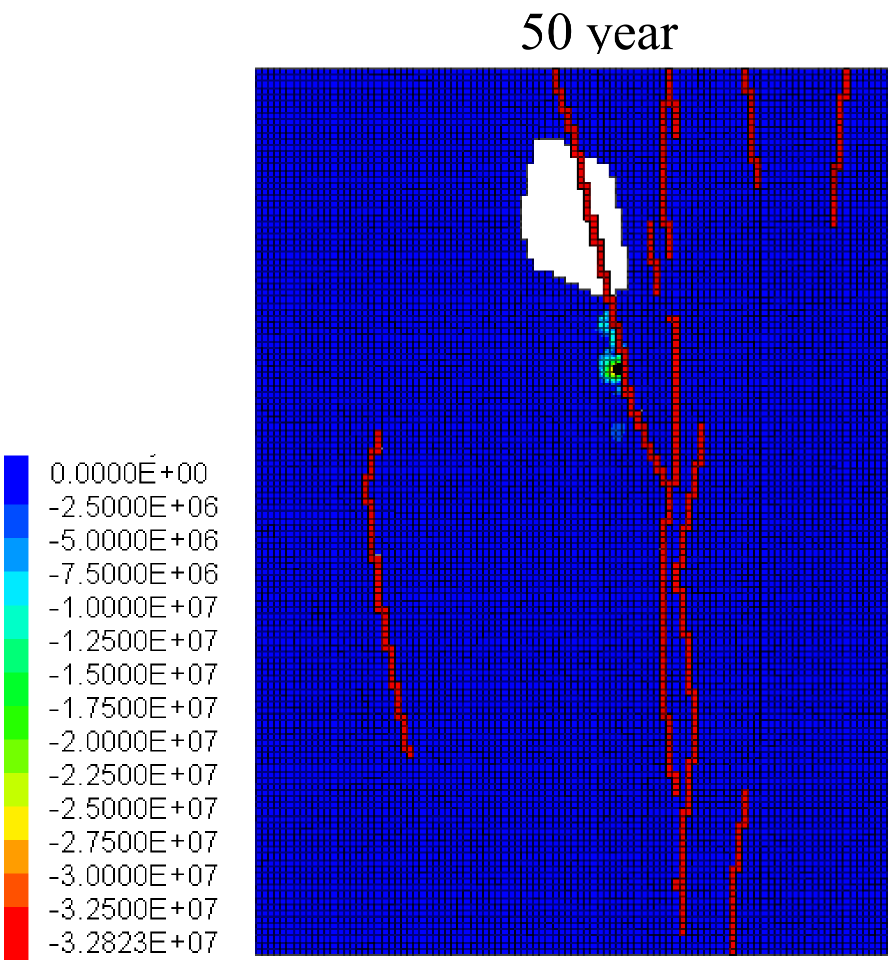

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# BIF-1



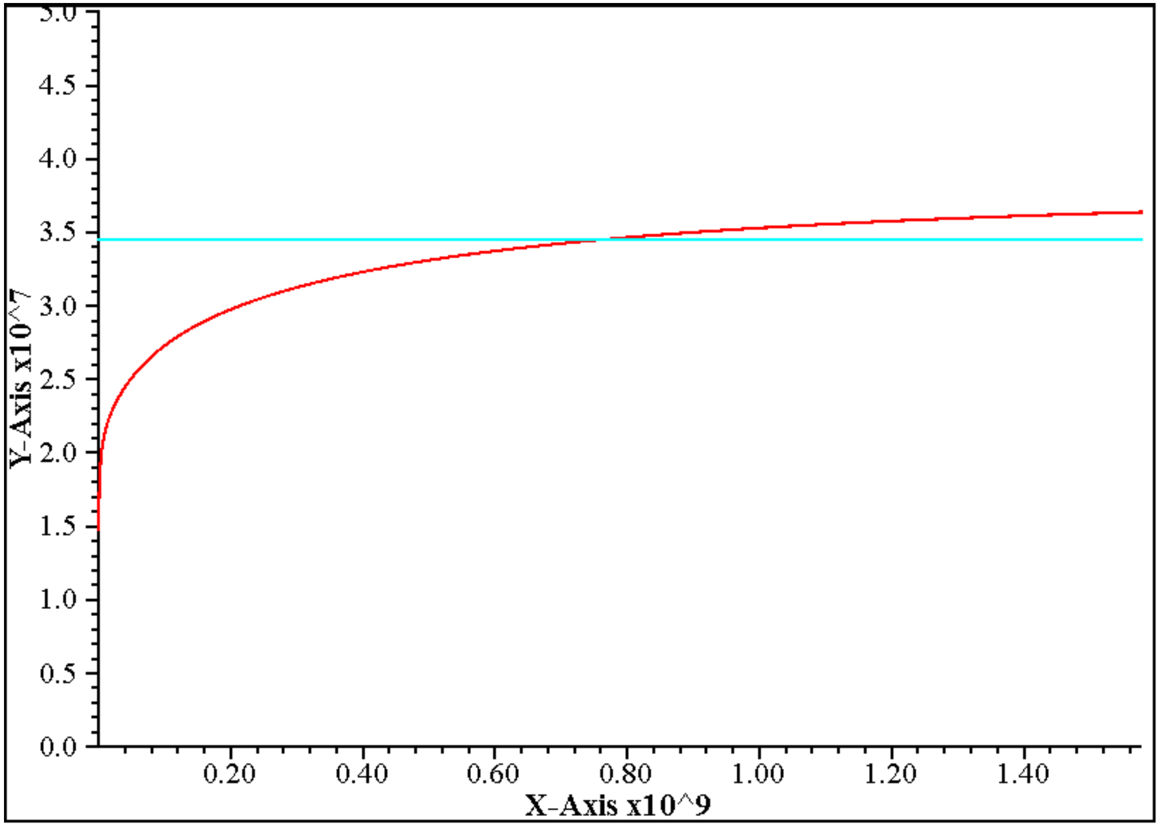

Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| BIF-1 | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| 25.24 year | 47.52 | 2.35 |
| 50 year | 49.37 | 5.08 |
| | | |

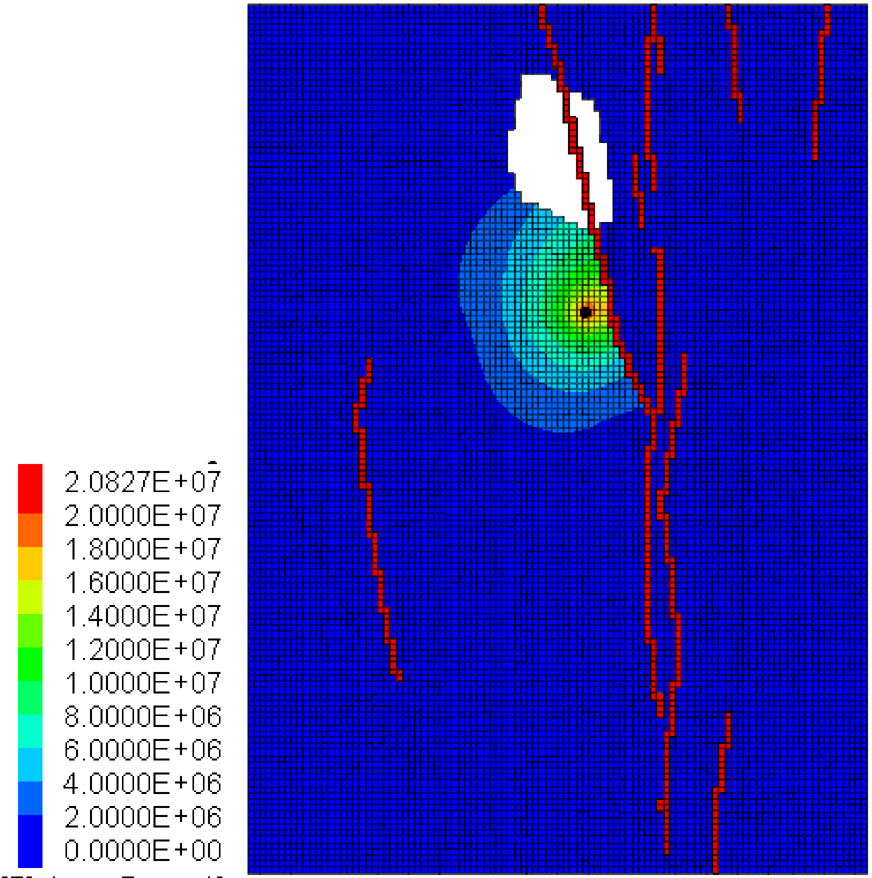
Slip predicted to occur,
based on elastic stress state in the model.

# BIF-2

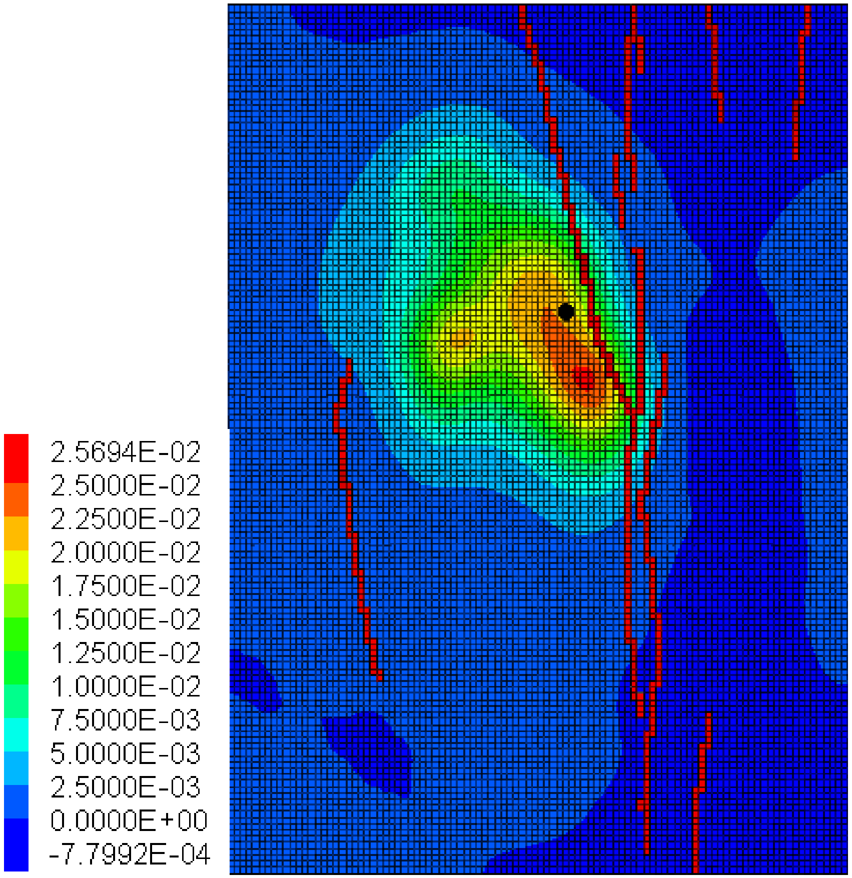



Wellhead pressure [Pa] vs time [sec]

# BIF-2 – 25.24 year

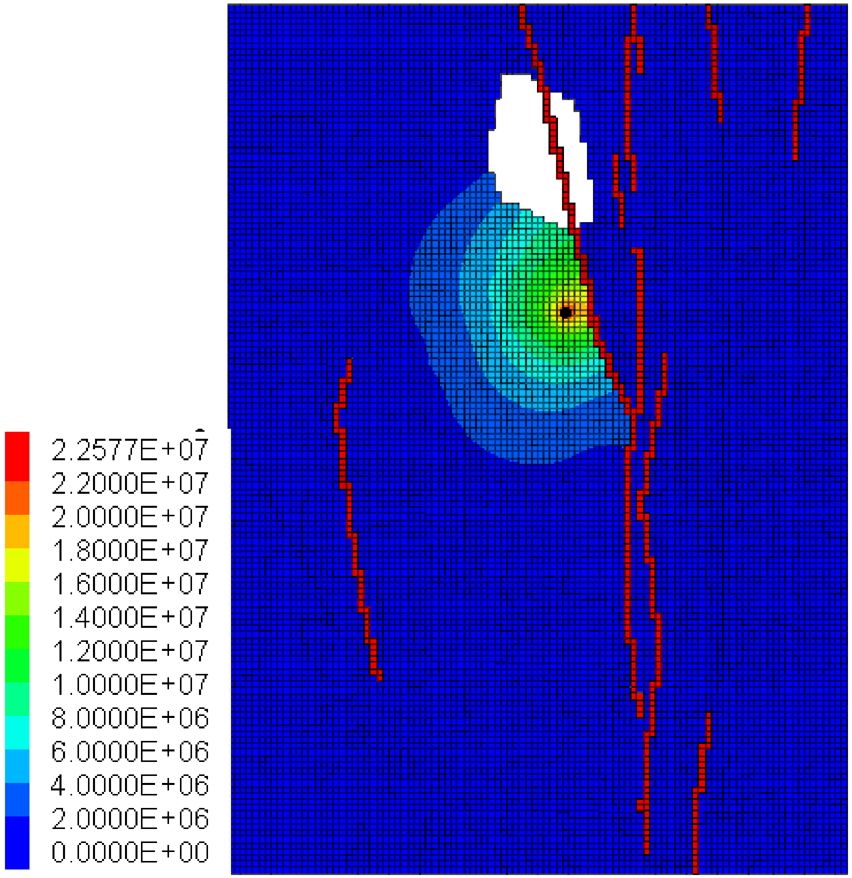



Excess pp contours [Pa] in Leadville

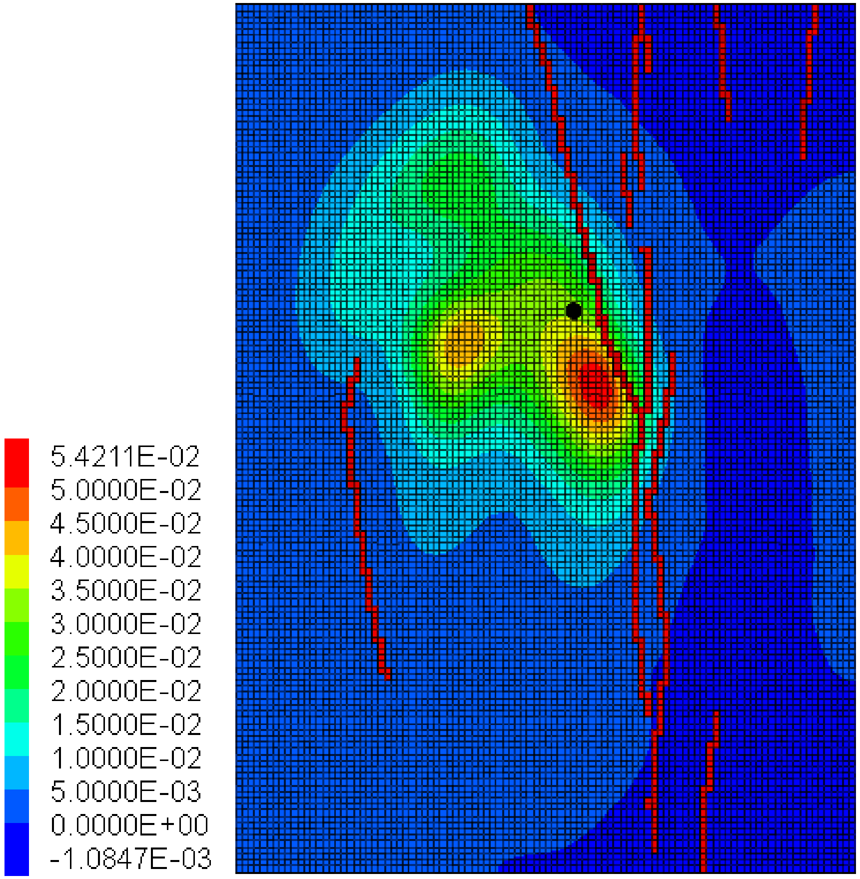



Contours of surface heave [m]

# BIF-2 – 50 year

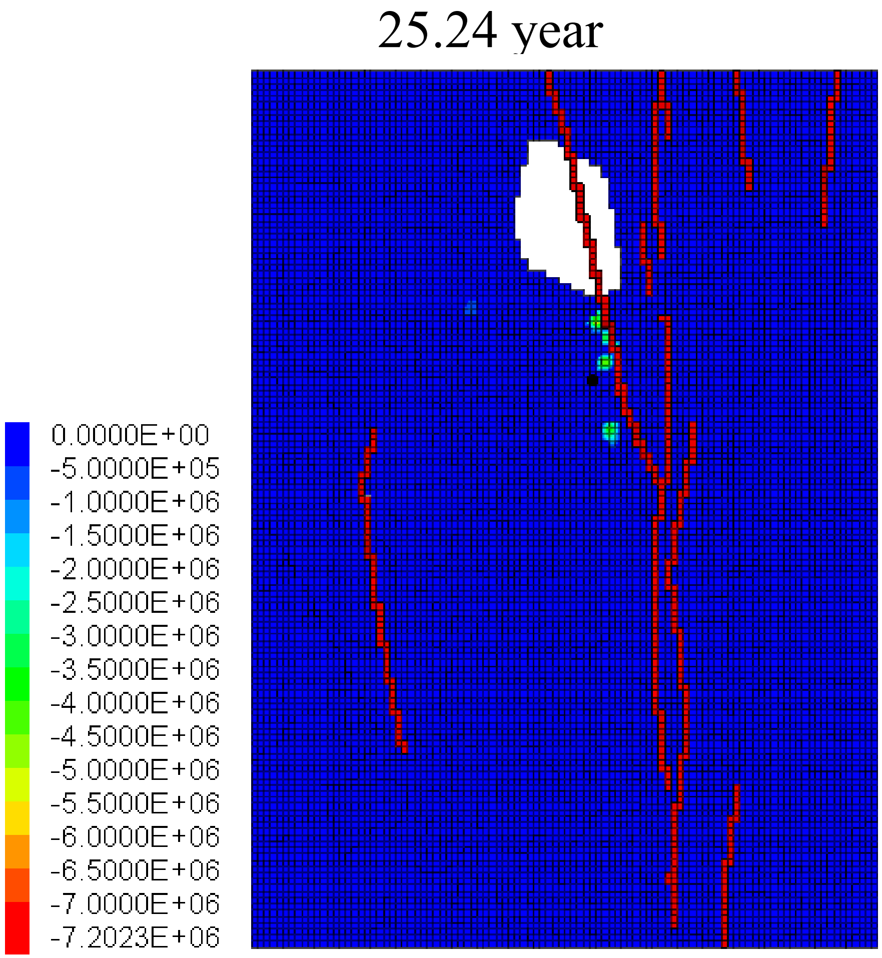


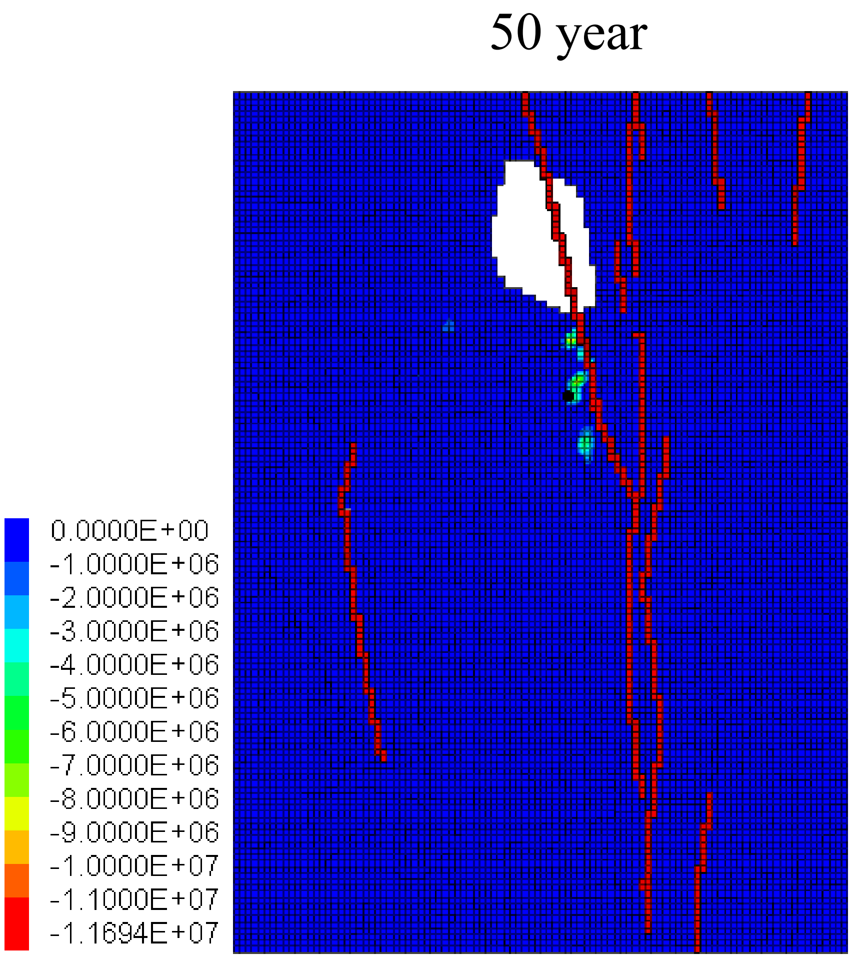

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# BIF-2



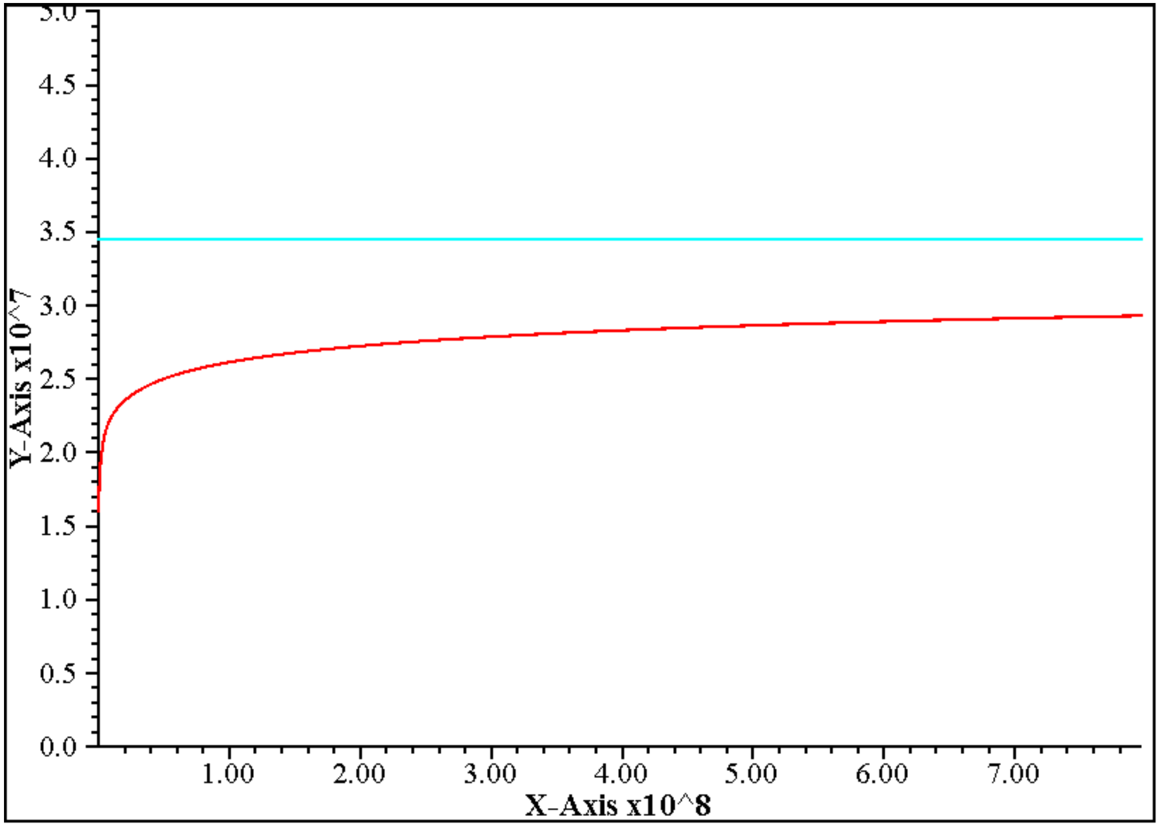

Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| BIF-2 | Wellhead pressure [MPa] | Maximum heave [cm] |
| --- | --- | --- |
| 25.24 year | 34.64 | 2.57 |
| 50 year | 36.38 | 5.42 |
| | | |

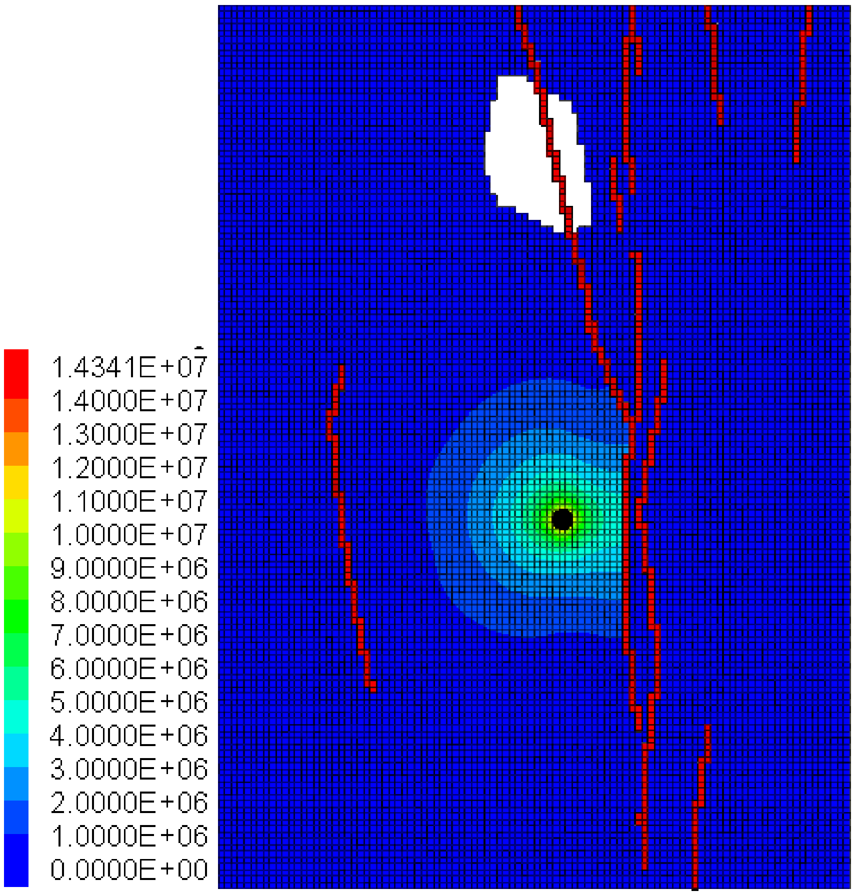
Slip predicted to occur,
based on elastic stress state in the model.

# Mesa-1

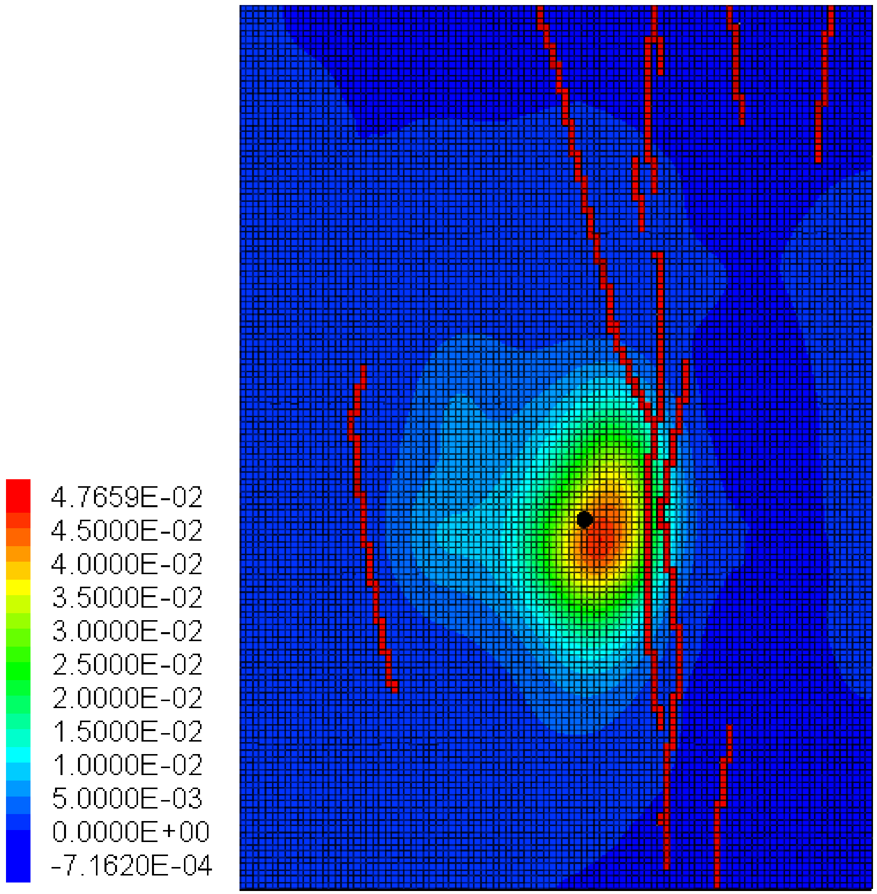



Wellhead pressure [Pa] vs time [sec]

# Mesa-1 – 25.24 year

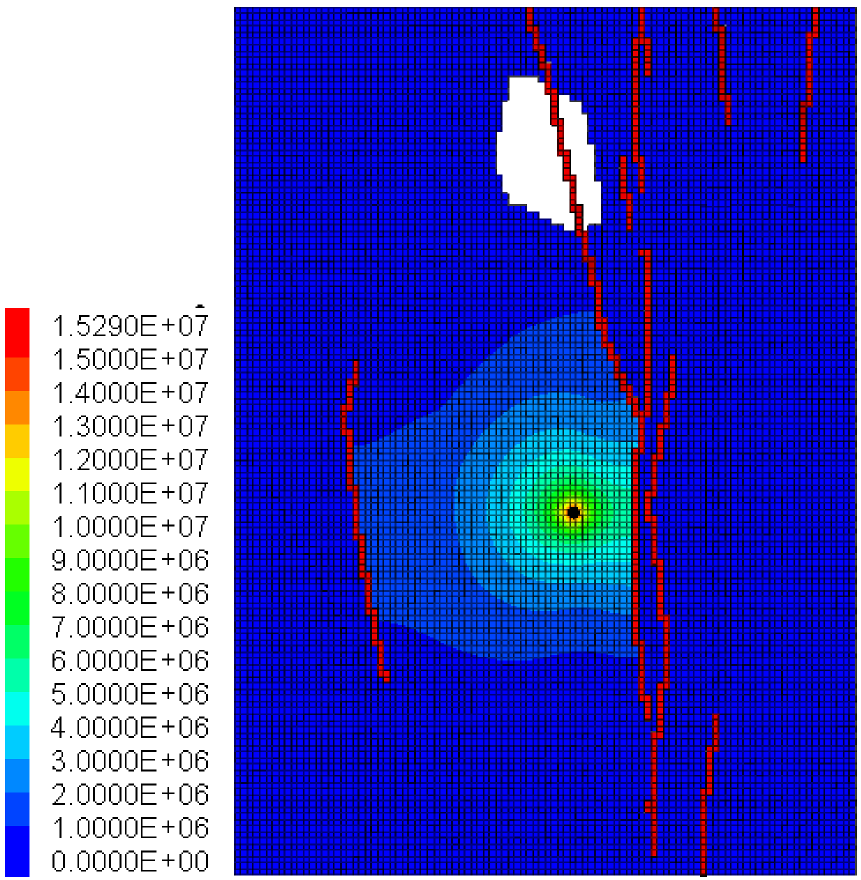



Excess pp contours [Pa] in Leadville

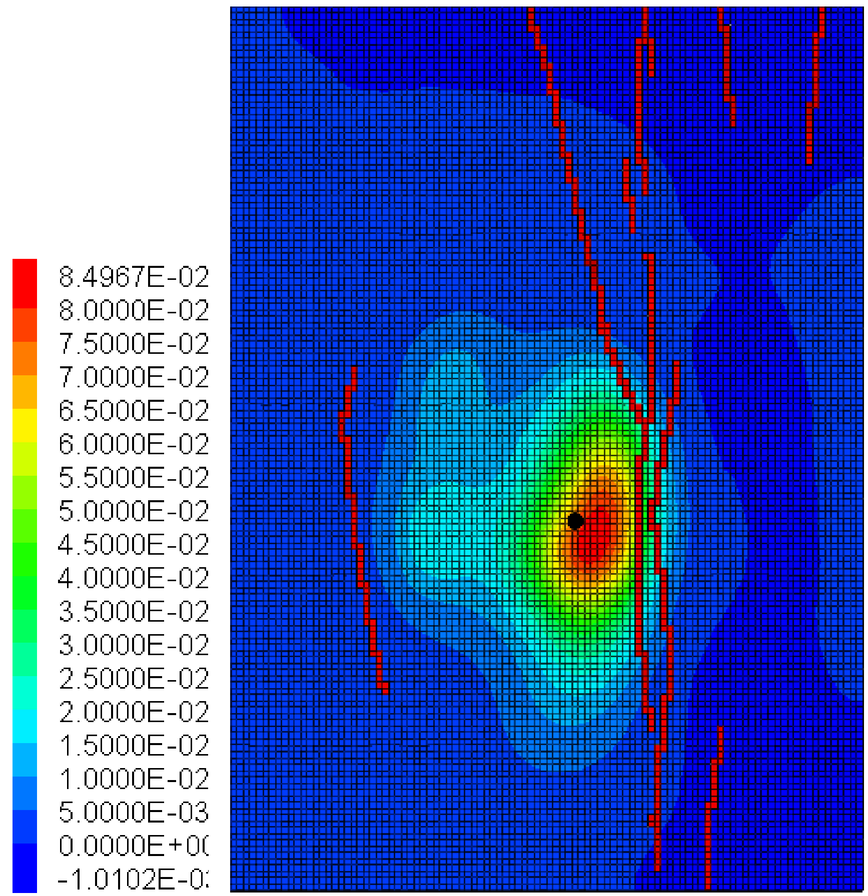



Contours of surface heave [m]

# Mesa-1 – 50 year




Excess pp contours [Pa] in Leadville

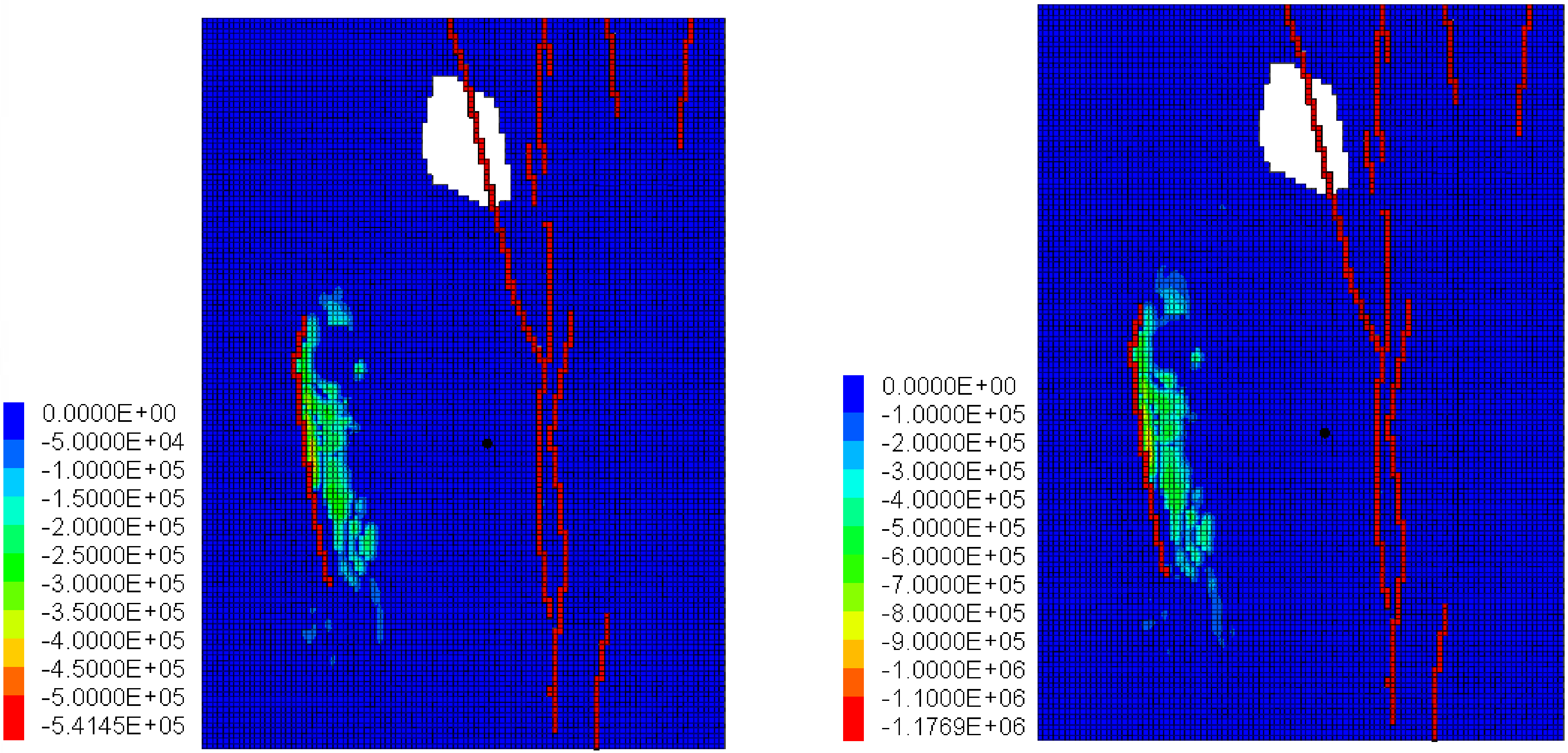



Contours of surface heave [m]

# Mesa-1

25.24 year

50 year



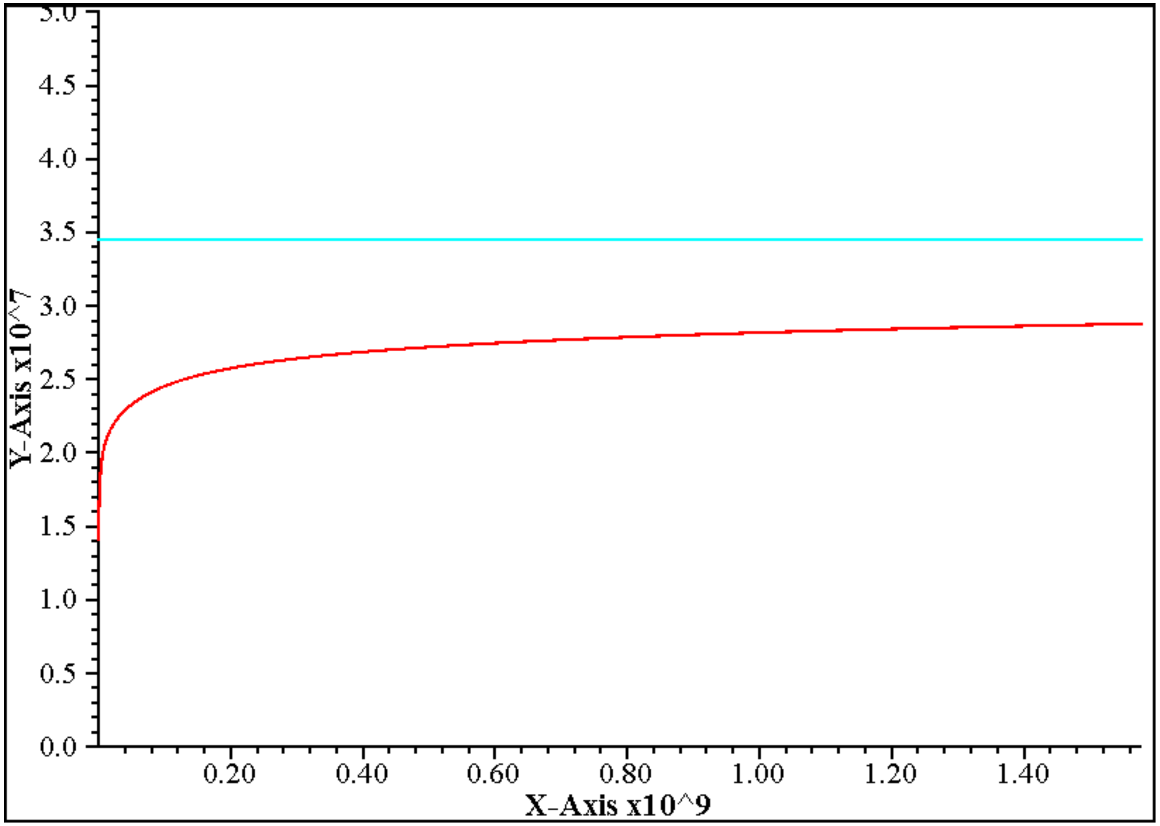

Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| Mesa-1 | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| 25.24 year | 29.31 | 4.77 |
| 50 year | 30.25 | 8.50 |
| | | |

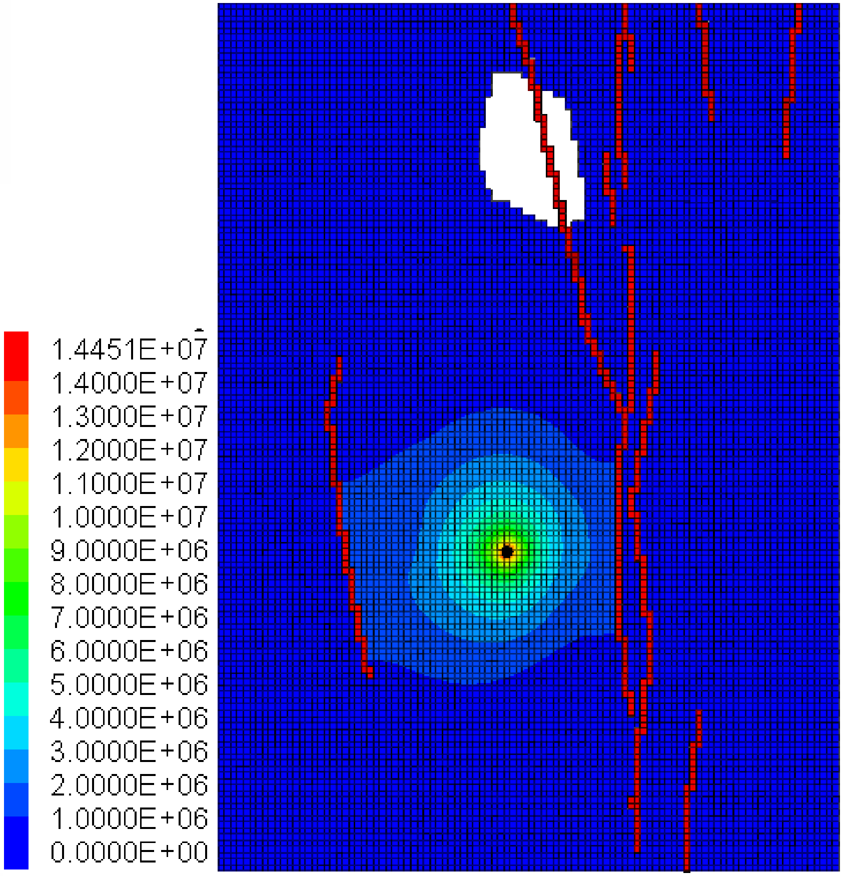
Slip is predicted to occur, but not in the vicinity of the well, based on elastic stress state in the model.

# Mesa-2

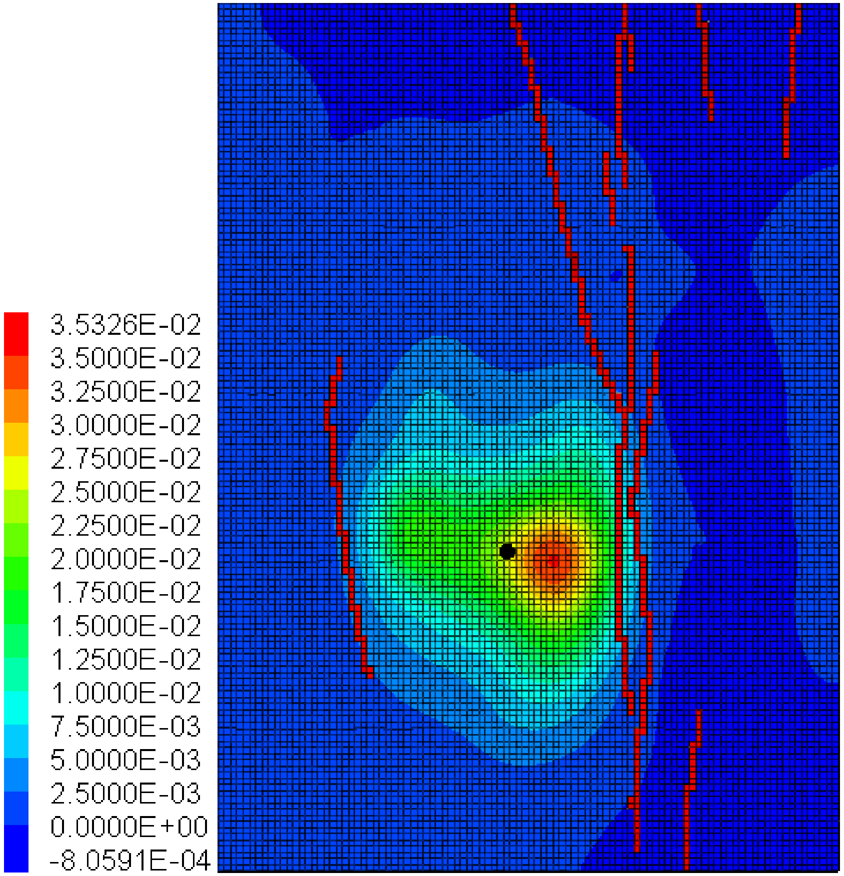



Wellhead pressure [Pa] vs time [sec]

# Mesa-2 – 25.24 year

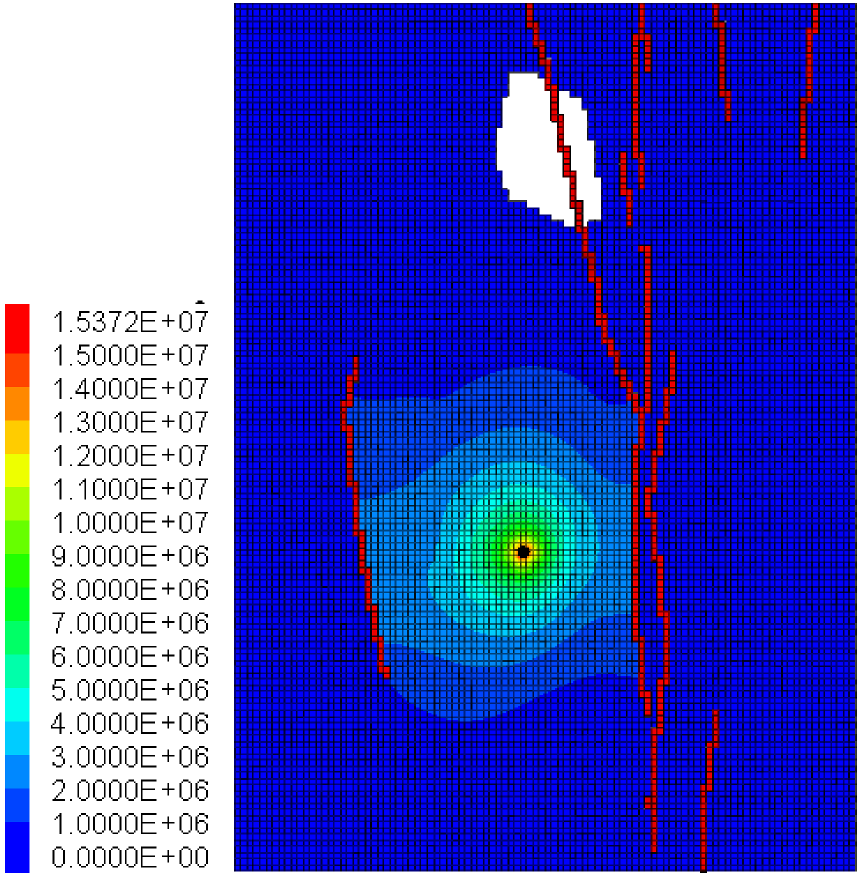



Excess pp contours [Pa] in Leadville

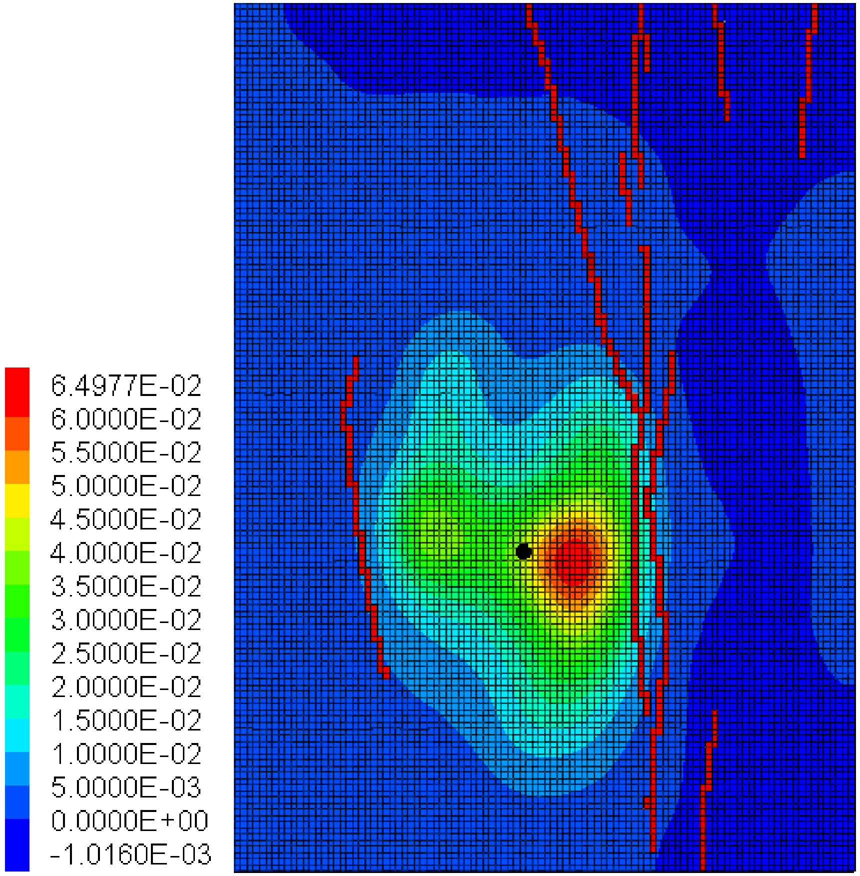



Contours of surface heave [m]

# Mesa-2 – 50 year




Excess pp contours [Pa] in Leadville

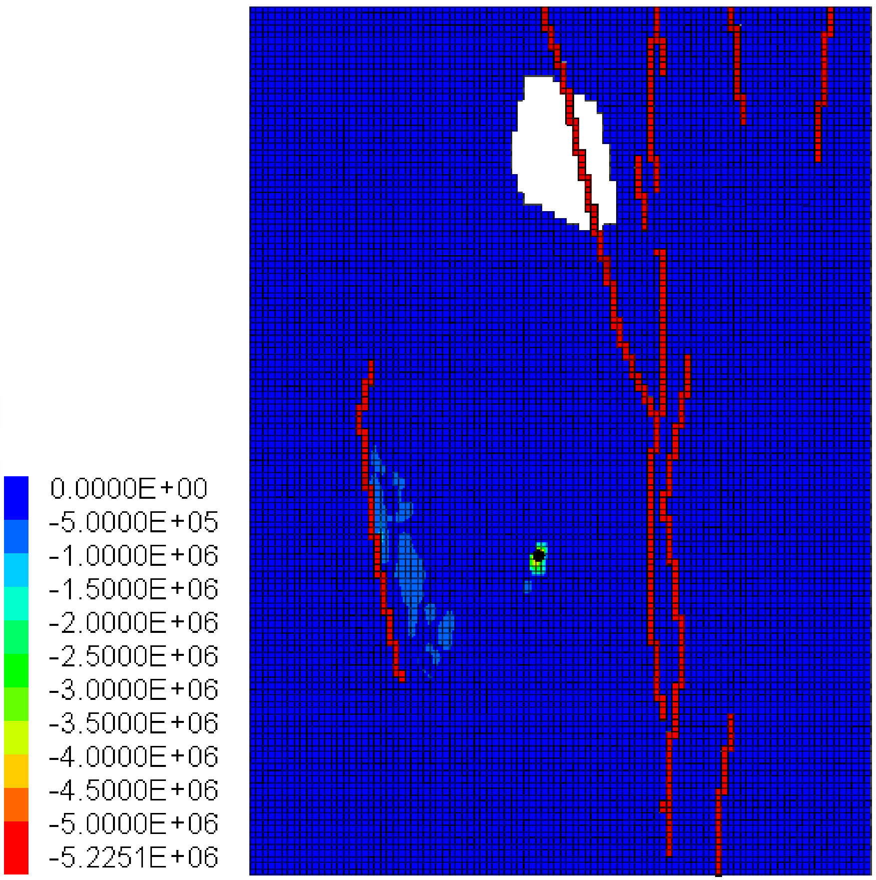



Contours of surface heave [m]

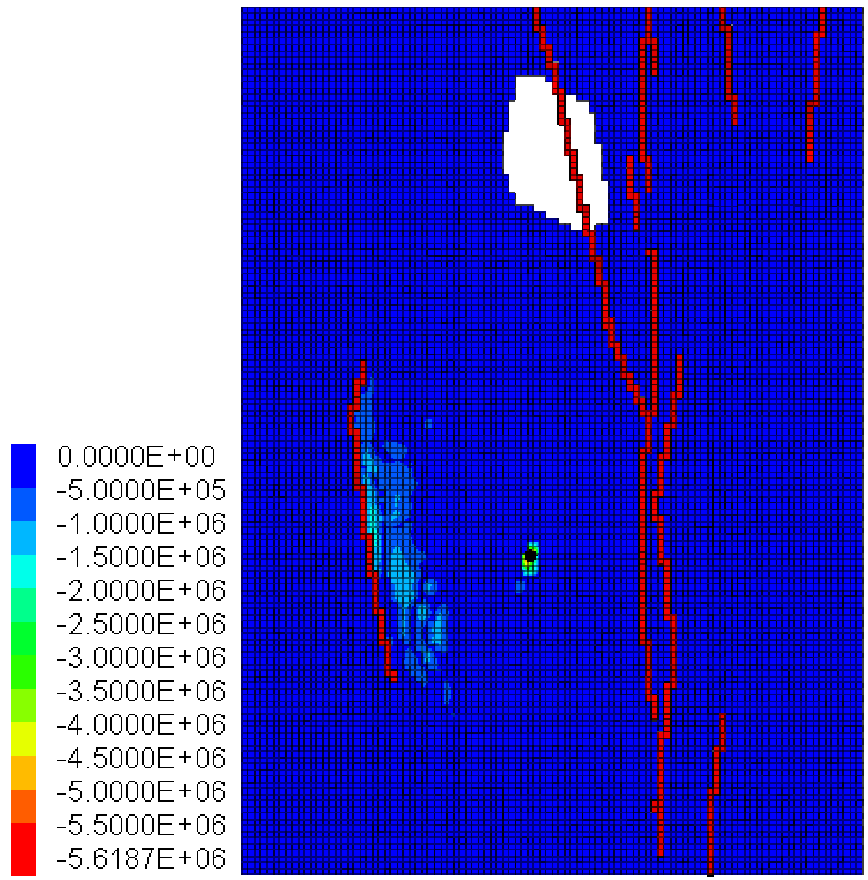
ITASCA

# Mesa-2

25.24 year




50 year



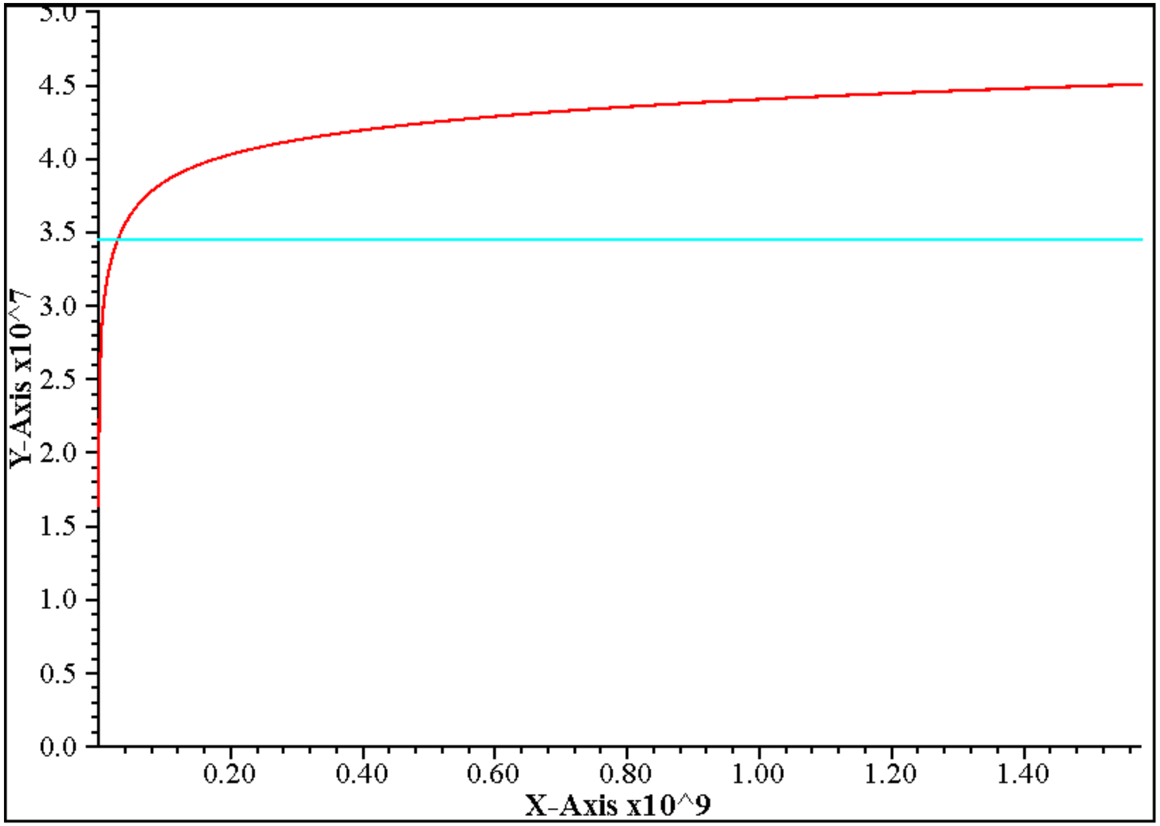

Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| Mesa-2 | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| 25.24 year | 27.86 | 3.53 |
| 50 year | 28.78 | 6.50 |
| | | |

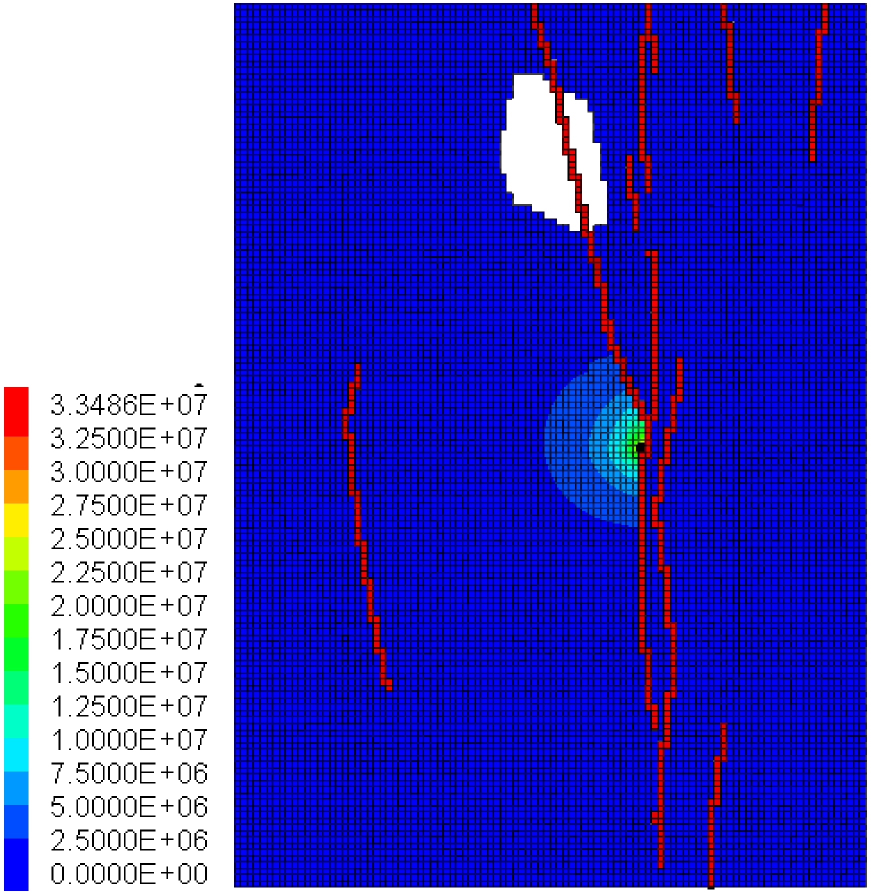
Slip predicted to occur,
based on elastic stress state in the model.

# Pinion Ridge

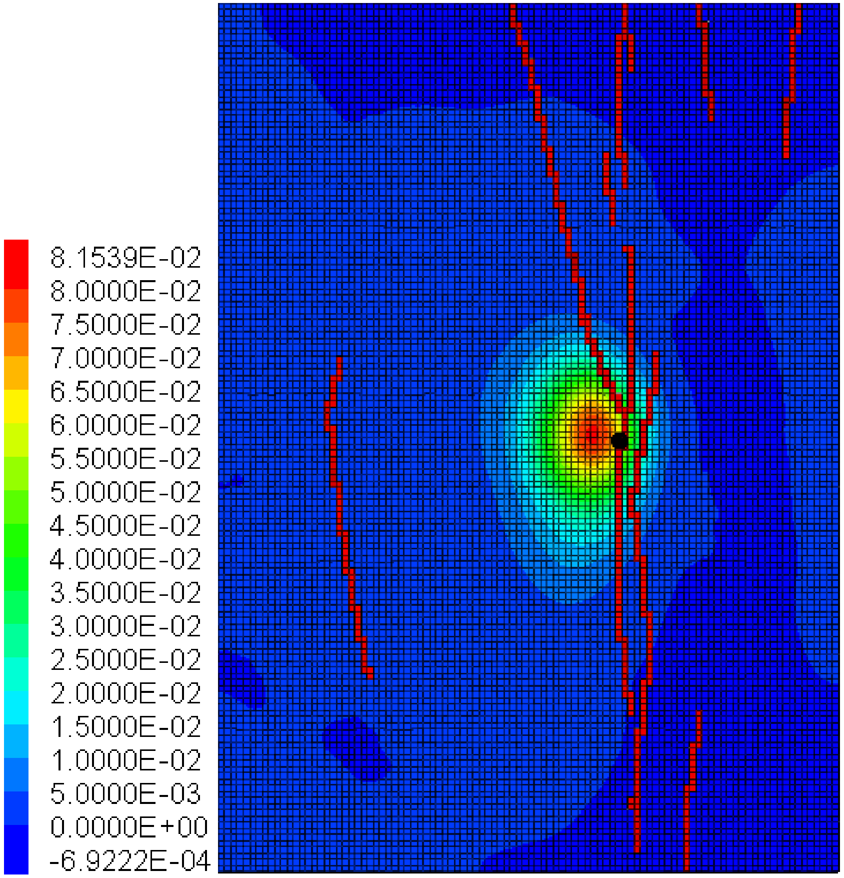



Wellhead pressure [Pa] vs time [sec]

# Pinion Ridge – 25.24 year

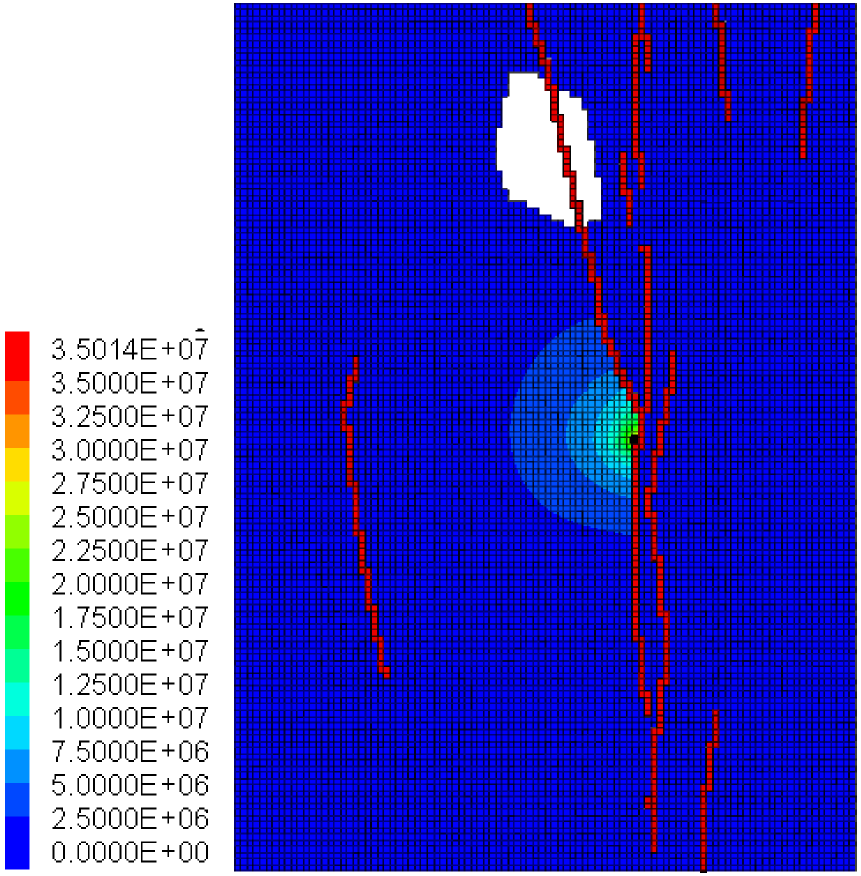



Excess pp contours [Pa] in Leadville

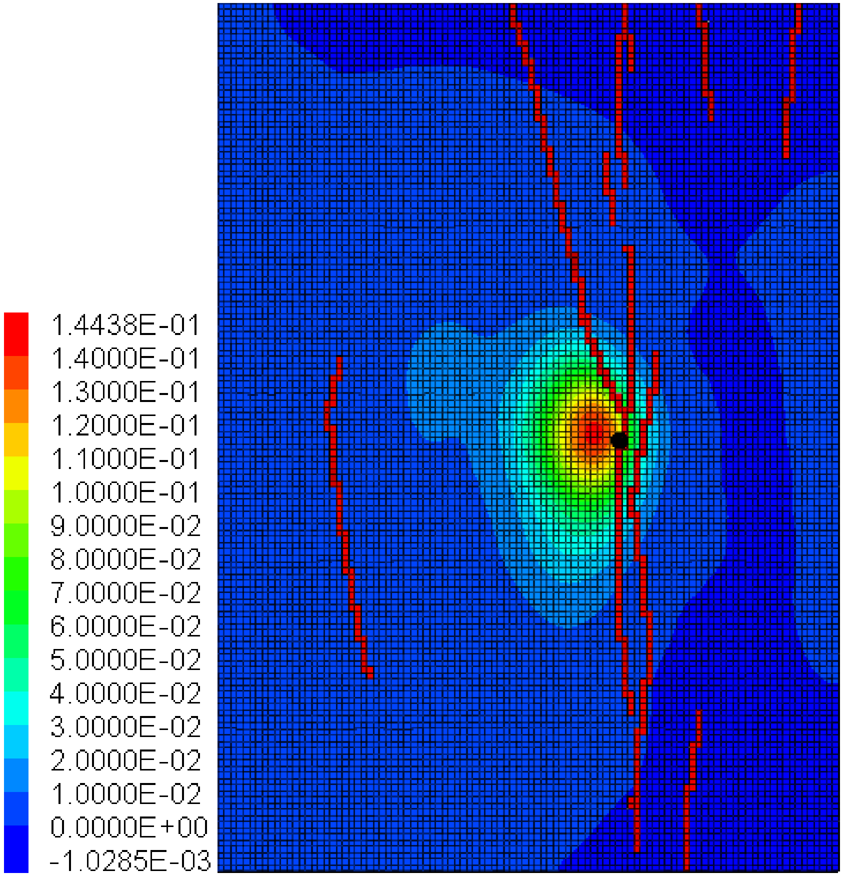



Contours of surface heave [m]

# Pinion Ridge – 50 year

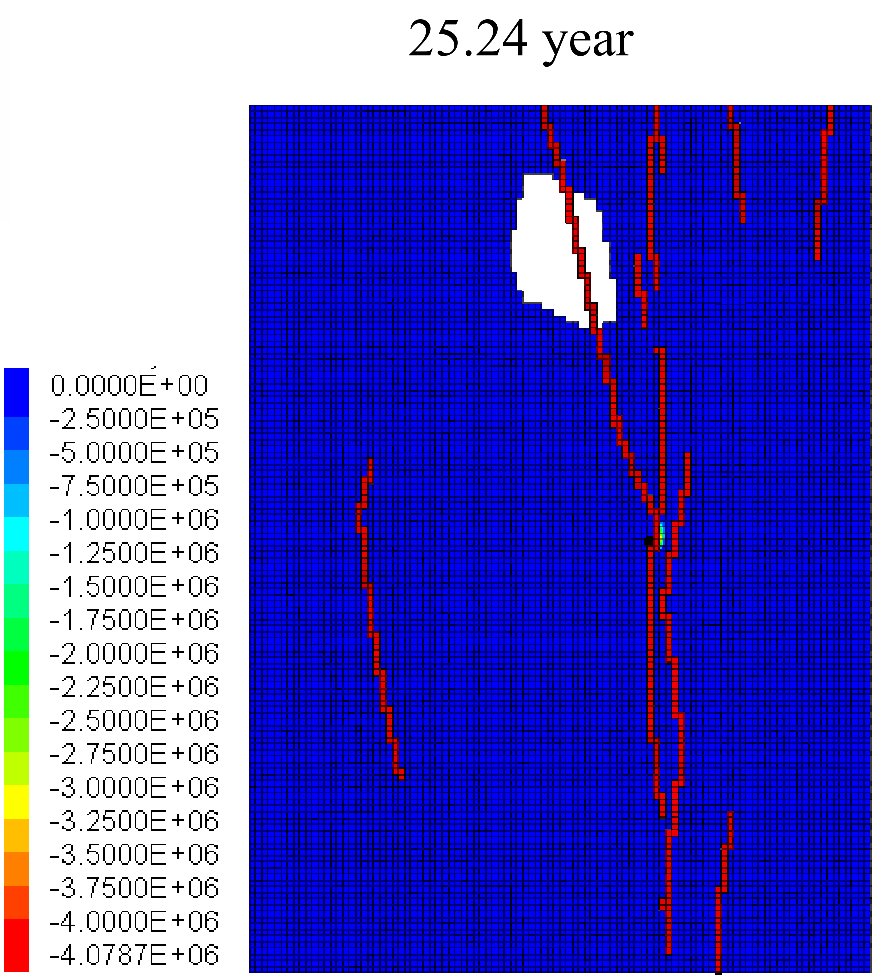


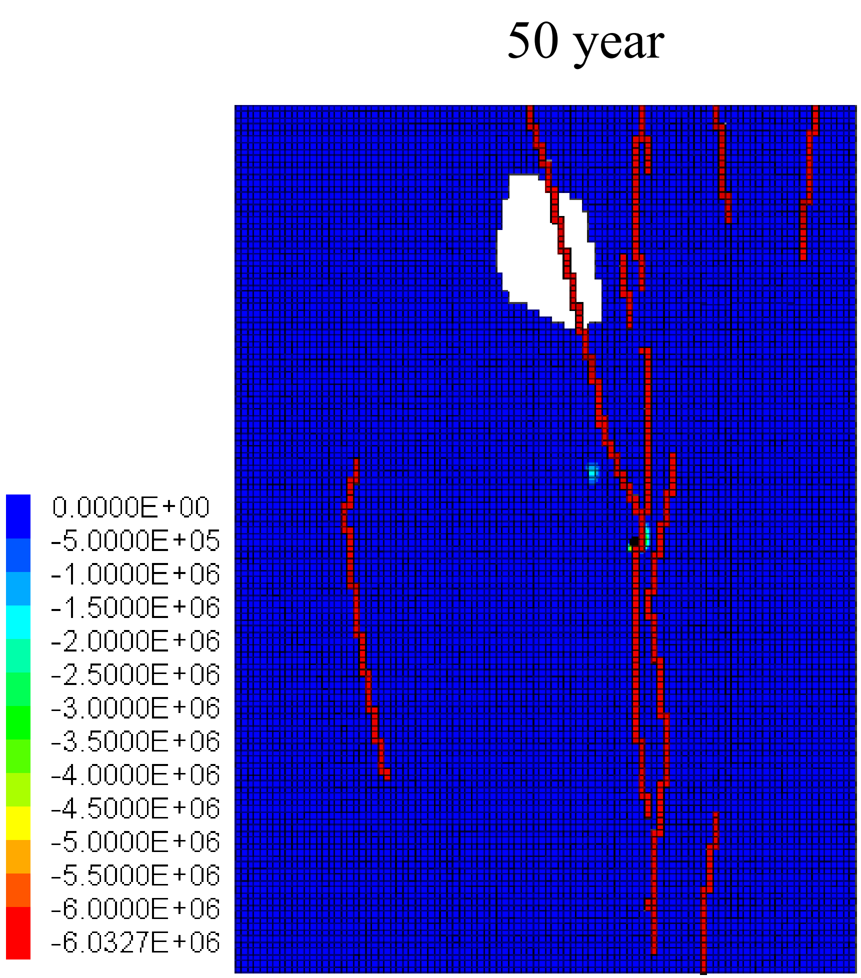

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# Pinion Ridge




Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| Pinion Ridge | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| 25.24 year | 43.53 | 8.15 |
| 50 year | 45.07 | 14.44 |
| | | |

Slip predicted to occur,
based on elastic stress state in the model.

# SUMMARY – HEAVE PREDICTION

# 25.24 year results

| Well | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| PVU-1 | 32.69 | 3.26 |
| BIF-1 | 47.52 | 2.35 |
| BIF-2 | 34.64 | 2.57 |
| Mesa-1 | 29.31 | 4.77 |
| Mesa-2 | 27.86 | 3.53 |
| Pinion Ridge | 43.53 | 8.15 |

# 50 year results

| Well | Wellhead pressure [MPa] | Maximum heave [cm] |
|---|---|---|
| PVU-1 | 34.85 | 7.72 |
| BIF-1 | 49.37 | 5.08 |
| BIF-2 | 36.38 | 5.42 |
| Mesa-1 | 30.25 | 8.50 |
| Mesa-2 | 28.78 | 6.50 |
| Pinion Ridge | 45.07 | 14.44 |

# SIMULATION RESULTS – $\alpha < 1$

# Biot coefficient

In the previous analyses, Biot coefficient was equal to 1.
However, for Sandstone and Limestone, the measured value is typically lower than 1.

For Sandstone in the Paradox Valley model, the Biot coefficient is assumed equal to the value documented for Ruhr sandstone (*):
alpha = 0.65
From the definition of Biot coefficient:

$$\alpha = 1 - K / K_s \quad \Longrightarrow \quad K_s = K / (1 - \alpha)$$

We assume that $K_s$ is the same for Sandstone and Limestone.
Sandstone : K ~ 50 Gpa → $K_s$=50/(1-0.65) GPa
Leadville limestone: K ~ 65 Gpa → $\alpha$ = 1-(1-0.65)65/50~0.55

(*) Detournay, E. and A. Cheng, 1993

# Biot coefficient values

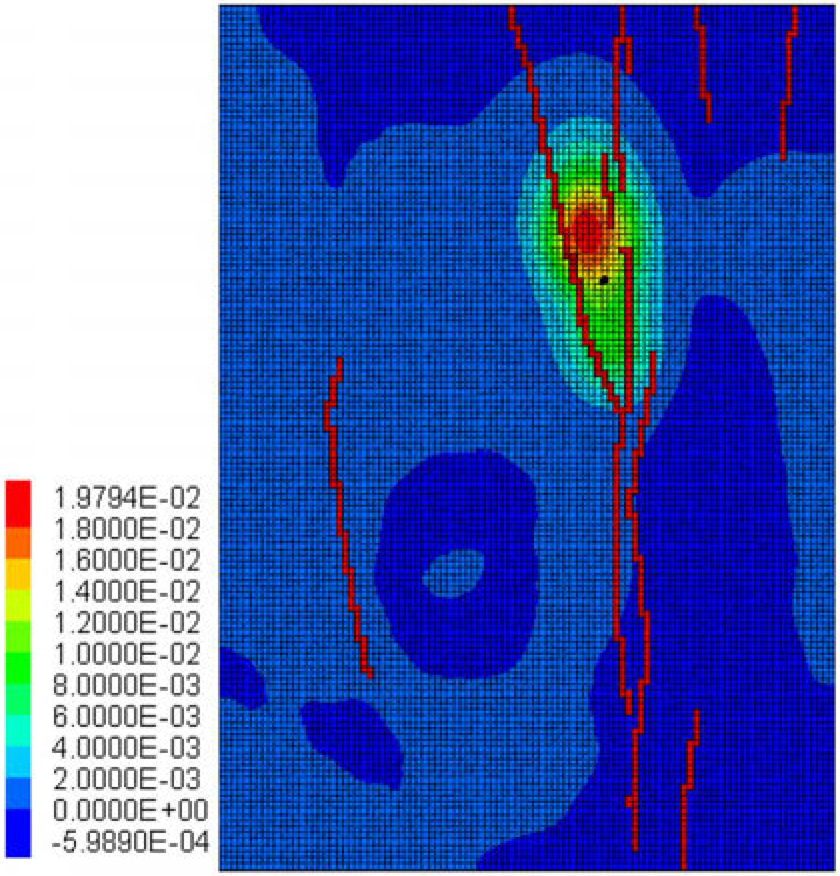
For the simulations, we use:

$\alpha$ = 0.65 for Upper, Welds, Sedimentary, Upper-Precambrian

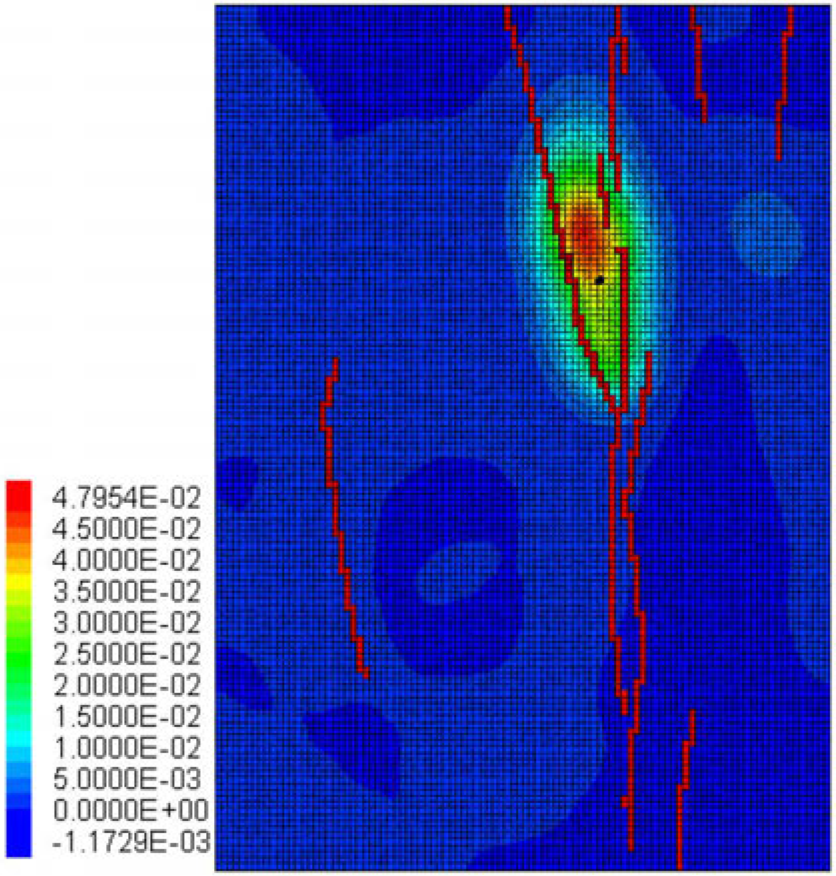
$\alpha$ = 0.55 for Leadville

(Salt and Lower-Precambrian are impermeable)

# PVU-1 – $\alpha < 1$

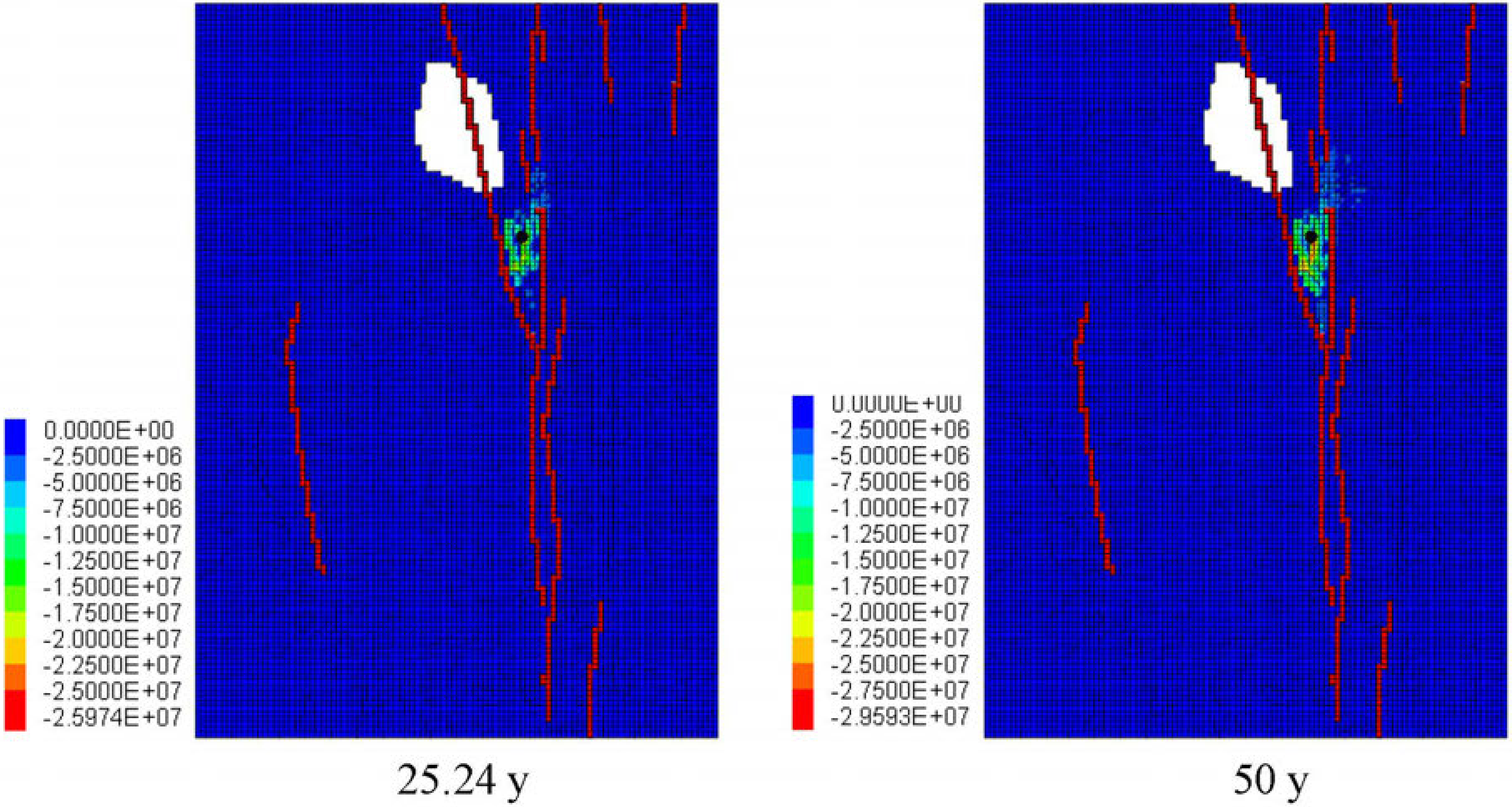



Contours of surface heave [m] – 25.24 y




Contours of surface heave [m] – 50 y

# PVU-1 – $\alpha < 1$




Negative contours of $\left(F - F_{ini}\right)$[Pa] in Leadville

# Numerical predictions

| PVU-1 | Maximum heave [cm] – alpha=1 | Maximum heave [cm] – alpha < 1 |
|---|---|---|
| 25.24 year | 3.26 | 1.98 |
| 50 year | 7.72 | 4.80 |
| | | |

Slip predicted to occur,
based on elastic stress state in the model.

# THANK YOU!

# Paradox Valley Project

## Fluid-Mechanical injection simulations with the Paradox Valley model

March 6, 2017

Christine Detournay
Itasca Consulting Group, Inc.

# Framework - a

At the last meeting (February 21, 2017), the results of fluid-mechanical injection simulations were reported for 6 well locations using the calibrated Paradox Valley model.

For the initial stress state:

- The maximum horizontal effective stress was assumed equal to the vertical effective stress
- The minimum horizontal effective stress was assumed equal to 0.32 times the vertical effective stress

The value $K_0 = (1 - \sin\phi)/(1 + \sin\phi) = 0.32$ corresponds to a state of incipient failure, consistent with a Coulomb criterion with no cohesion and a friction angle of 31 degree (USBR data).

However, the maximum horizontal (compressive) stress direction was taken parallel to the valley axis (this is different from USBR specification)

# Framework - b

The induced surface heave was evaluated and a simplified approach (based on elastic stress state) was used to predict possible locations of increased potential for slip in the model.

The model results for potential slip induced by injection in the Leadville were rather difficult to interpret because:

1. With the Coulomb criterion and strength properties used, slip was predicted to already occur in the leadville at the in-situ state in the model

2. The chosen Yield indicator (difference in yield function value between current and in-situ stress state) was dimensional

# Updates

The following changes were made to produce results for the current progress report:

1. To compute the initial stress state, a Mohr-Coulomb constitutive model with zero cohesion, zero dilation, and a friction angle of 31 degree is assigned to the Leadville. The model is reset to elastic after that.

2. The direction of maximum (compressive) effective stress *in-situ* is rotated 25.2 degree anticlockwise from the Paradox Valley axis, oriented North in the model (USBR data)

3. A Coulomb yield criterion with zero cohesion, and a friction angle of 31 degree is considered to evaluate the potential for slip induced by injection in the Leadville

4. The dimensionless yield index (based on elastic stress state) is taken as the Factor of Safety with respect to fluid pressure.

# FoS Index

The factor of safety with respect to fluid pressure is introduced as:

$$FoS = \frac{p_{cr}}{p}$$

where $p_{cr}$ is the critical fluid pressure at the onset of slip, based on a Coulomb criterion, and $p$ is the fluid pressure under current conditions.

The Coulomb criterion (negative compressive stress convention) is:

$$(\sigma_1 + p_{cr}) - (\sigma_3 + p_{cr}) N_\phi + 2c\sqrt{N_\phi} = 0$$

$$N_\phi = \frac{1+\sin\phi}{1-\sin\phi} = \left[\sqrt{1+\tan^2\phi} + \tan\phi\right]^2 = \tan^2\left(\frac{\pi}{4} + \frac{\phi}{2}\right)$$

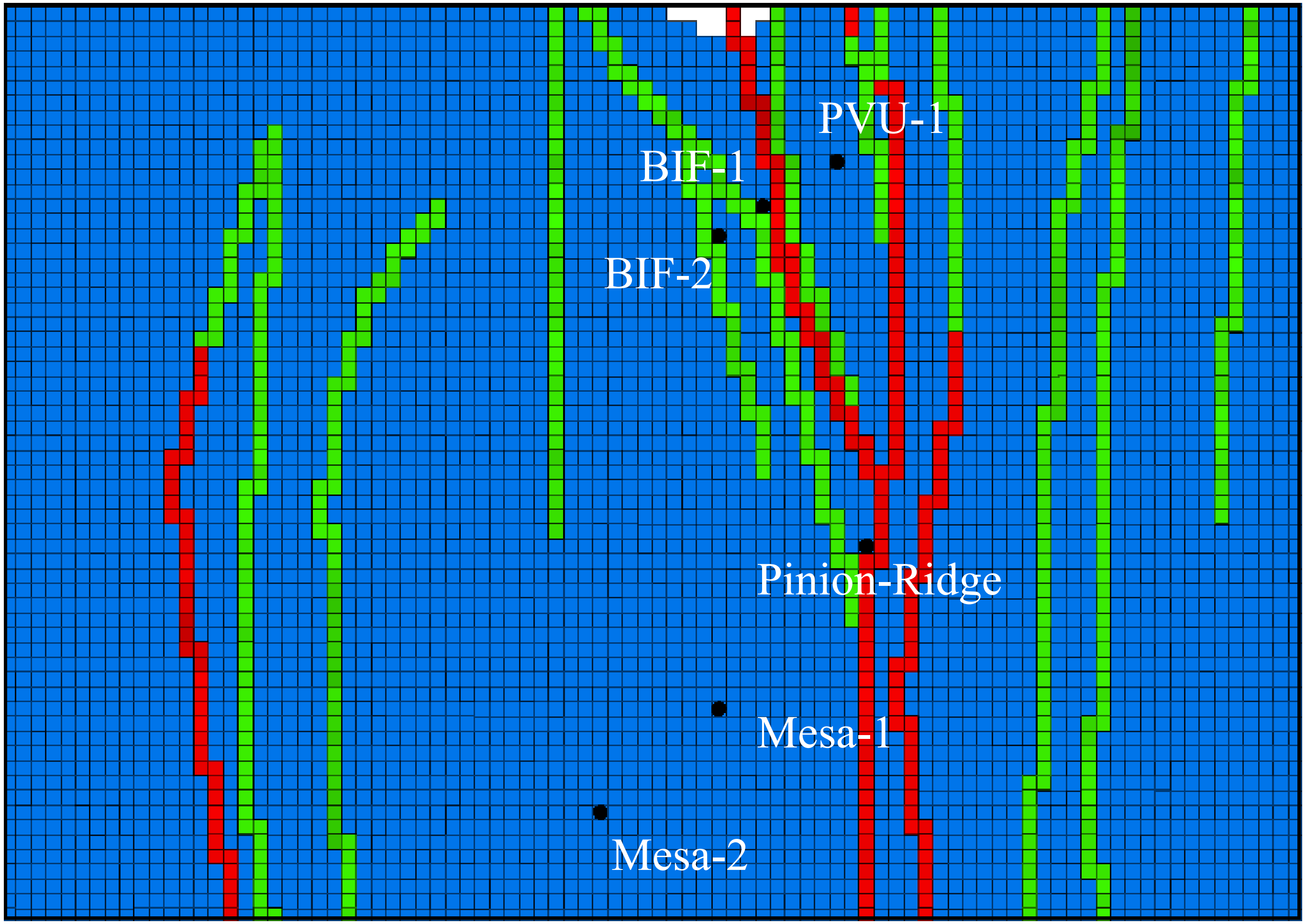
Hence:

$$FoS = -\frac{\sigma_1 - \sigma_3 N_\phi + 2c\sqrt{N_\phi}}{(1-N_\phi)(p_{ini} + p_{excess})}$$

Yield is predicted to occur (based on an elastic stress distribution) if :

$$FoS \le 1$$

# *FLAC3D* Wells and Faults location




Impermeable Faults shown in red

# Modeling technique

The fluid mechanical simulations are carried out as follows:

1. The Biot elastic framework is assumed for the simulations

2. The initial stress state is established, assuming elastic material model, except for the Leadville which uses a frictional Mohr-Coulomb constitutive law (31 degree friction).

3. The fluid pressures induced by the brine injection are computed.

4. The elastic deformations induced by the fluid pressure changes are evaluated, and the new equilibrium stress state is calculated.

5. Total elastic effective stresses, and total water pressures (assuming initial horizontal water table) are used locally to evaluate the value of the FOS index, and to estimate the potential for slip.

# Initial stress state - a

The initial stress state is calculated using the following procedure:

1. An elastic constitutive model and the USBR elastic properties for the Upper, Welds, Salt, Leadville, Sedimentary, Upper Precambrian, and Lower Precambrian are assigned in the model

2. The mechanical boundary conditions are prescribed (fixity at the base, roller boundary along the lateral sides), gravity is specified. A low shear modulus is specified for the Salt, (to prevent build-up of shear stresses) and the model is cycled to equilibrium

3. A Mohr-Coulomb constitutive model with zero cohesion and a friction angle of 31 degree is assigned to the Leadville

# Initial stress state - b

4. An in-situ water table is assumed that matches the 42.3 MPa in-situ pressure at the injection location in PVU-1 (USBR data).
   The horizontal effective stresses are computed, based on the vertical effective stress in the model, and the USBR specifications (see value on Slide 2, and direction on Slide 4).
   Total horizontal stresses are assigned to all zones in the model, except in the Salt, consistent with the effective stresses and fluid pressures. The model is cycled to equilibrium.

5. An elastic model and associated properties are assigned to the Leadville, the realistic salt shear modulus is specified, and the displacements are reset to zero.

# Yield index limitation

The Factor of Safety with respect to fluid pressure,
if less than 1, is taken as an indicator of possible yield
in the model.

While the index, based on elastic stresses, is reliable
to detect the *onset* of yield, the prediction of the extent of
yielding region in the model may be inaccurate because
elasto-plastic readjustments would modify the stress-state
in the model and make the indicator values unreliable over
the whole region initially detected as yielding.

# Biot Parameters

It is assumed that the diffusivity is a (measured) field quantity in the simulations: the same value is used independent of the value of Biot coefficient, $\alpha$ .

This implies that the Specific storage remains unchanged. Thus the numerical fluid pressure predictions are the same, independent of the assumed value of Biot coefficient.

Note that a reduction in Biot coefficient is expected to produce a reduction in maximum surface heave in the elastic simulations.

We report the simulation results obtained using alpha=1 for the 6 wells. Results obtained using more realistic values for alpha are also reported.

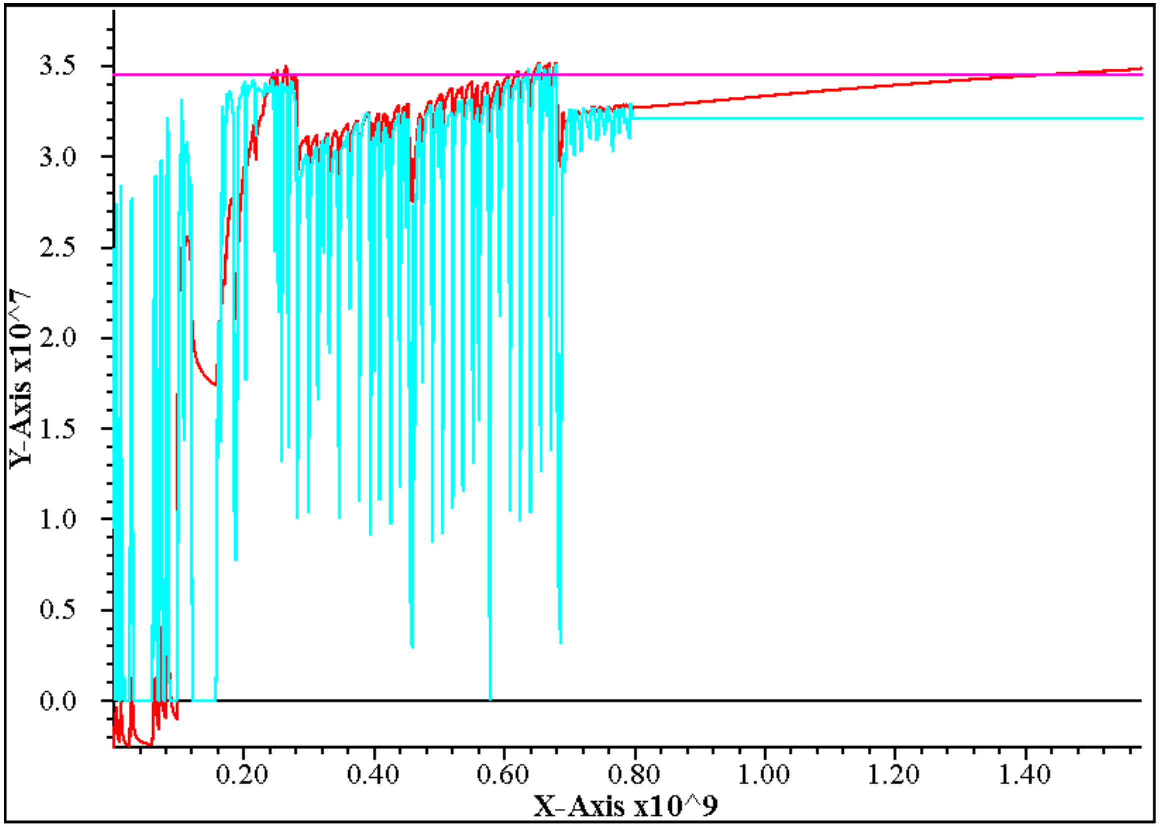
# Note

The excess fluid pressure and FoS values on the plots are
the zone values: they do not reflect the well pressure
correction. Also, the horizontal zone size in the model is 400mx400m.
Thus, potential slip failure in the vicinity of the well is not
captured at the scale of the discretization used in the model.

The simulation results for the different cases investigated
in this progress report are presented at the same scale for
the same alpha coefficient.
However, the scales are different for the two sets of alpha values.

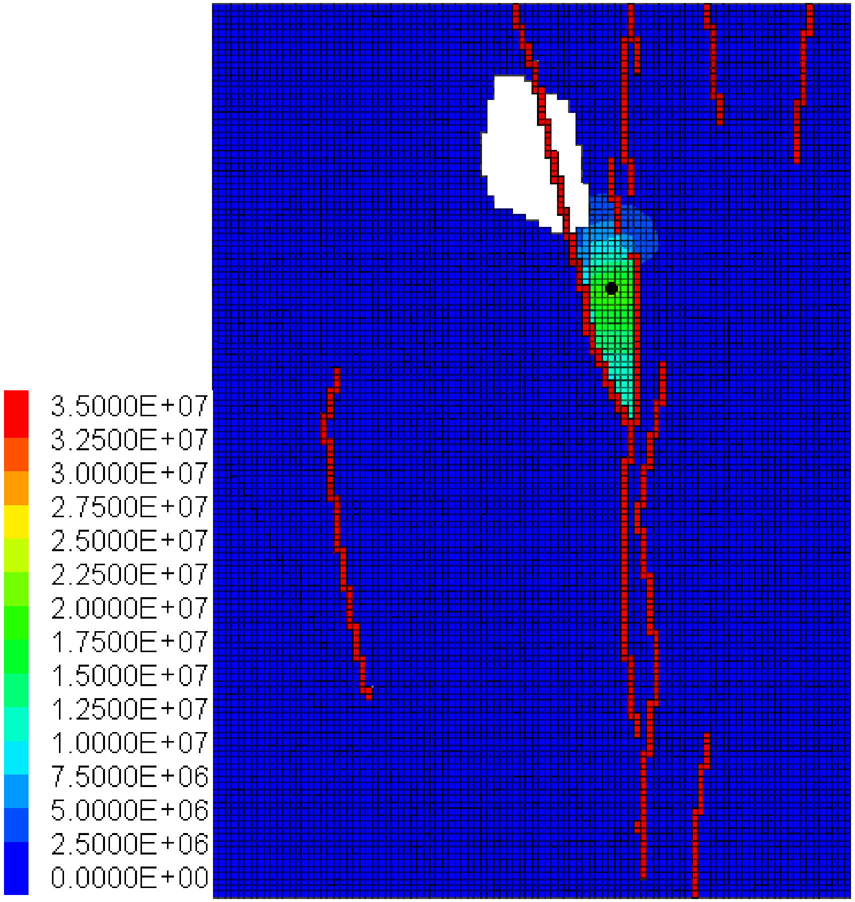
# SIMULATION RESULTS – $\alpha = 1$

# PVU-1

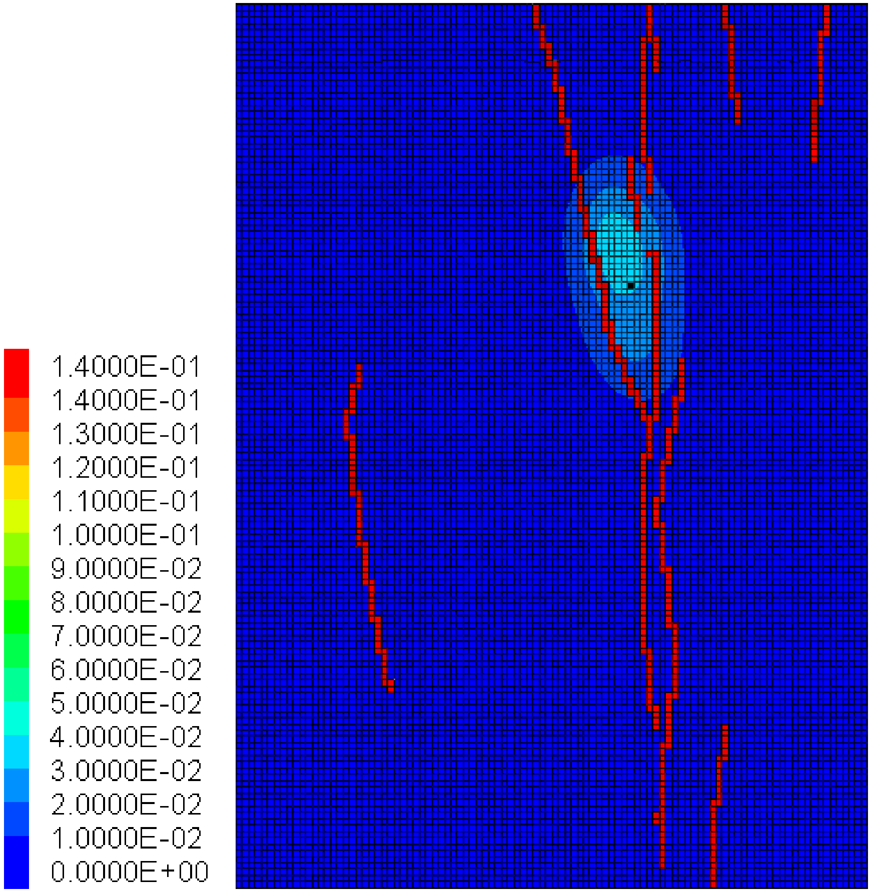



Wellhead pressure [Pa] vs time [sec]

# PVU-1 – 25.24 year

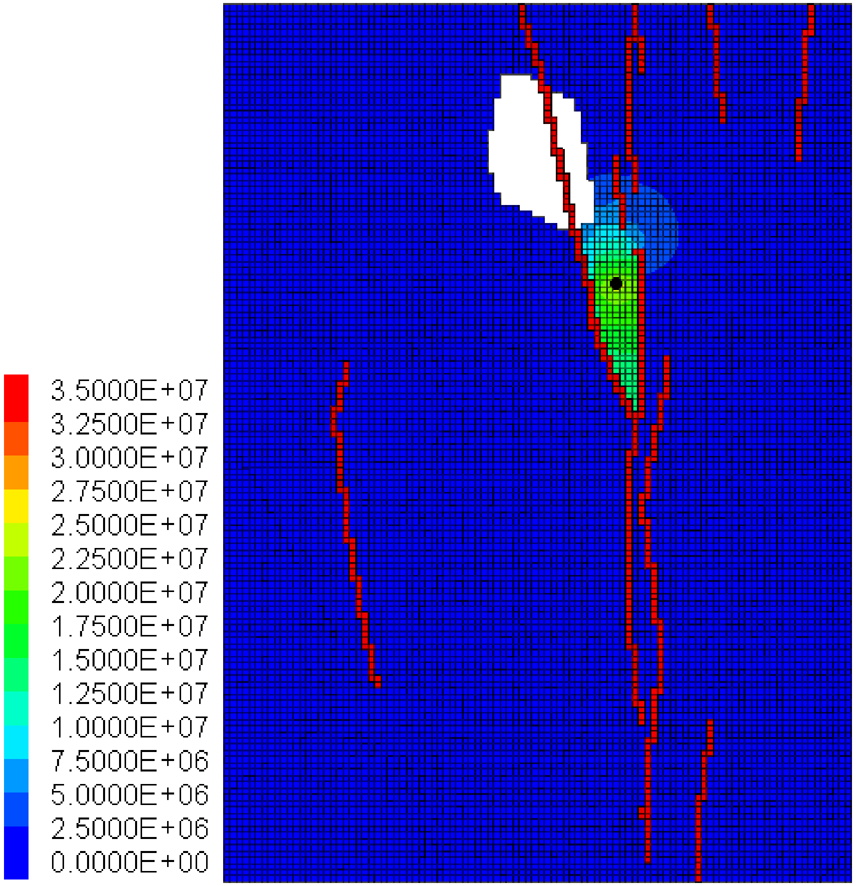



Excess pp contours [Pa] in Leadville

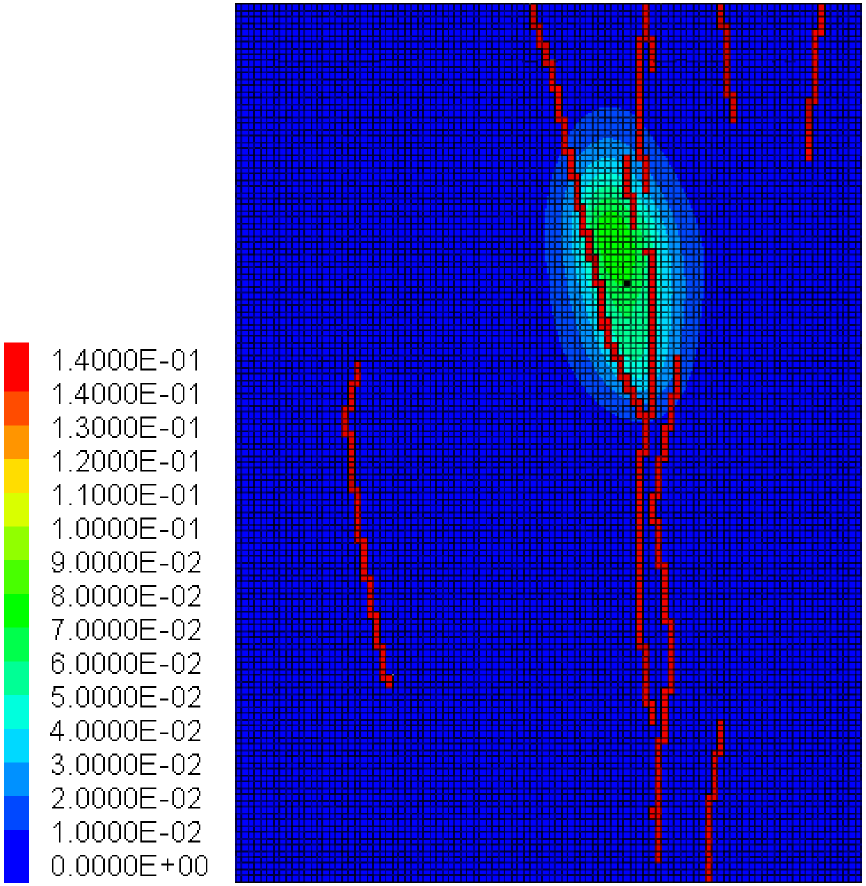



Contours of surface heave [m]

# PVU-1 – 50 year



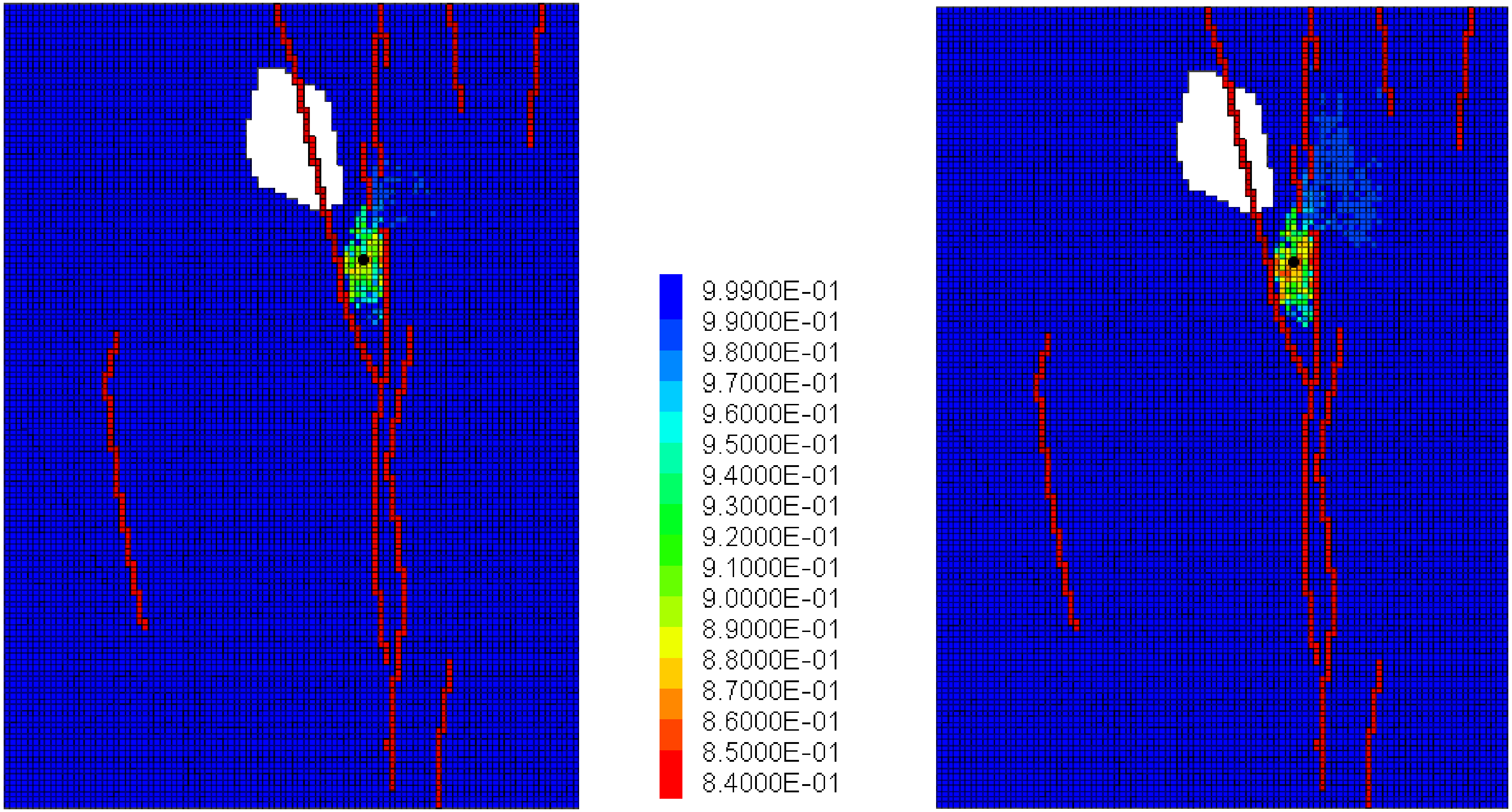

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# PVU-1 – FoS Index

**25.24 year**: FoS > 0.860 **50 year**: FoS > 0.845



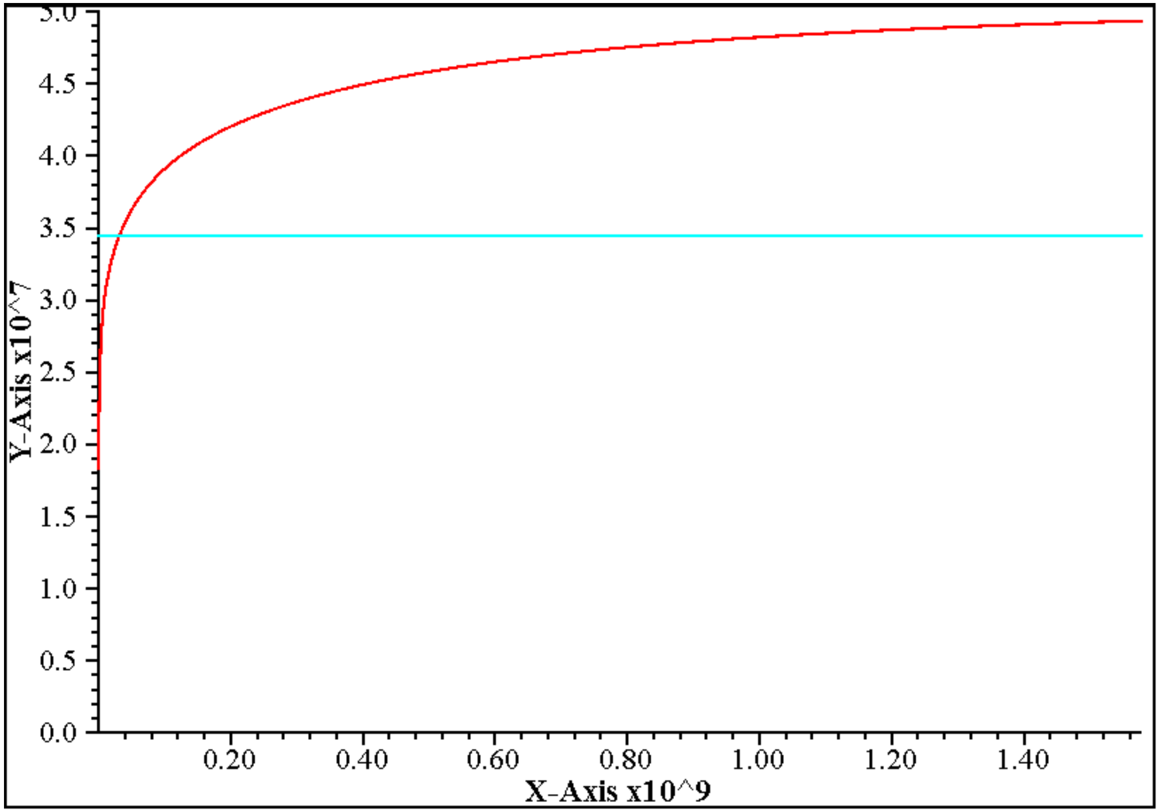

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| PVU-1 | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 32.69 | 3.49 | 0.860 |
| 50 year | 34.85 | 7.89 | 0.845 |
| | | | |

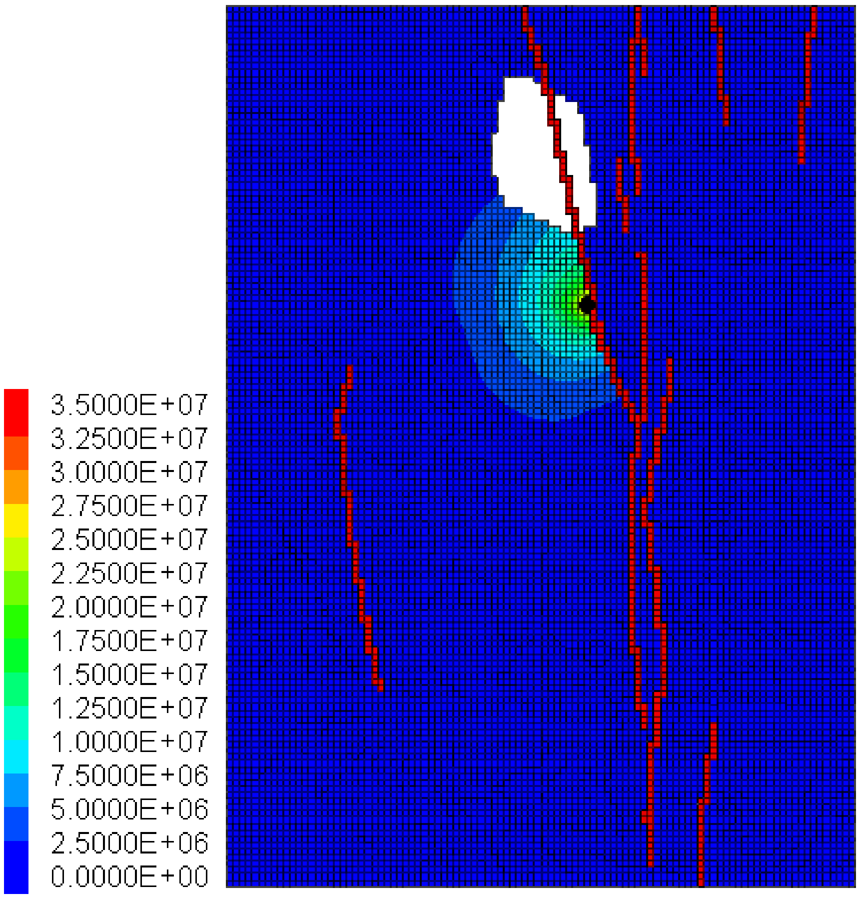
Slip is predicted to occur,
based on elastic stress state in the model.

# BIF-1

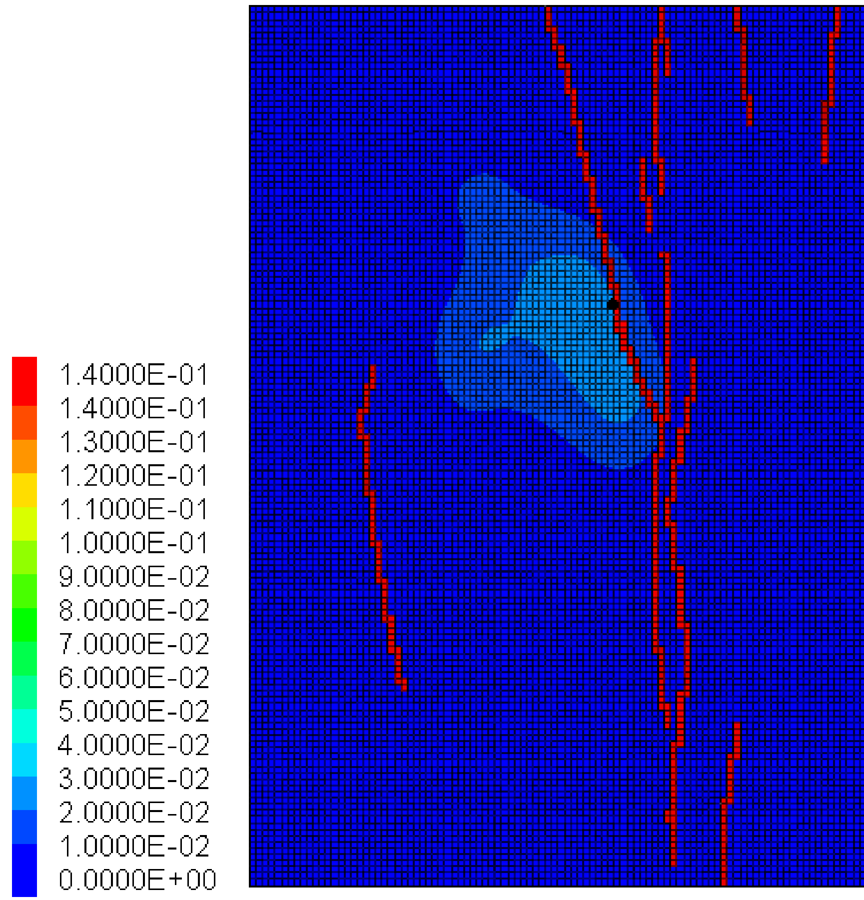



Wellhead pressure [Pa] vs time [sec]

# BIF-1 – 25.24 year

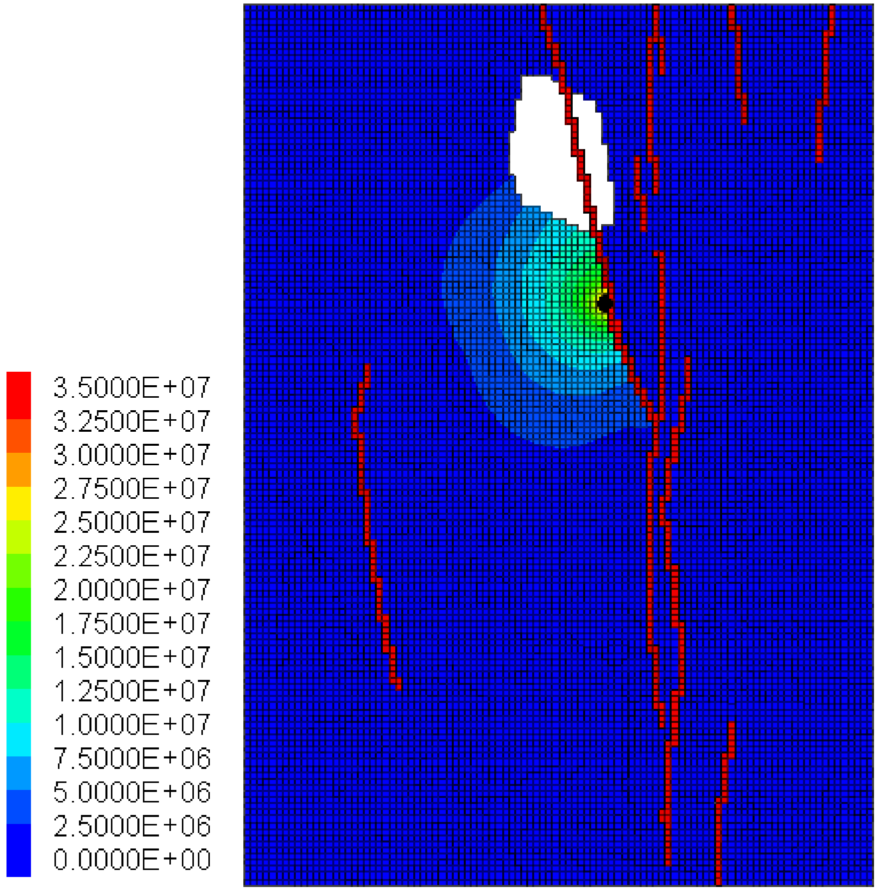



Excess pp contours [Pa] in Leadville

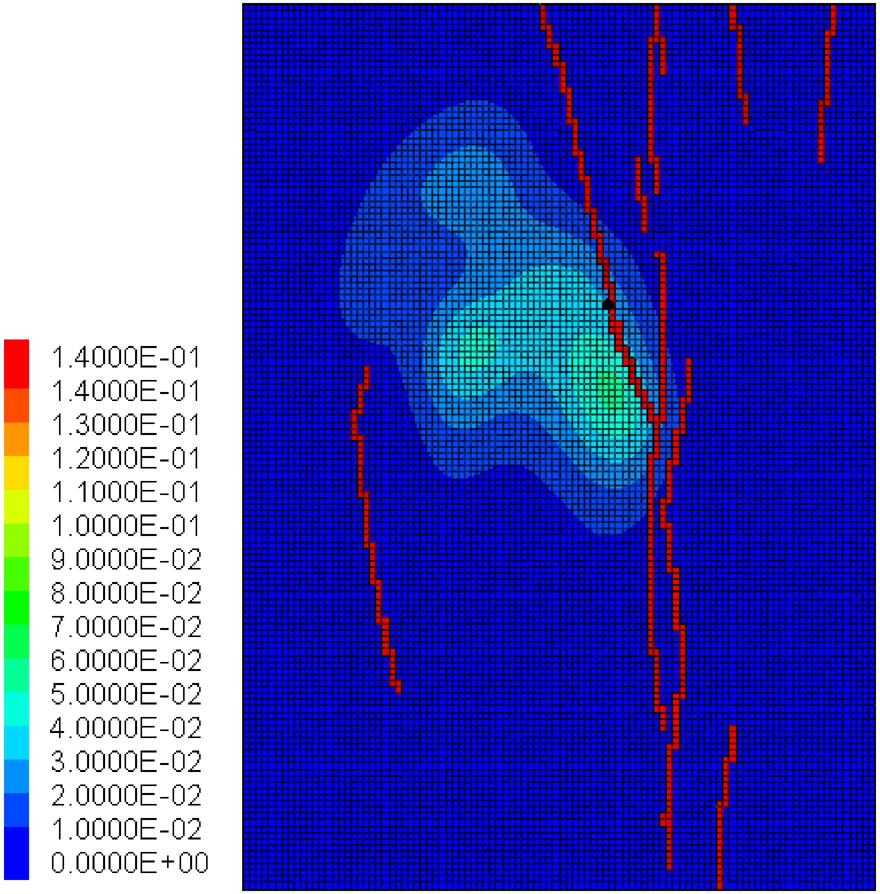



Contours of surface heave [m]

# BIF-1 – 50 year



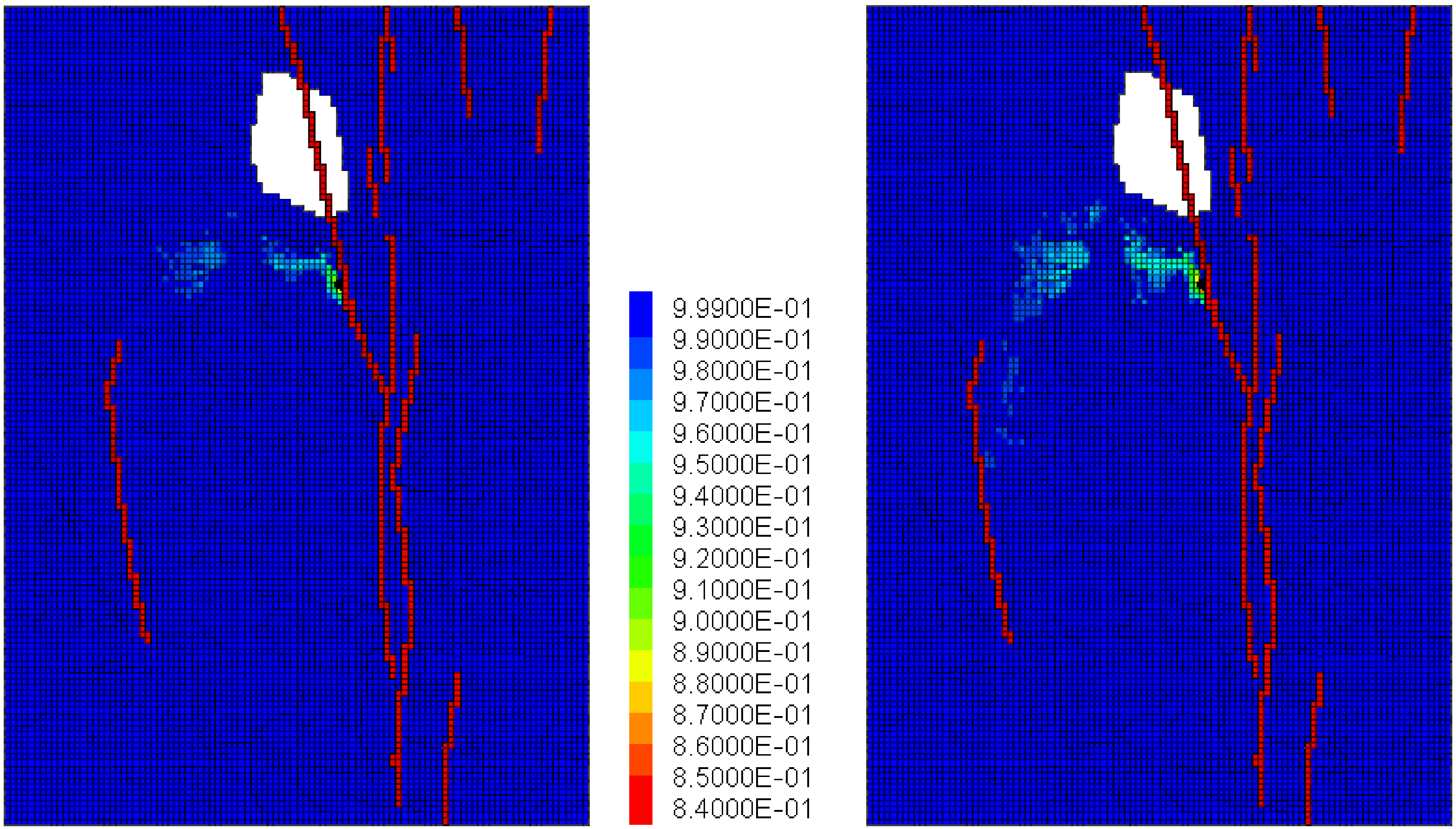

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# BIF-1 – FoS Index

**25.24 year**: FoS > 0.882 **50 year**: FoS > 0.866



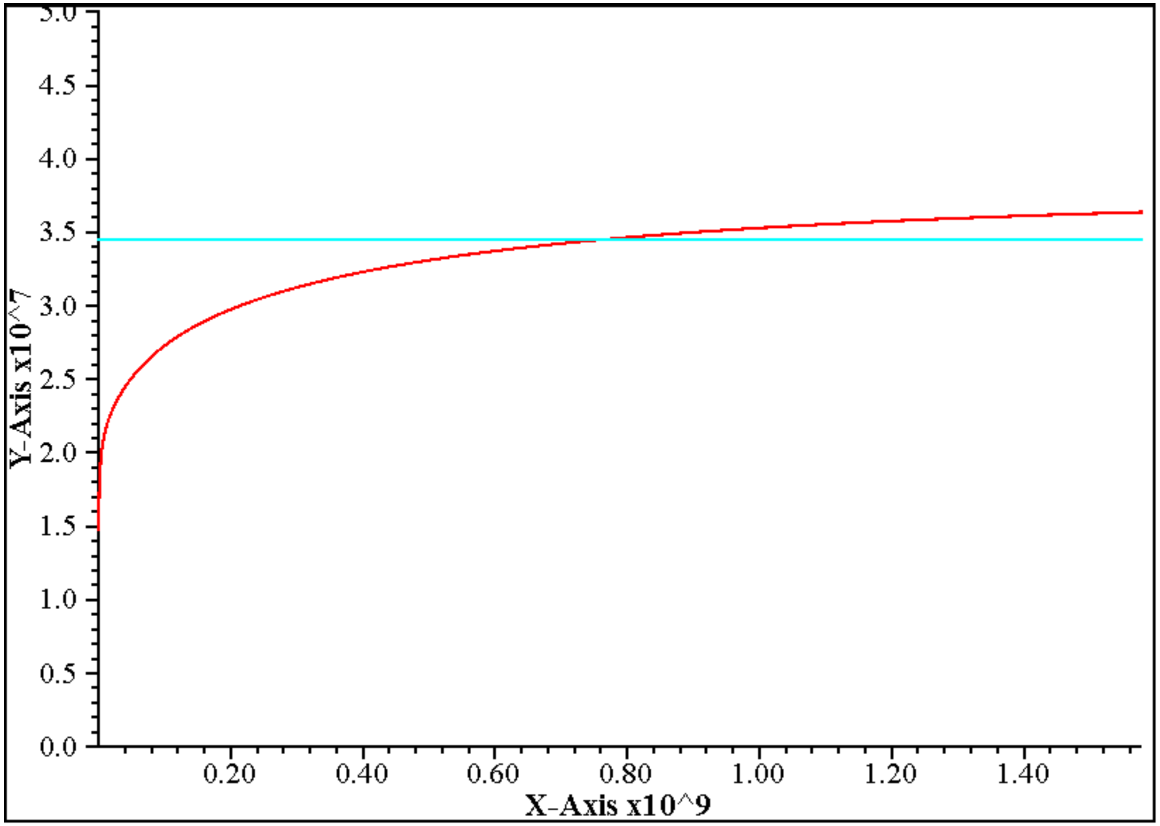

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| BIF-1 | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 47.52 | 2.60 | 0.882 |
| 50 year | 49.37 | 5.31 | 0.866 |
| | | | |

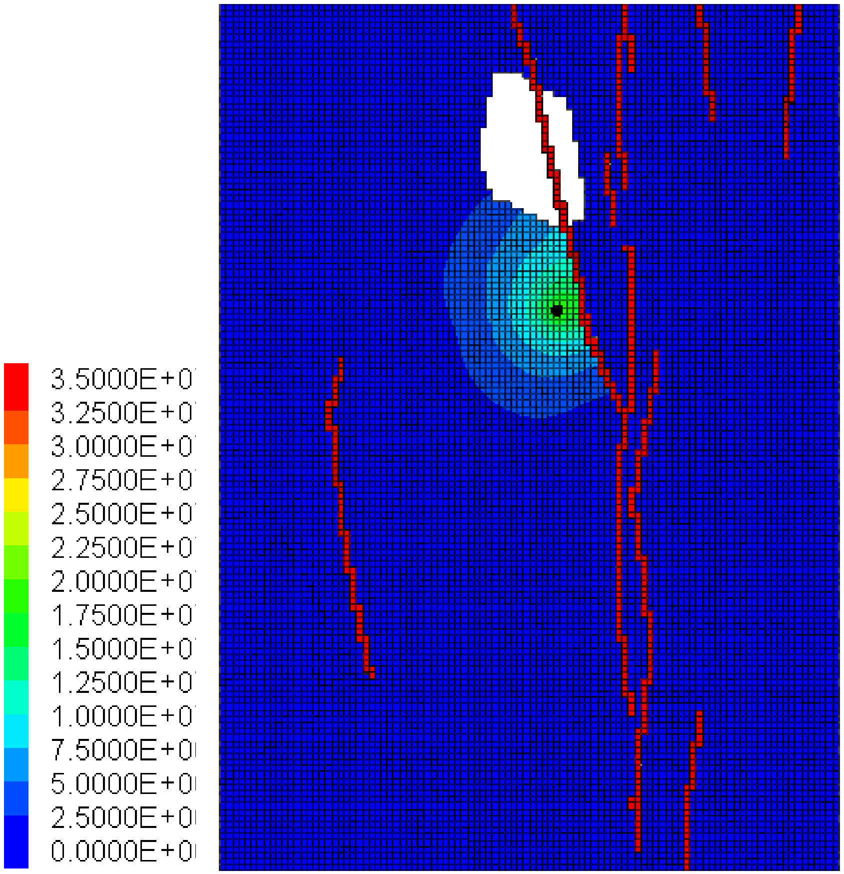
Slip predicted to occur in the vicinity of the well, based on elastic stress state in the model.

# BIF-2

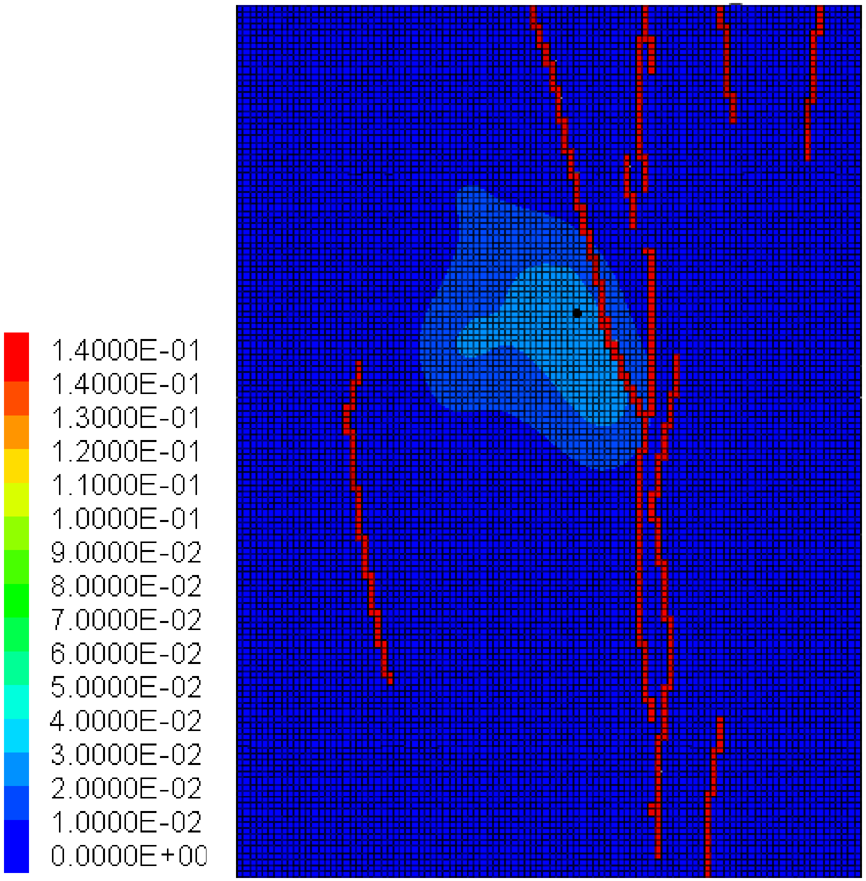



Wellhead pressure [Pa] vs time [sec]

# BIF-2 – 25.24 year

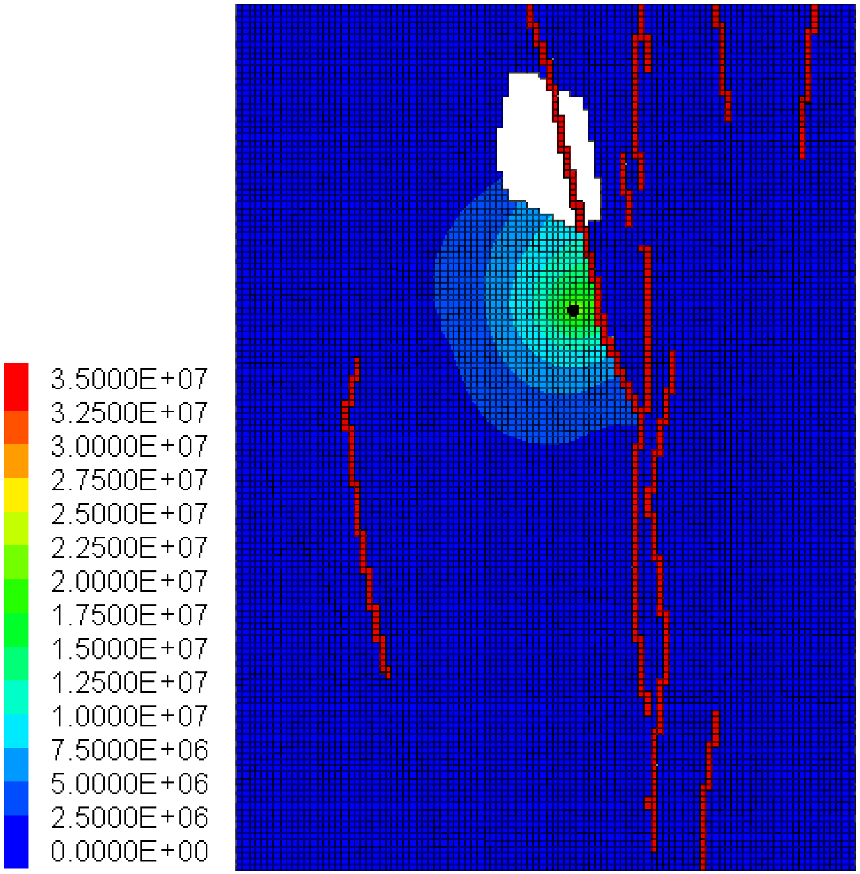



Excess pp contours [Pa] in Leadville

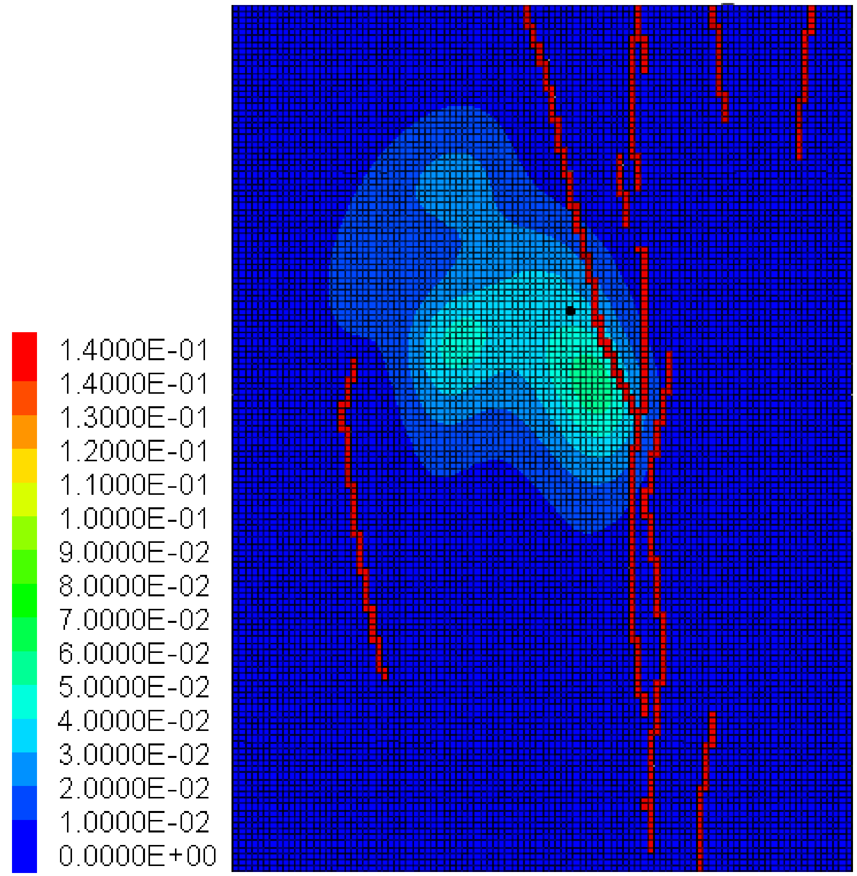



Contours of surface heave [m]

# BIF-2 – 50 year



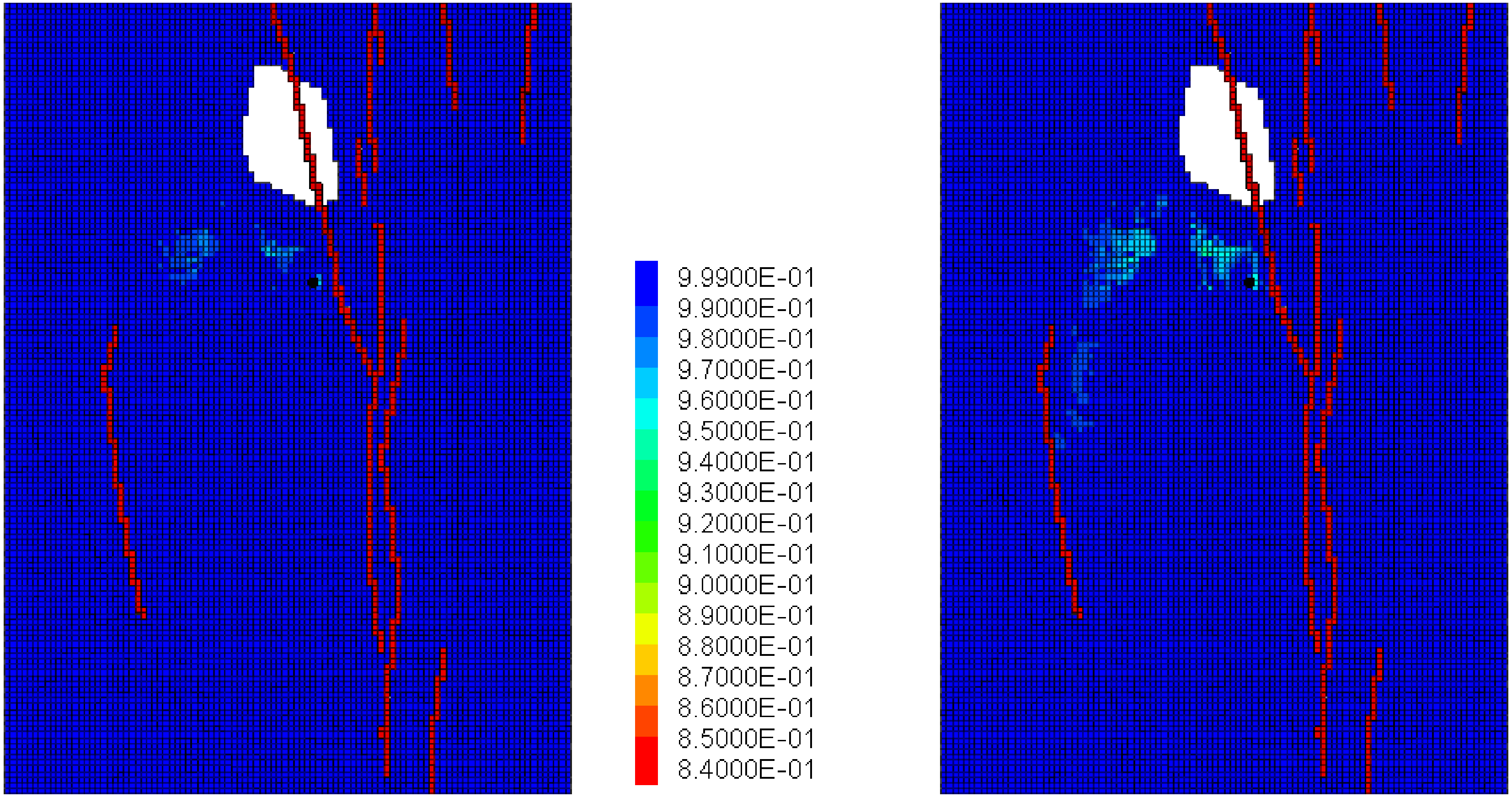

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# BIF-2 - FoS

**25.24 year**: FoS > 0.964 **50 year**: FoS > 0.946



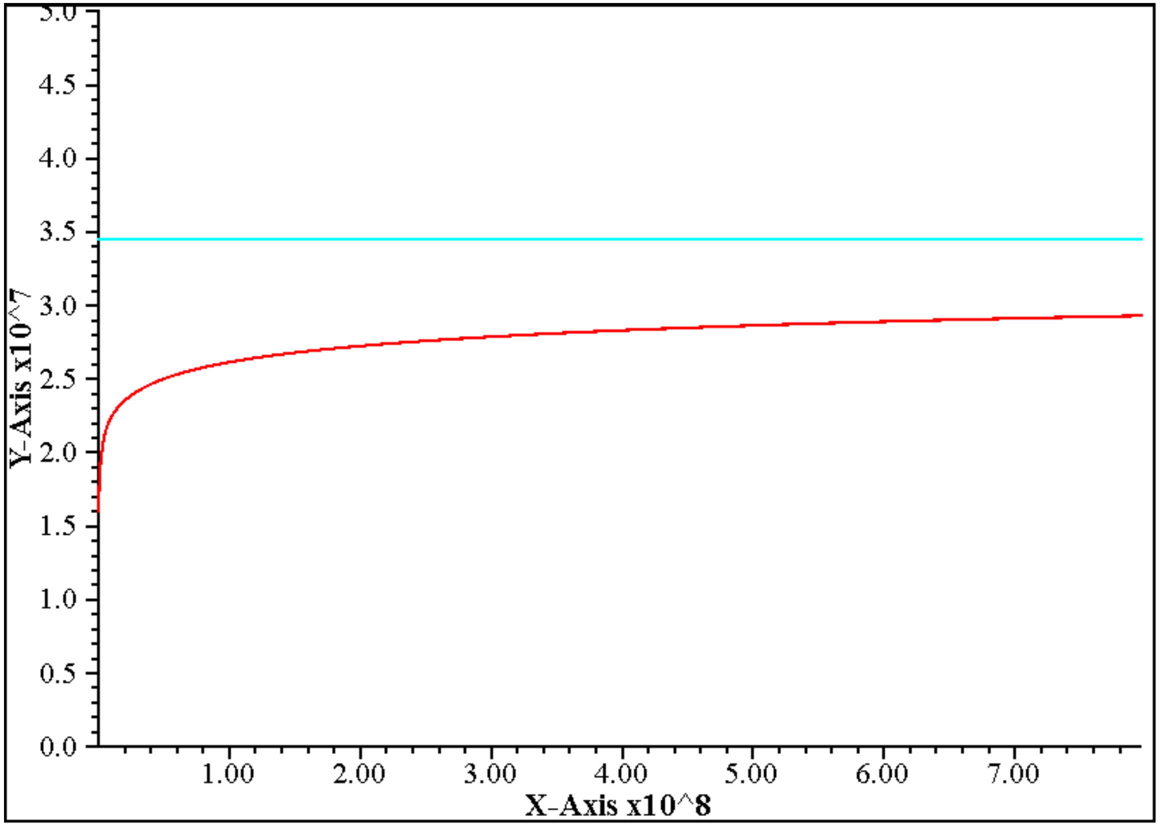

Contours of FoS < 1 in Leadville

# Numerical predictions

| BIF-2 | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 34.64 | 2.76 | 0.964 |
| 50 year | 36.38 | 5.64 | 0.946 |
| | | | |

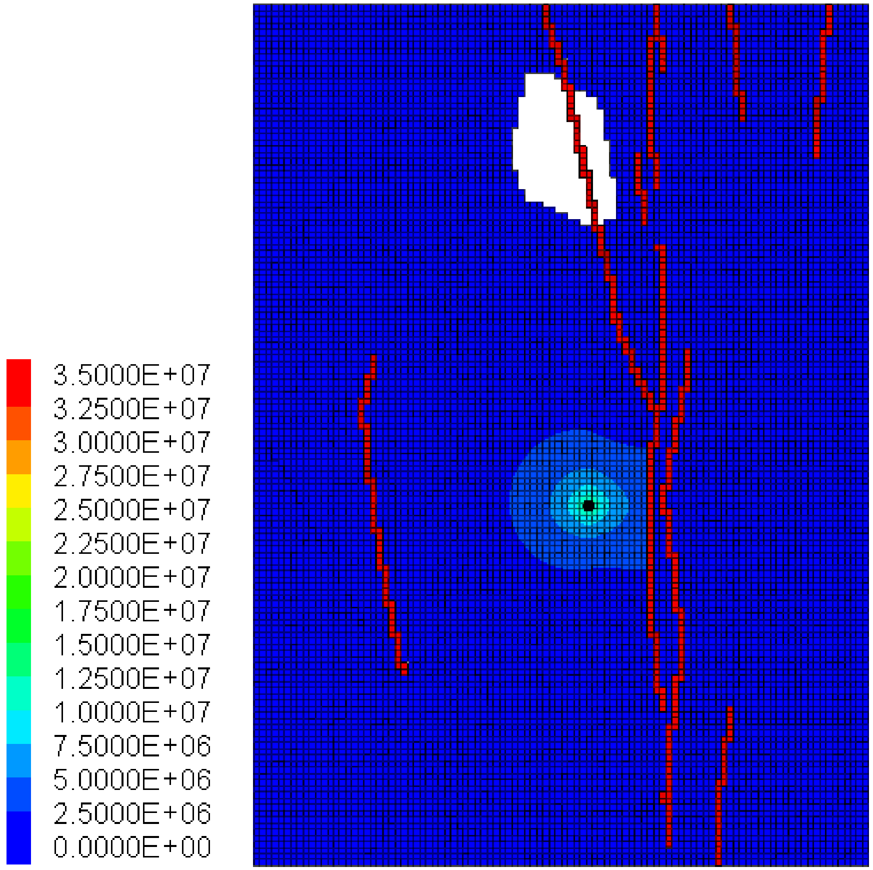
Slip predicted to occur,
based on elastic stress state in the model.

# Mesa-1

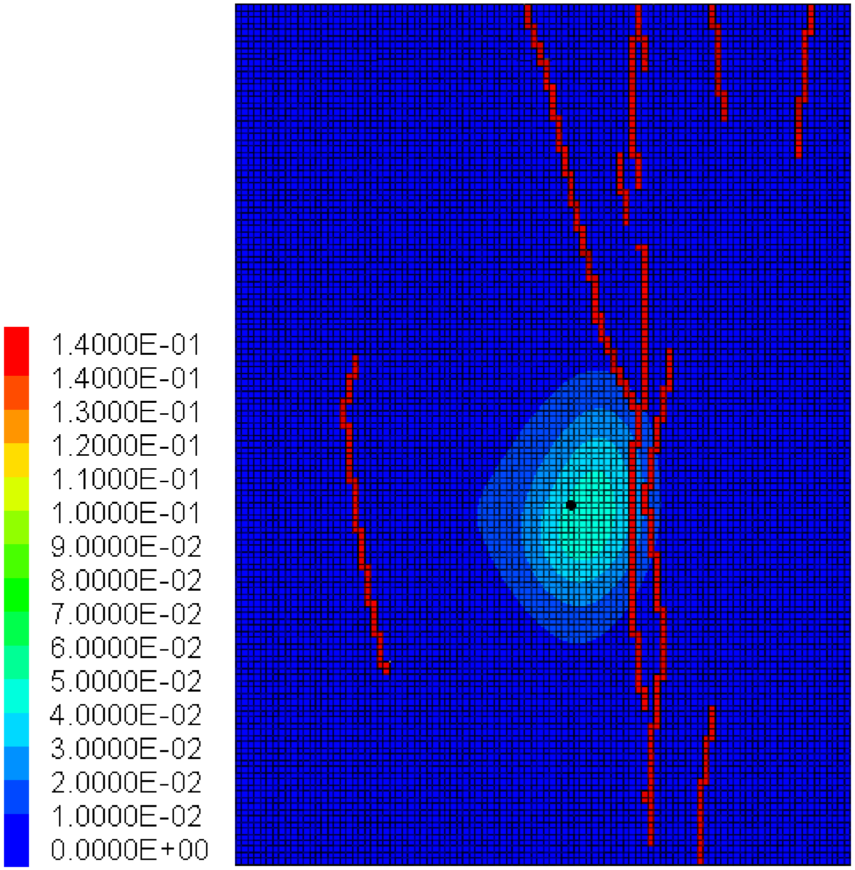



Wellhead pressure [Pa] vs time [sec]

# Mesa-1 – 25.24 year

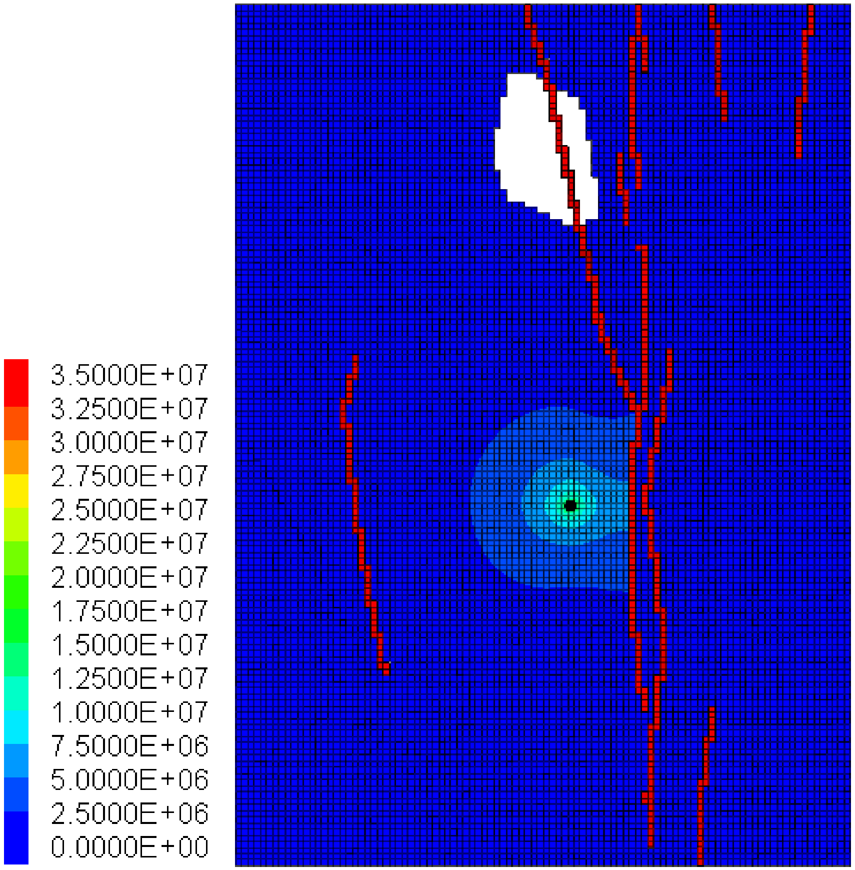



Excess pp contours [Pa] in Leadville

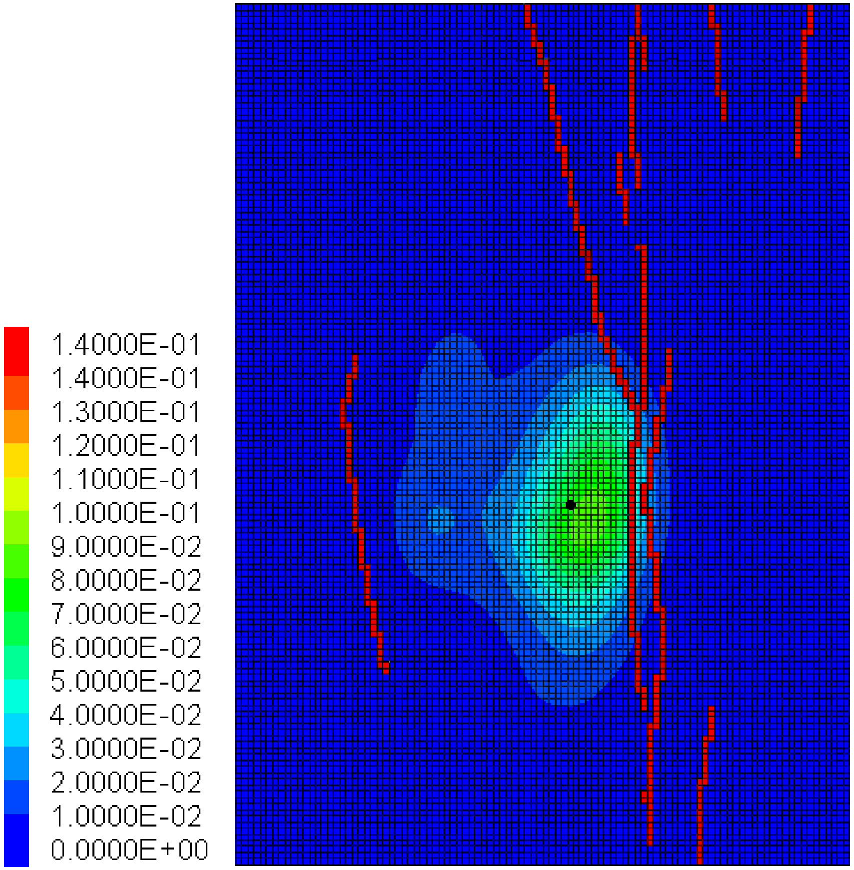



Contours of surface heave [m]

# Mesa-1 – 50 year



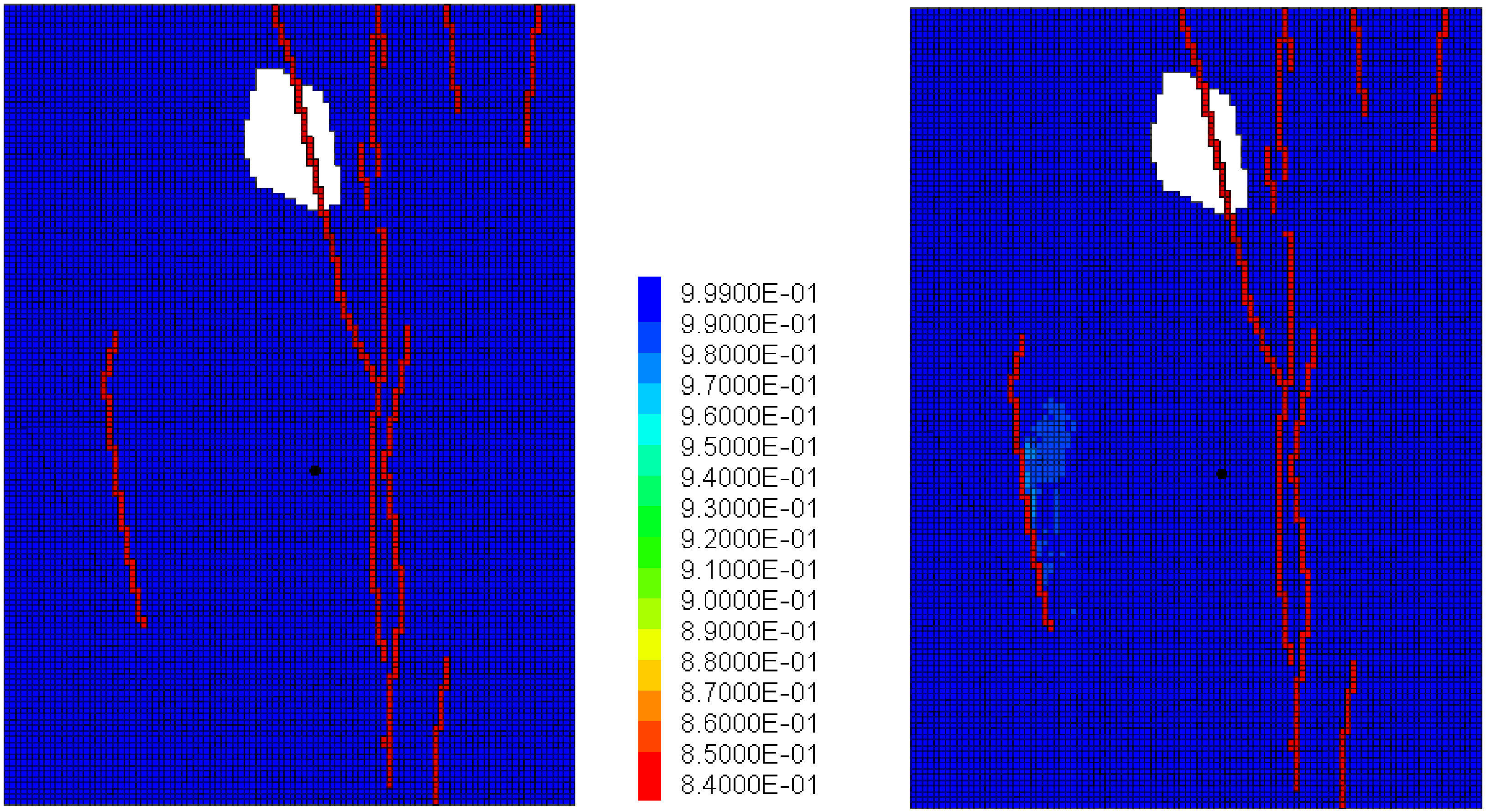

Excess pp contours [Pa] in Leadville




Contours of surface heave [m]

# Mesa-1 - FoS

**25.24 year**: FoS > 0.990 **50 year**: FoS > 0.975



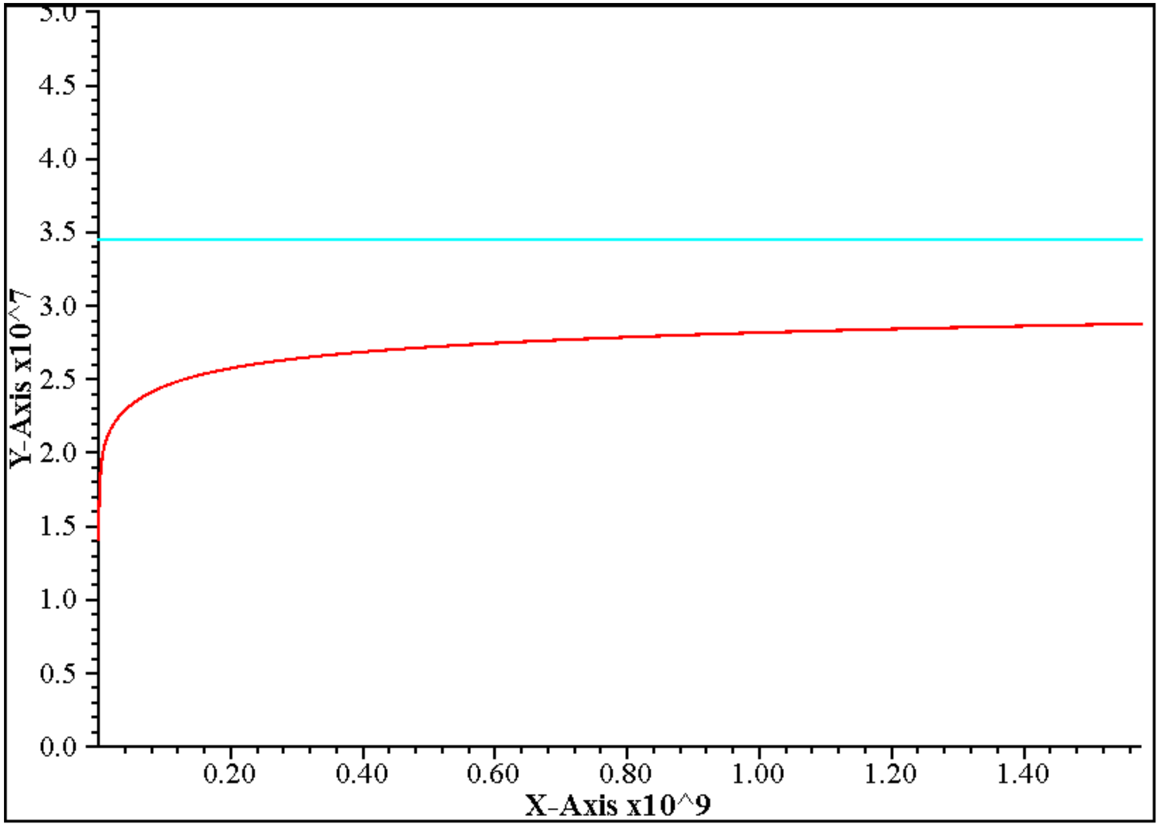

Contours of FoS < 1 in Leadville

# Numerical predictions

| Mesa-1 | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 29.31 | 4.86 | 0.990 |
| 50 year | 30.25 | 8.60 | 0.975 |
| | | | |

Slip is predicted to occur, in the vicinity of the left Fault, based on elastic stress state in the model.

# Mesa-2




Wellhead pressure [Pa] vs time [sec]

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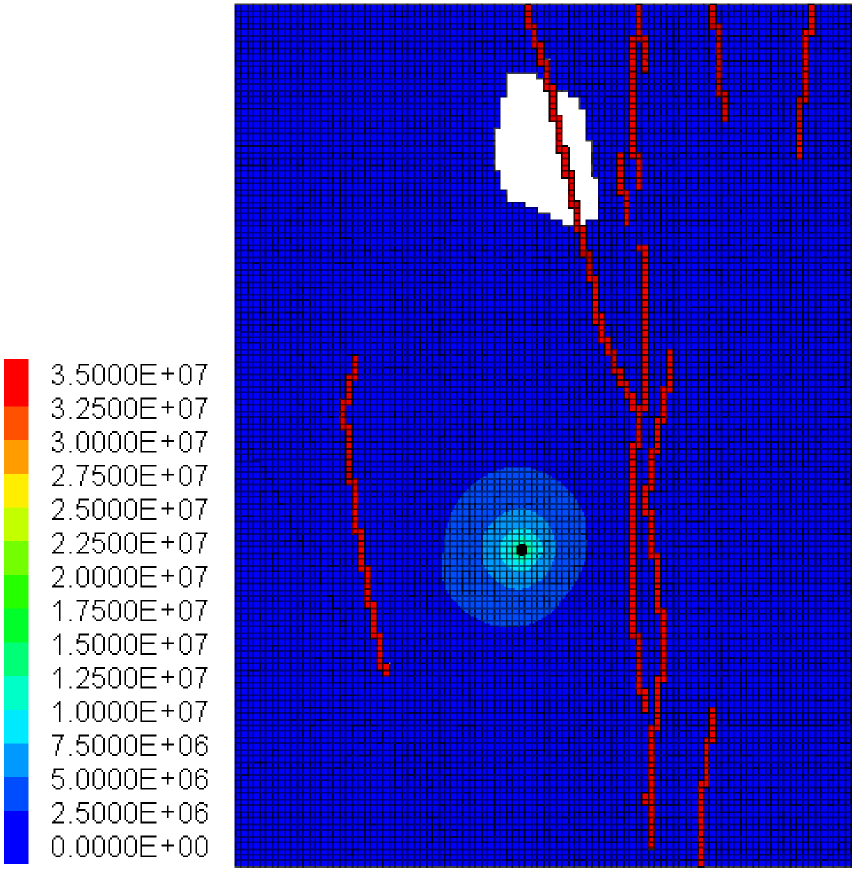
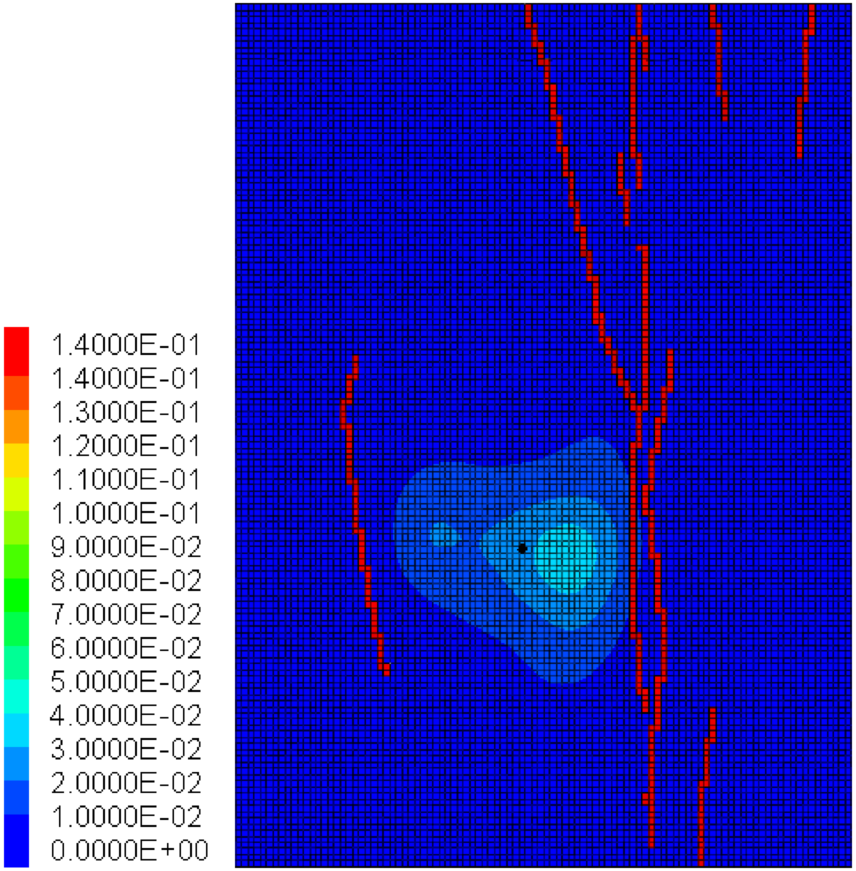
# Mesa-2 – 25.24 year

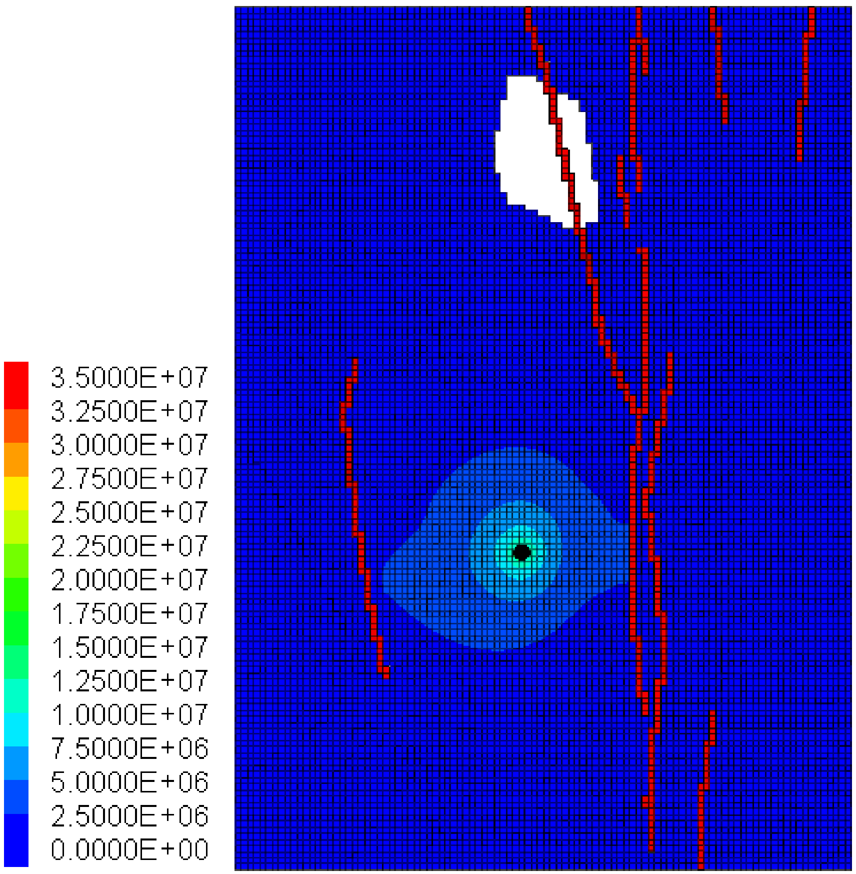



Excess pp contours [Pa] in Leadville

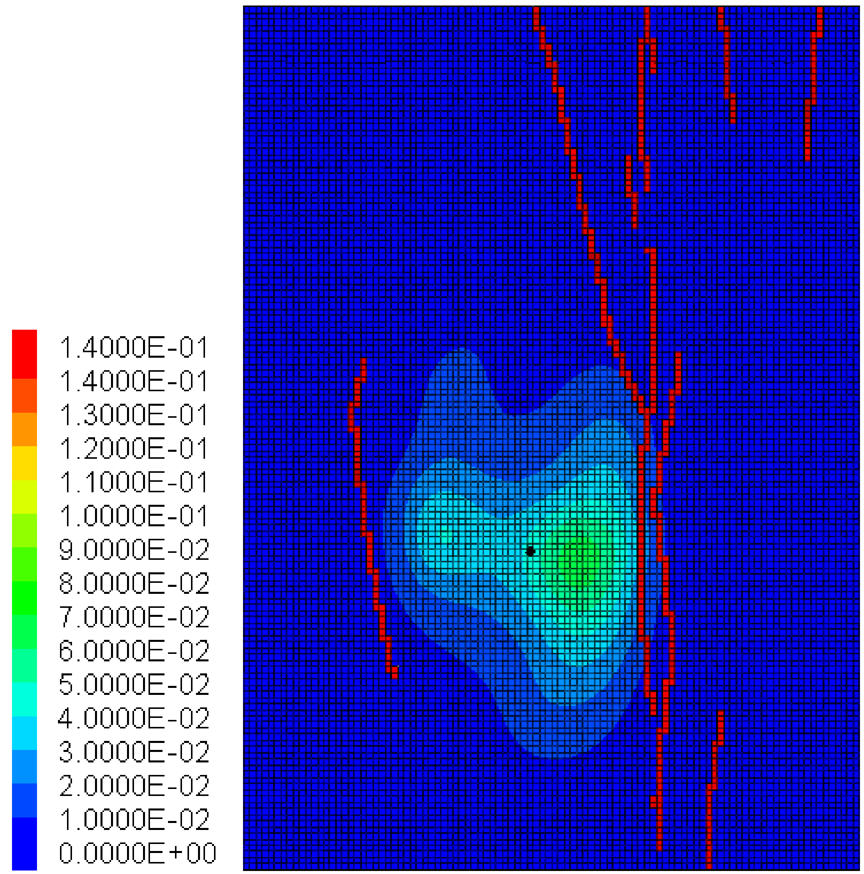



Contours of surface heave [m]

# Mesa-2 – 50 year




Excess pp contours [Pa] in Leadville

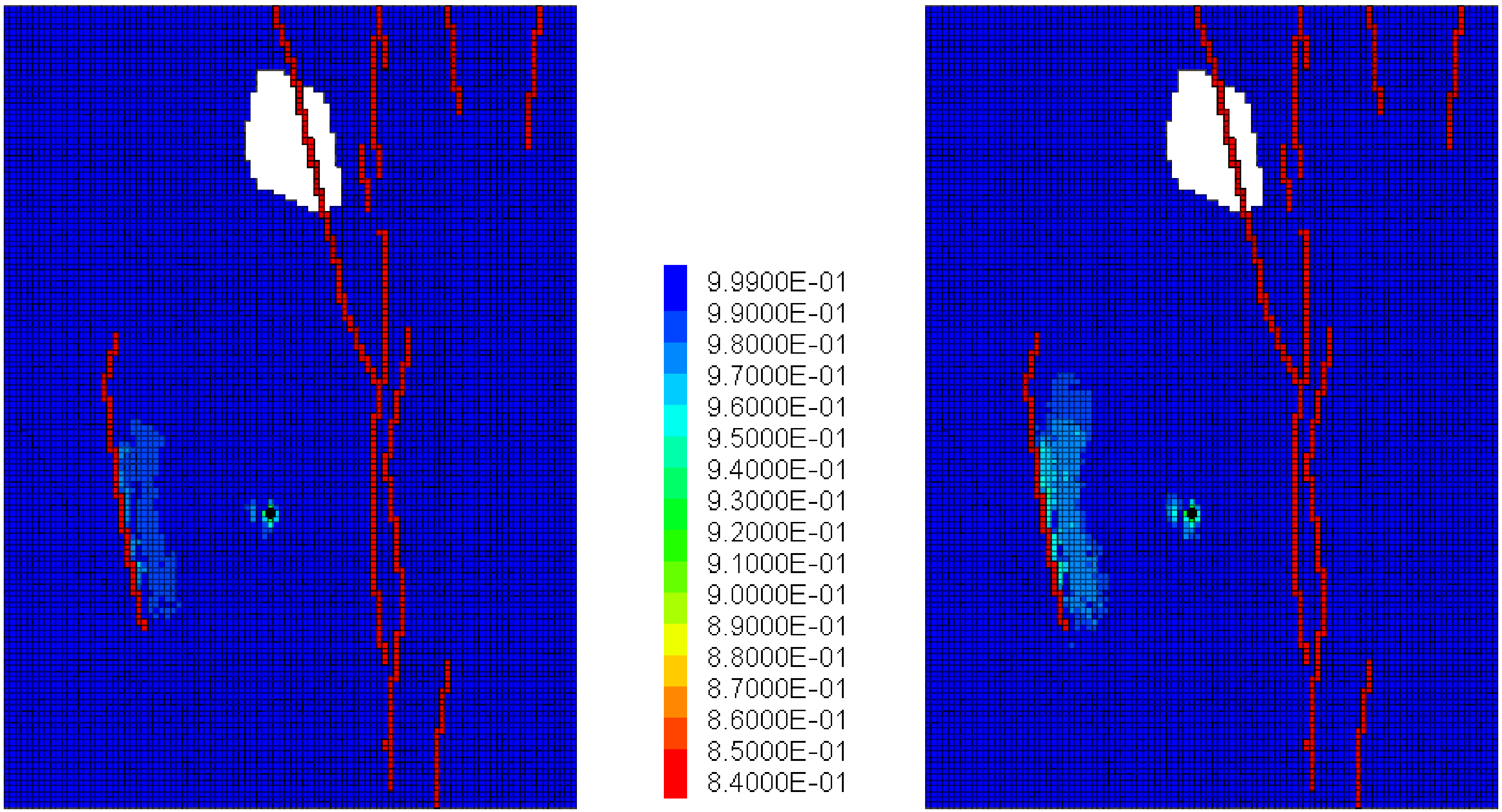



Contours of surface heave [m]

# Mesa-2 - FoS

**25.24 year**: FoS > 0.917

**50 year**: FoS > 0.910



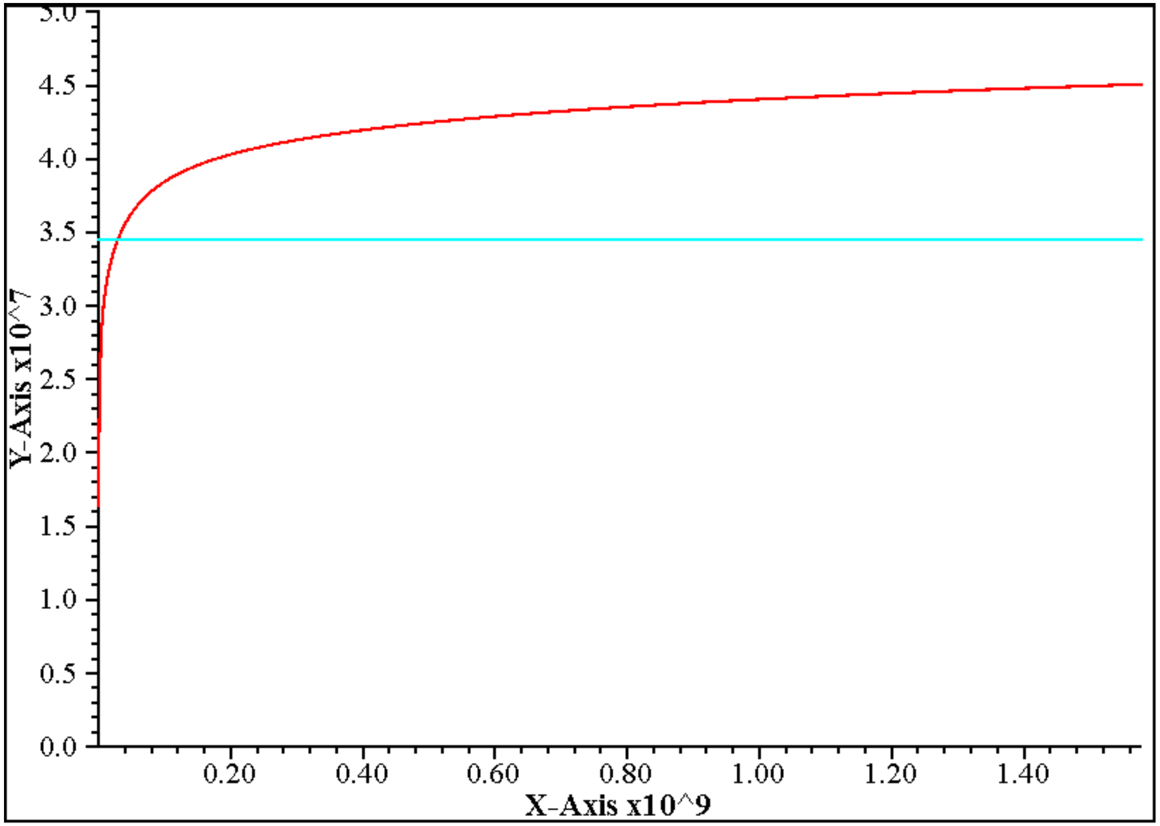

Contours of FoS < 1 in Leadville

# Numerical predictions

| Mesa-2 | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 27.86 | 3.64 | 0.917 |
| 50 year | 28.78 | 6.58 | 0.910 |
| | | | |

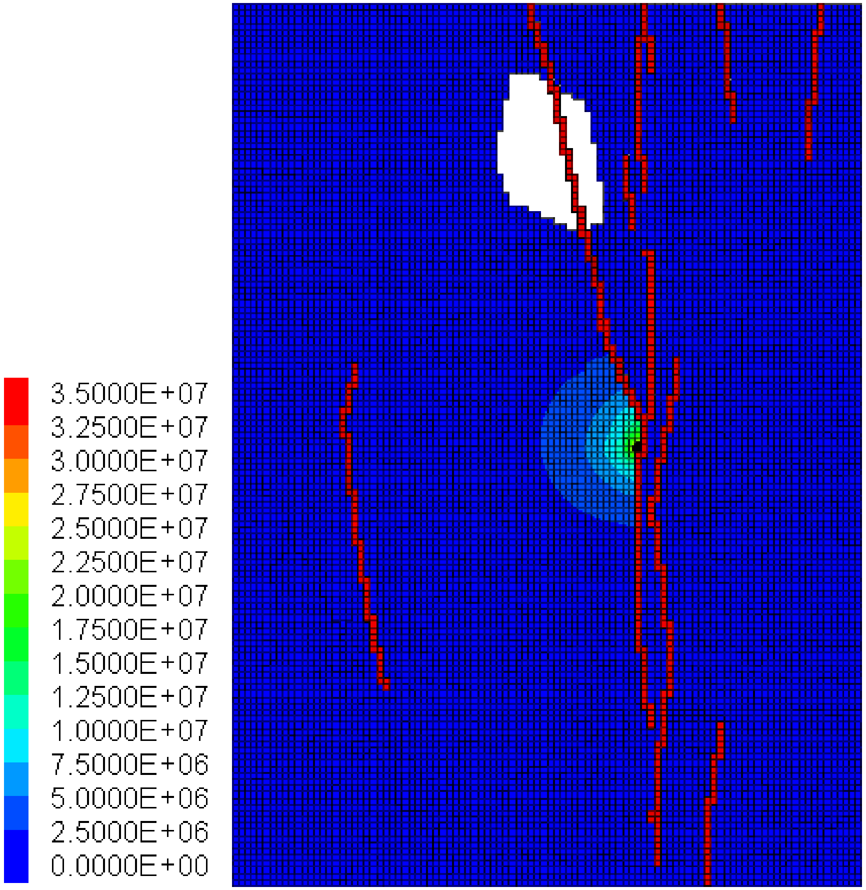
Slip predicted to occur,
based on elastic stress state in the model.

# Pinion Ridge

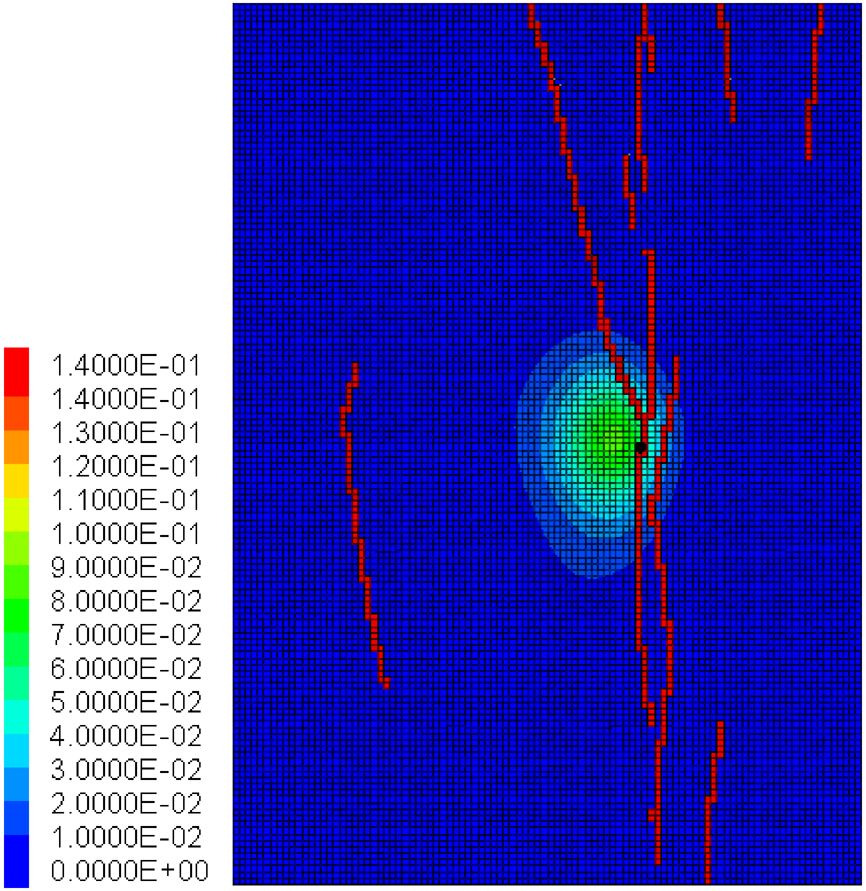



Wellhead pressure [Pa] vs time [sec]

# Pinion Ridge – 25.24 year

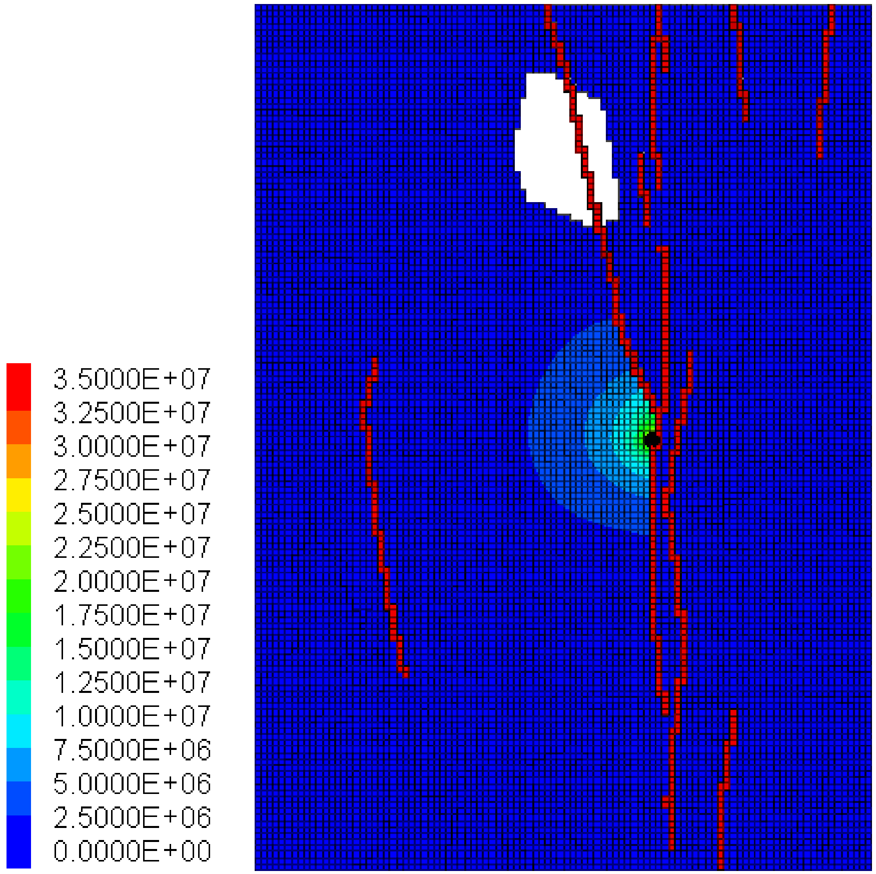



Excess pp contours [Pa] in Leadville

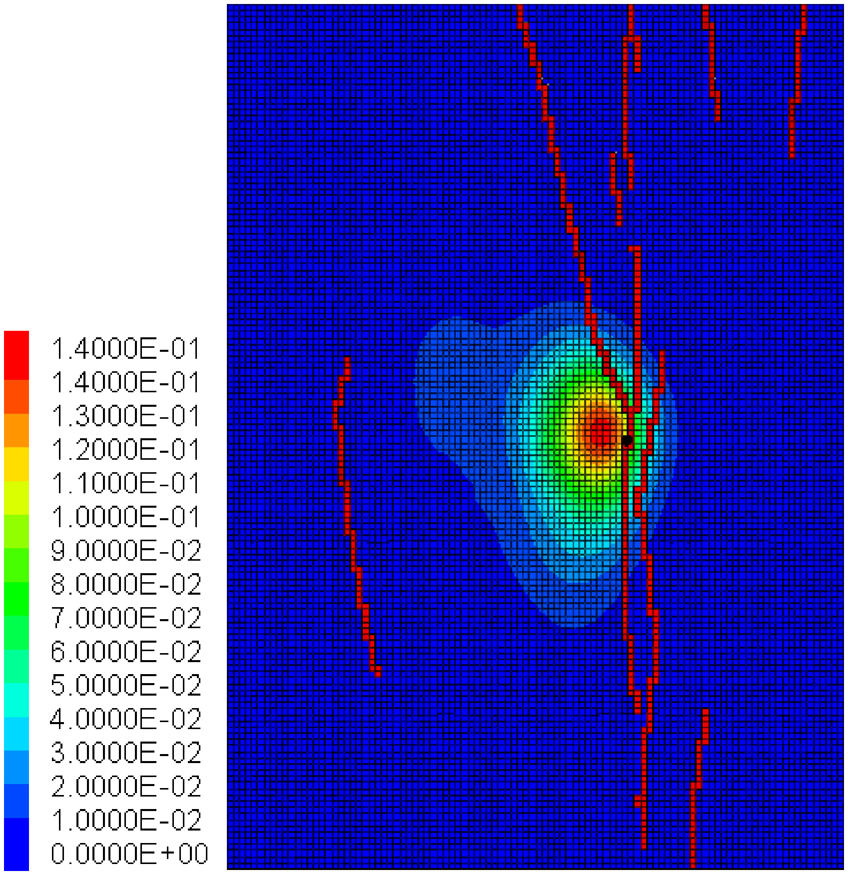



Contours of surface heave [m]

# Pinion Ridge – 50 year




Excess pp contours [Pa] in Leadville

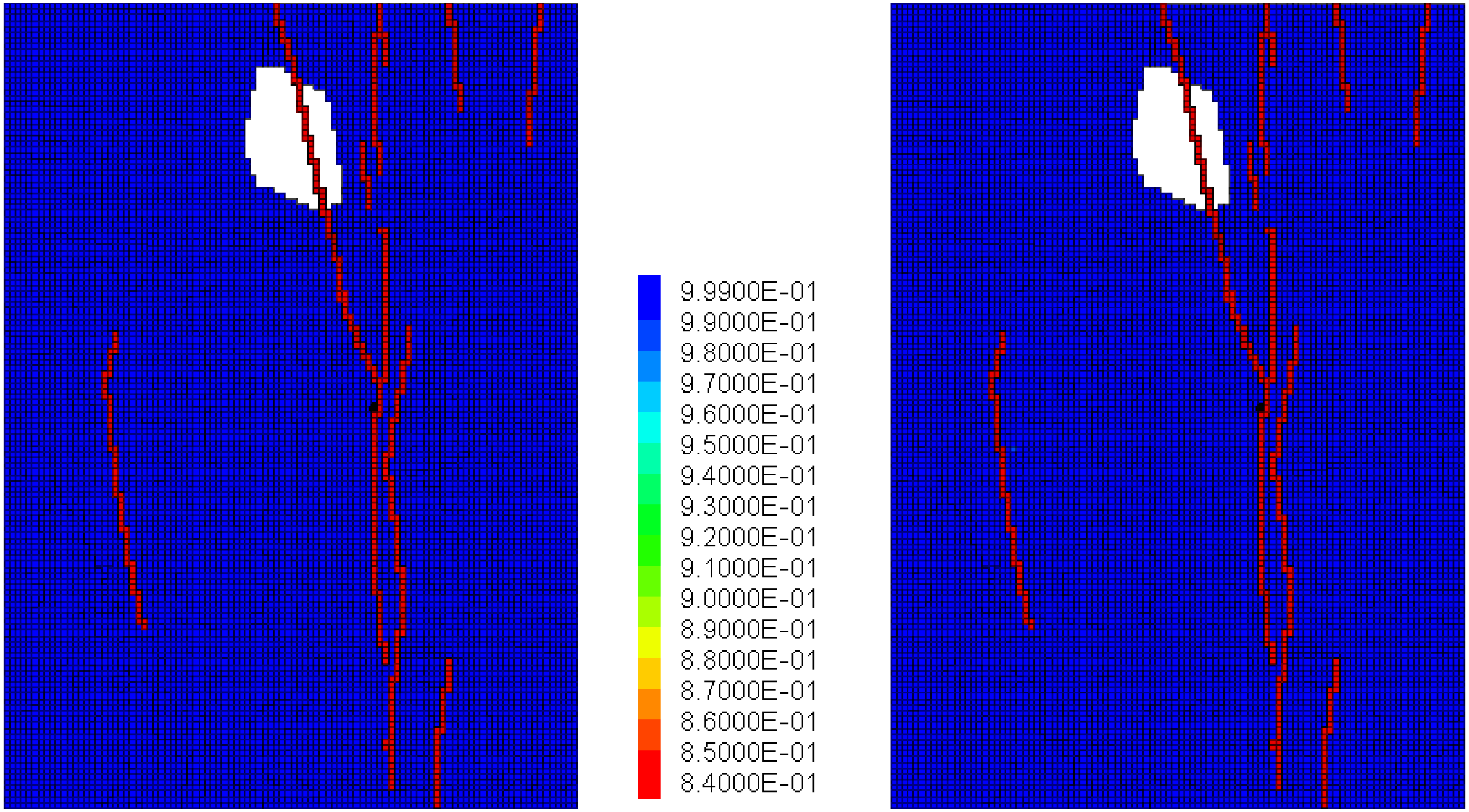



Contours of surface heave [m]

# Pinion Ridge – FoS Index

**25.24 year**: FoS > 0.998

**50 year**: FoS > 0.989




Contours of FoS Index < 1 in Leadville

# Numerical predictions

| Pinion Ridge | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| 25.24 year | 43.53 | 8.34 | 0.998 |
| 50 year | 45.07 | 14.65 | 0.989 |
| | | | |

No significant slip predicted to occur,
based on elastic stress state in the model.

# SUMMARY OF RESULTS

# 25.24 year results

| Well | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| PVU-1 | 32.69 | 3.49 | 0.860 |
| BIF-1 | 47.52 | 2.60 | 0.882 |
| BIF-2 | 34.64 | 2.76 | 0.964 |
| Mesa-1 | 29.31 | 4.86 | 0.990 |
| Mesa-2 | 27.86 | 3.64 | 0.917 |
| Pinion Ridge | 43.53 | 8.34 | 0.998 |

# 50 year results

| Well | Wellhead pressure [MPa] | Maximum heave [cm] | Minimum FoS |
|---|---|---|---|
| PVU-1 | 34.85 | 7.89 | 0.845 |
| BIF-1 | 49.37 | 5.31 | 0.866 |
| BIF-2 | 36.38 | 5.64 | 0.946 |
| Mesa-1 | 30.25 | 8.60 | 0.975 |
| Mesa-2 | 28.78 | 6.58 | 0.910 |
| Pinion Ridge | 45.07 | 14.65 | 0.989 |

# SIMULATION RESULTS – $\alpha < 1$

# Biot coefficient

In the previous analyses, Biot coefficient was equal to 1. However, for Sandstone and Limestone, the measured value is typically lower than 1.

For Sandstone in the Paradox Valley model, the Biot coefficient is assumed equal to the value documented for Ruhr sandstone (*):

$$\alpha = 0.65$$

From the definition of Biot coefficient:

$$\alpha = 1 - K / K_s \quad \Rightarrow \quad K_s = K / (1-\alpha)$$

We assume that $K_s$ is the same for Sandstone and Limestone.

Sandstone : K ~ 50 Gpa → $K_s$ = 50/(1-0.65) GPa

Leadville limestone: K ~ 65 Gpa → $\alpha$ = 1-(1-0.65)65/50~0.55

(*) Detournay, E. and A. Cheng, 1999

# Biot coefficient values

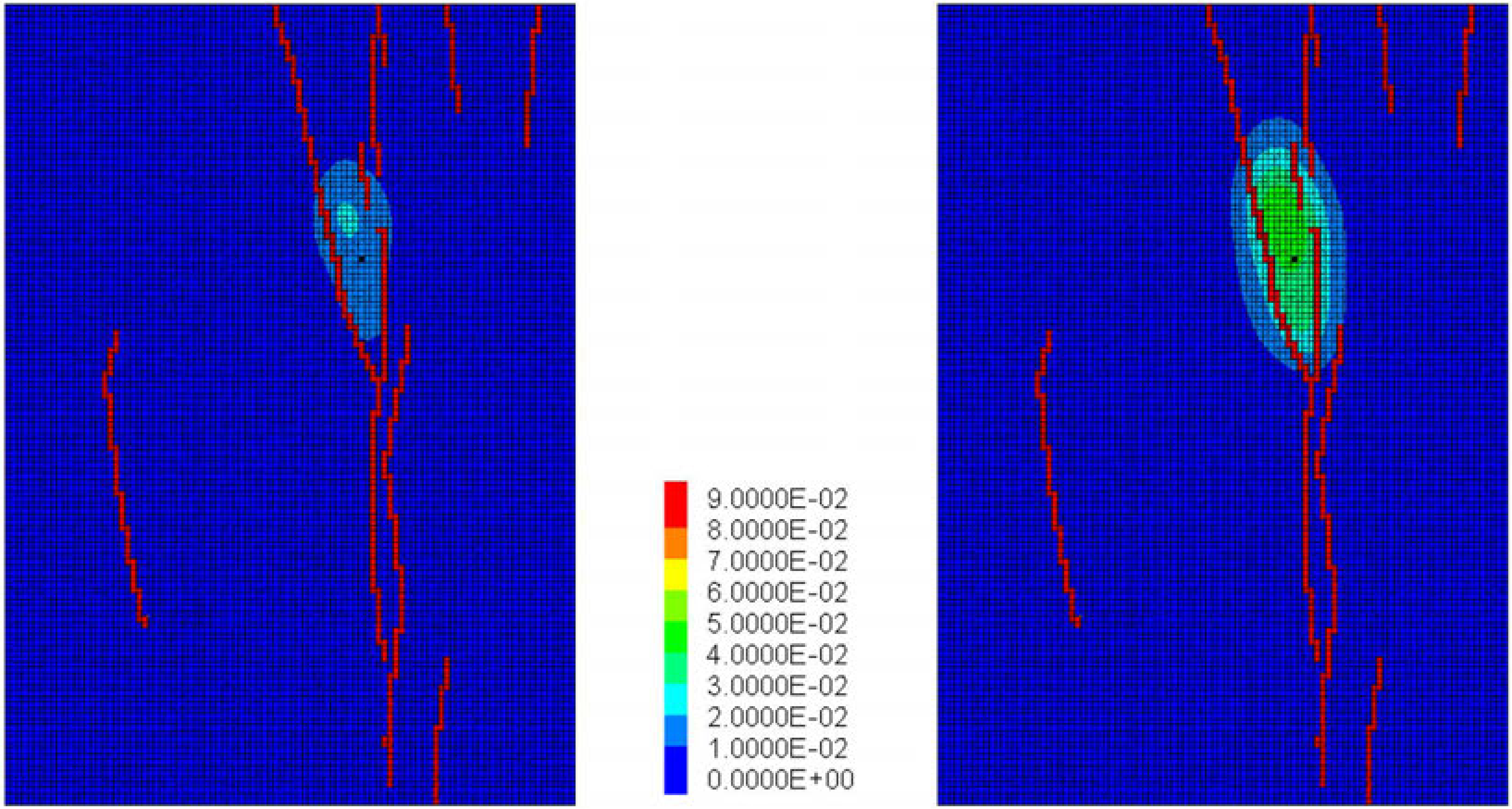
For the simulations, we use:

$\alpha$ = 0.65 for Upper, Welds, Sedimentary, Upper-Precambrian

$\alpha$ = 0.55 for Leadville

(Salt and Lower-Precambrian are impermeable)

# PVU-1 – heave – $\alpha < 1$



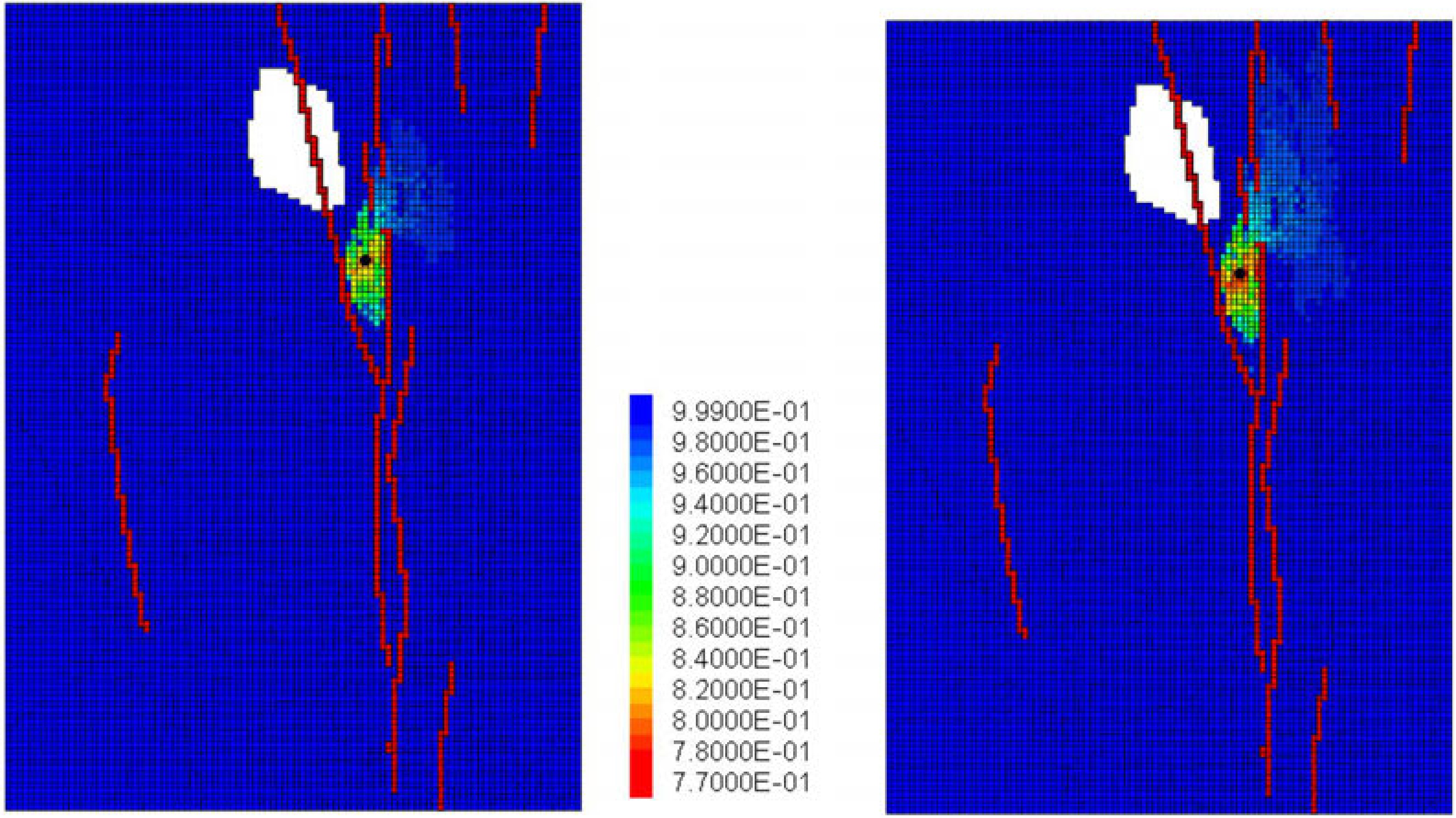

Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# PVU-1 - FoS Index $-\alpha < 1$

**25.24 year**: FoS > 0.794

**50 year**: FoS > 0.774



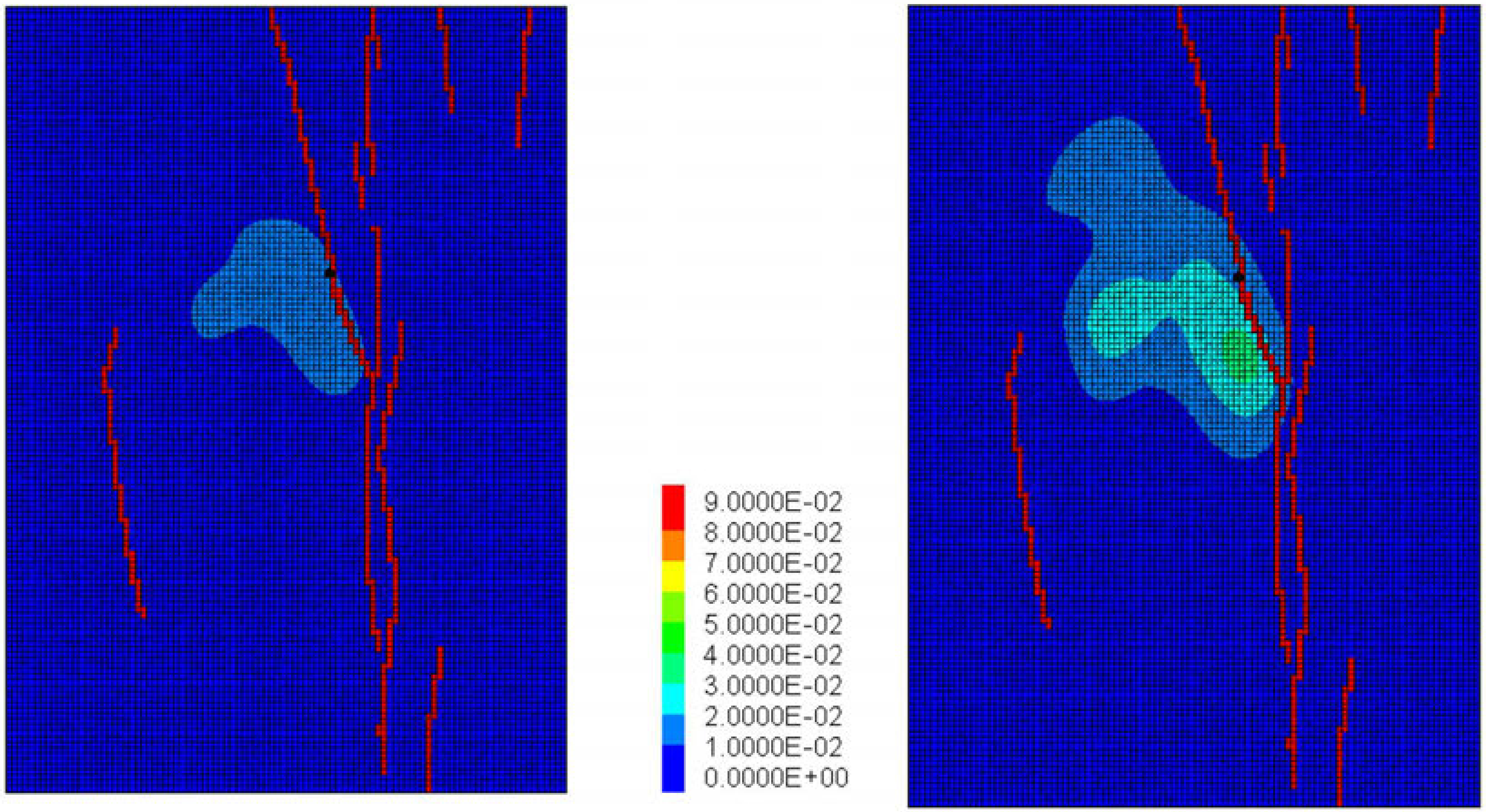

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| PVU-1 | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 3.49 | 2.10 | 0.860 | 0.794 |
| 50 year | 7.89 | 4.94 | 0.845 | 0.774 |

Slip predicted to occur,
based on elastic stress state in the model.

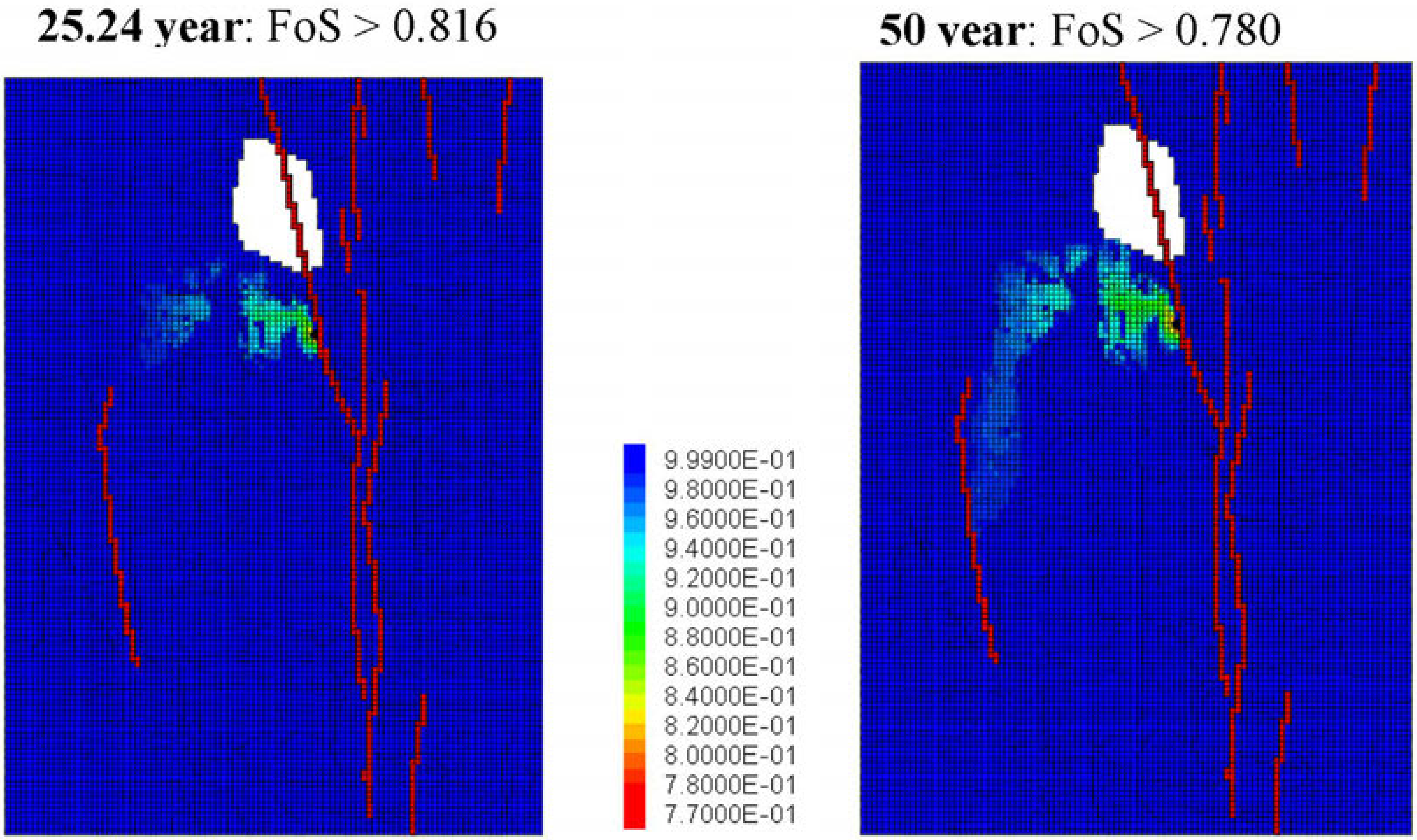
# BIF-1 – heave – $\alpha < 1$




Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# BIF-1 - FoS Index – $\alpha < 1$



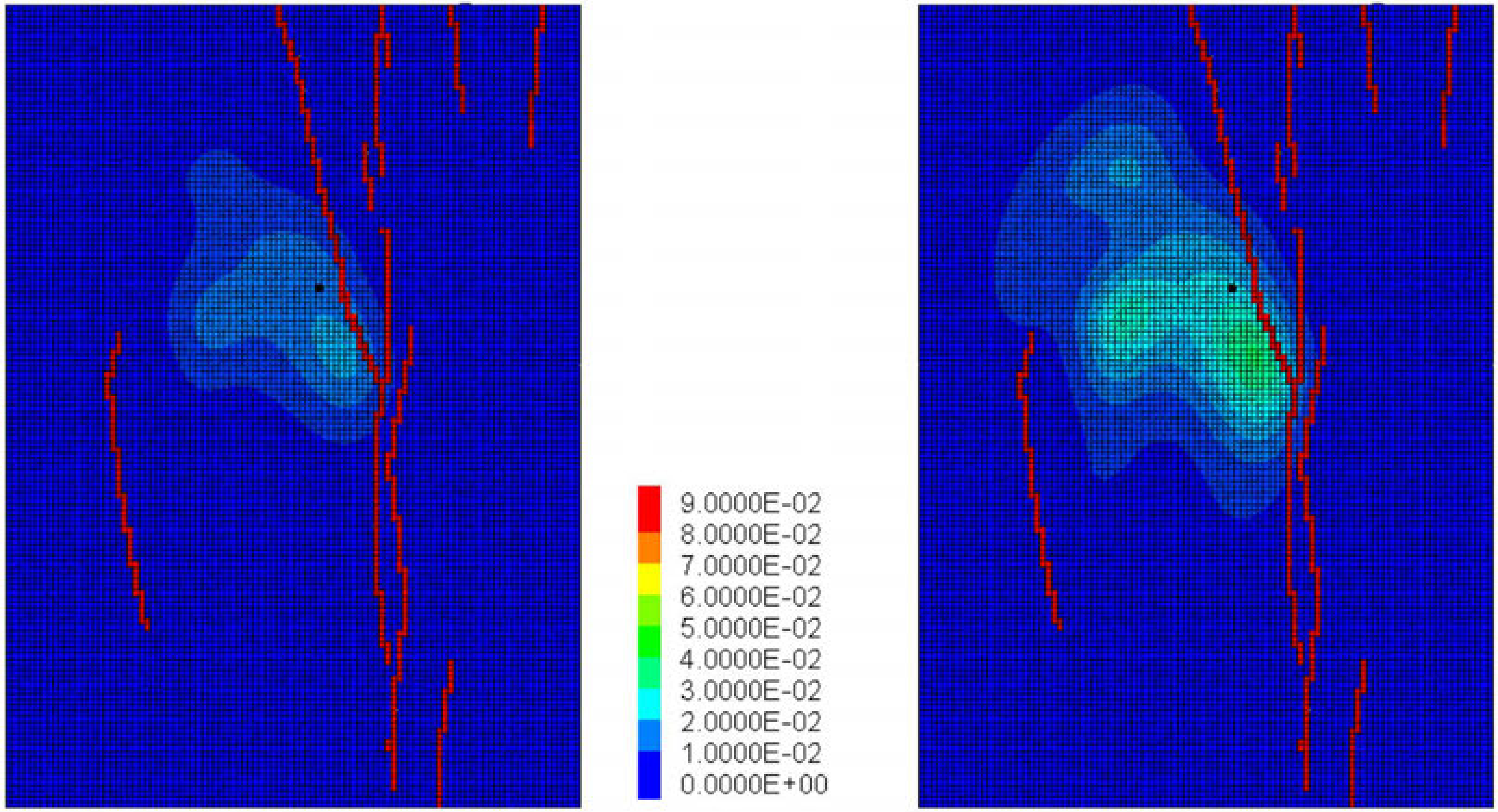

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| BIF-1 | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 2.60 | 1.59 | 0.882 | 0.816 |
| 50 year | 5.31 | 3.39 | 0.866 | 0.780 |

Slip predicted to occur,
based on elastic stress state in the model.

# BIF-2 – heave – $\alpha < 1$

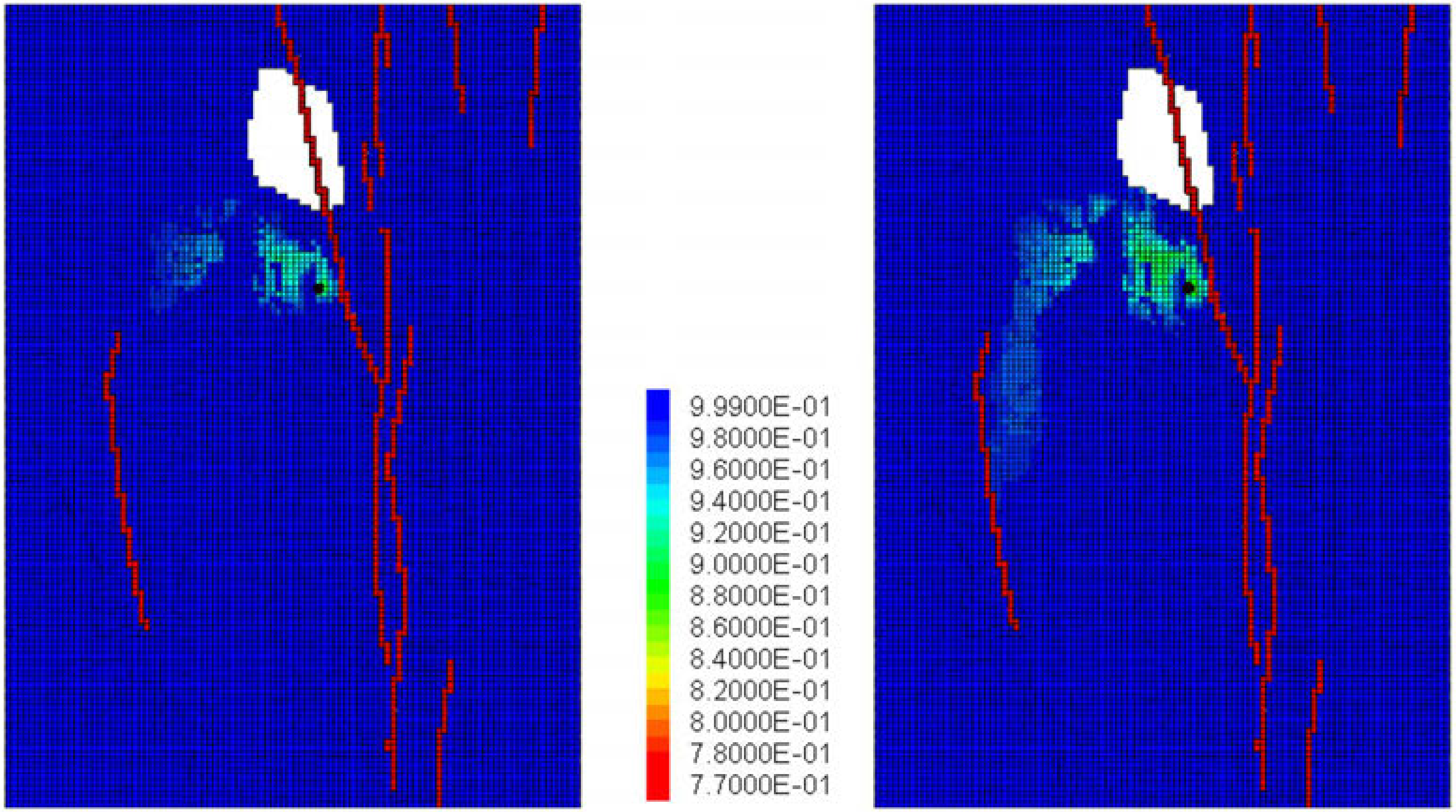



Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# BIF-2 - FoS Index – $\alpha < 1$

**25.24 year**: FoS > 0.891 **50 year**: FoS > 0.869



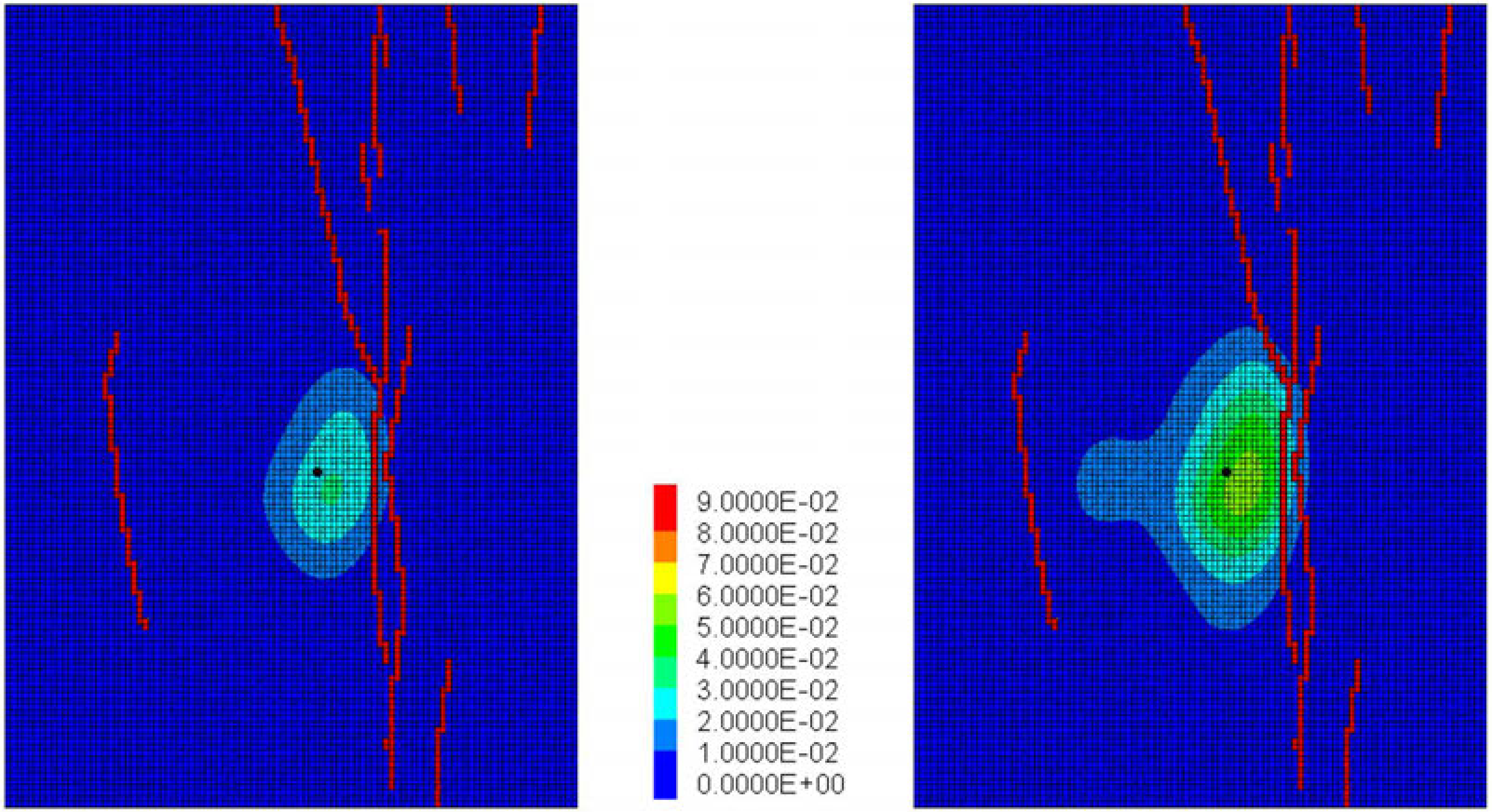

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| BIF-2 | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 2.76 | 1.73 | 0.964 | 0.891 |
| 50 year | 5.64 | 3.60 | 0.946 | 0.869 |

Slip predicted to occur,
based on elastic stress state in the model.

# Mesa-1 – heave – $\alpha < 1$



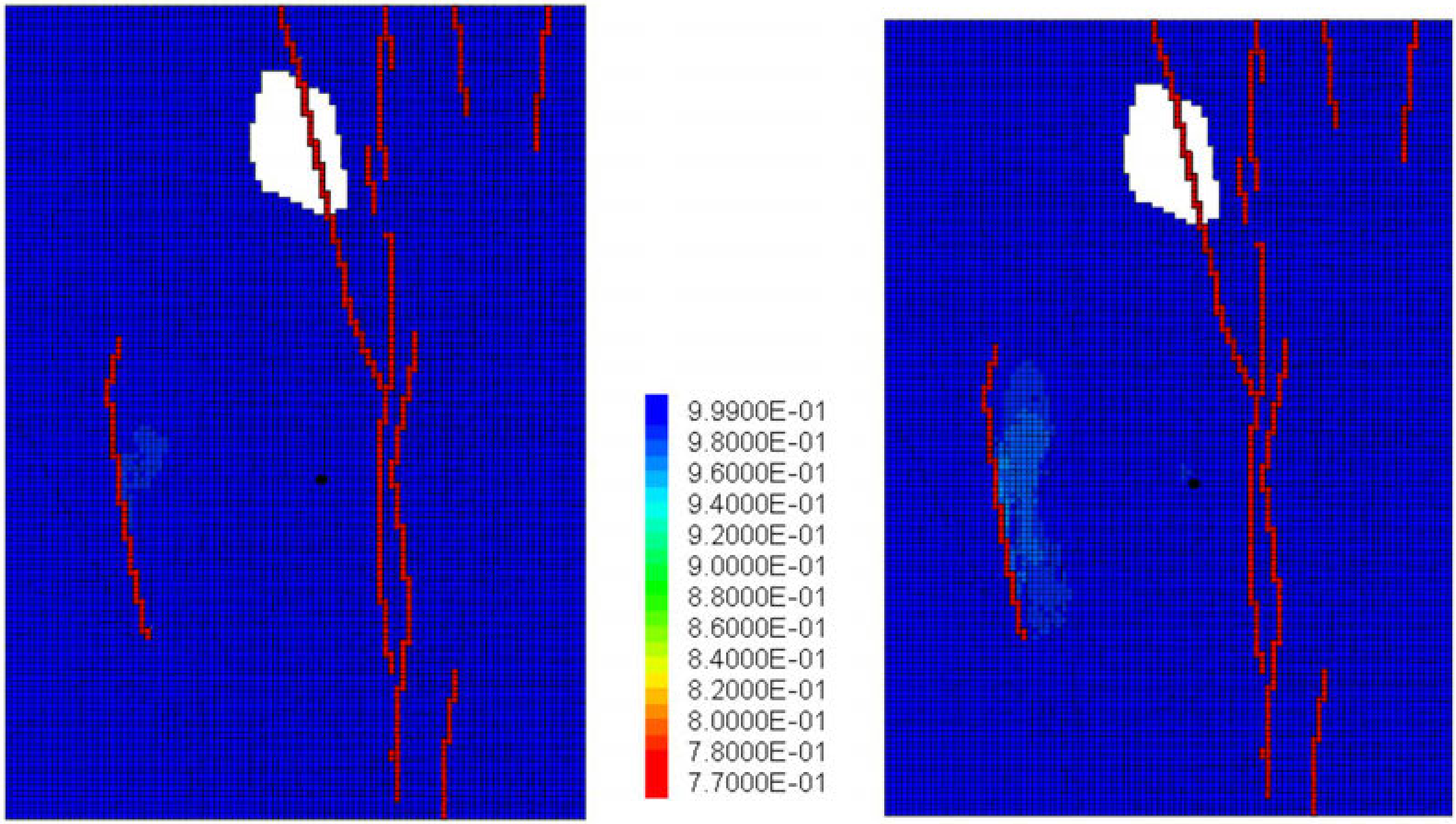

Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# Mesa-1 - FoS Index $-\alpha < 1$

**25.24 year**: FoS > 0.986

**50 year**: FoS > 0.967



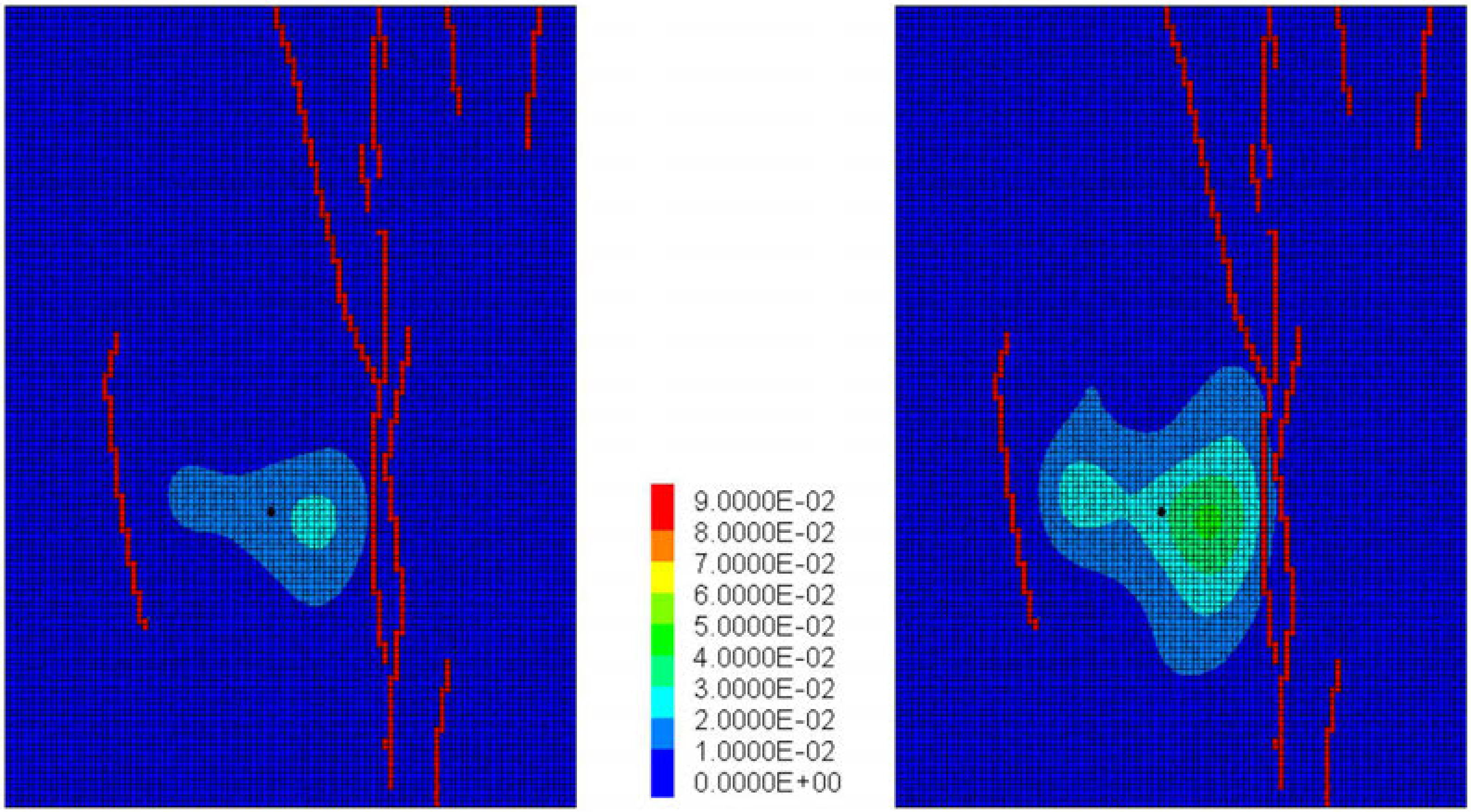

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| Mesa-1 | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 4.86 | 3.12 | 0.990 | 0.986 |
| 50 year | 8.60 | 5.50 | 0.975 | 0.967 |

Slip predicted to occur,
based on elastic stress state in the model.

# Mesa-2 – heave – $\alpha < 1$

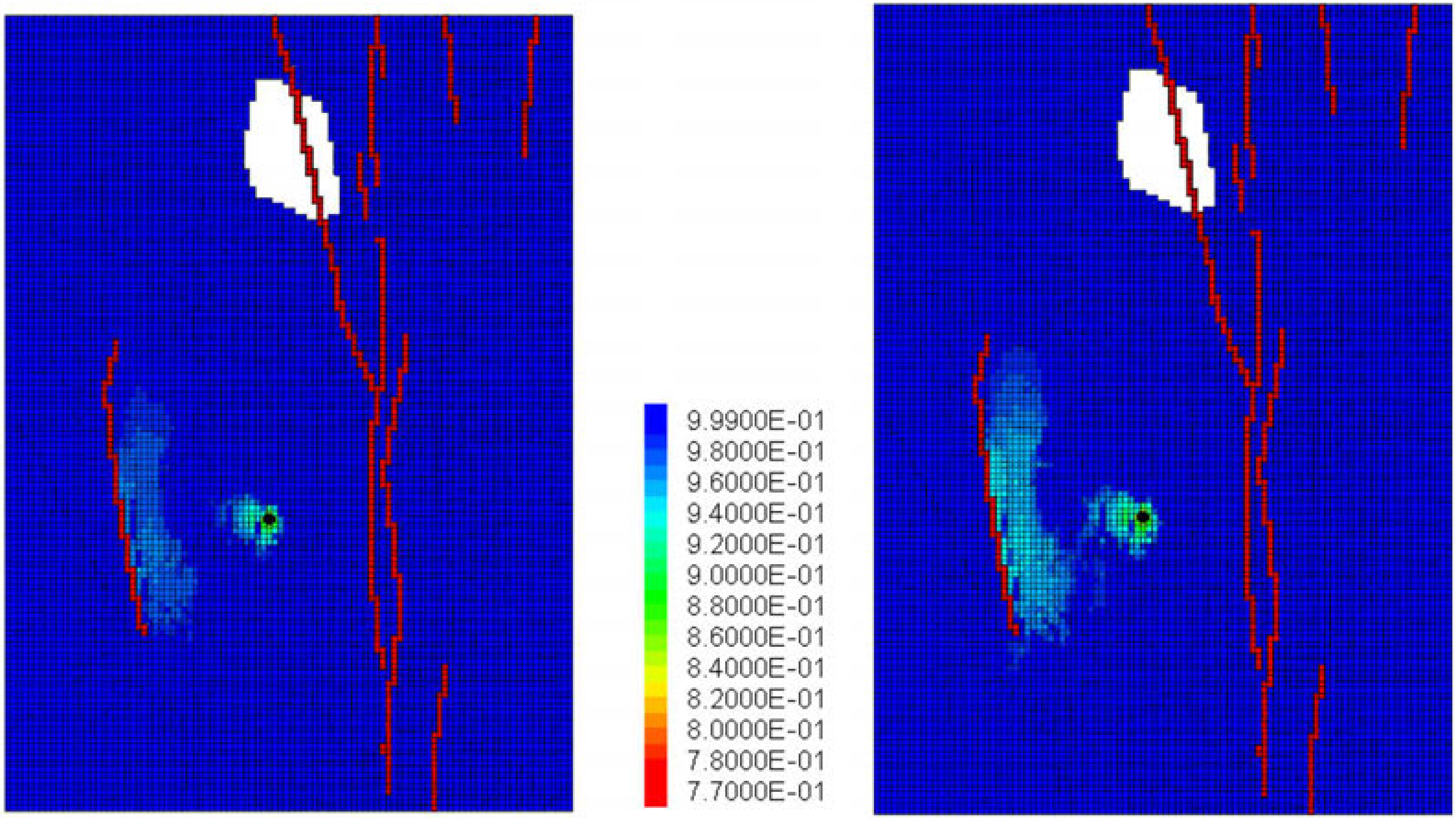



Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# Mesa-2 - FoS Index $-\alpha < 1$

**25.24 year**: FoS > 0.844 **50 year**: FoS > 0.832



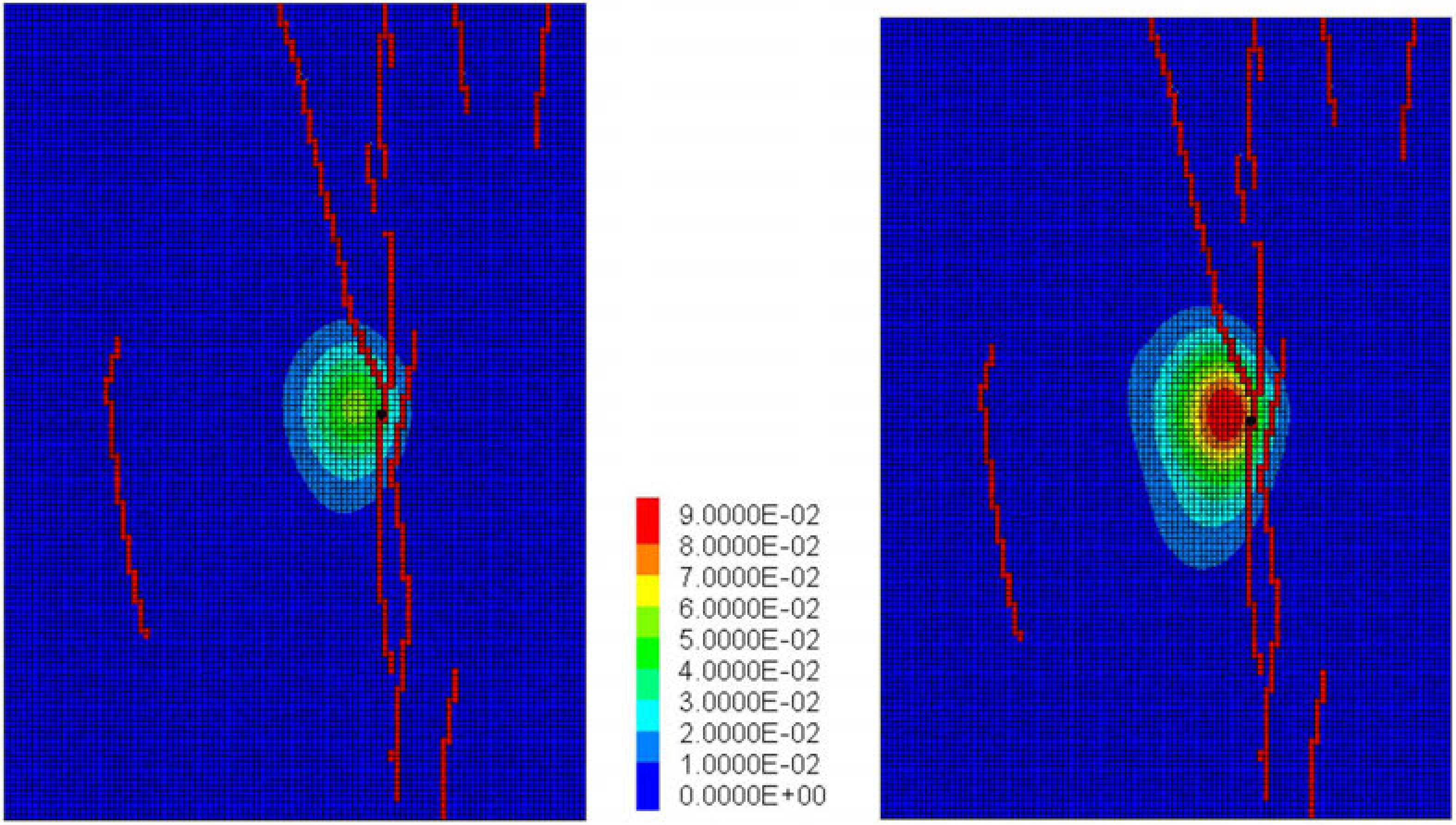

Contours of FoS Index < 1 in Leadville

# Numerical predictions

| Mesa-2 | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 3.64 | 2.30 | 0.917 | 0.844 |
| 50 year | 6.58 | 4.21 | 0.910 | 0.832 |

Slip predicted to occur,
based on elastic stress state in the model.

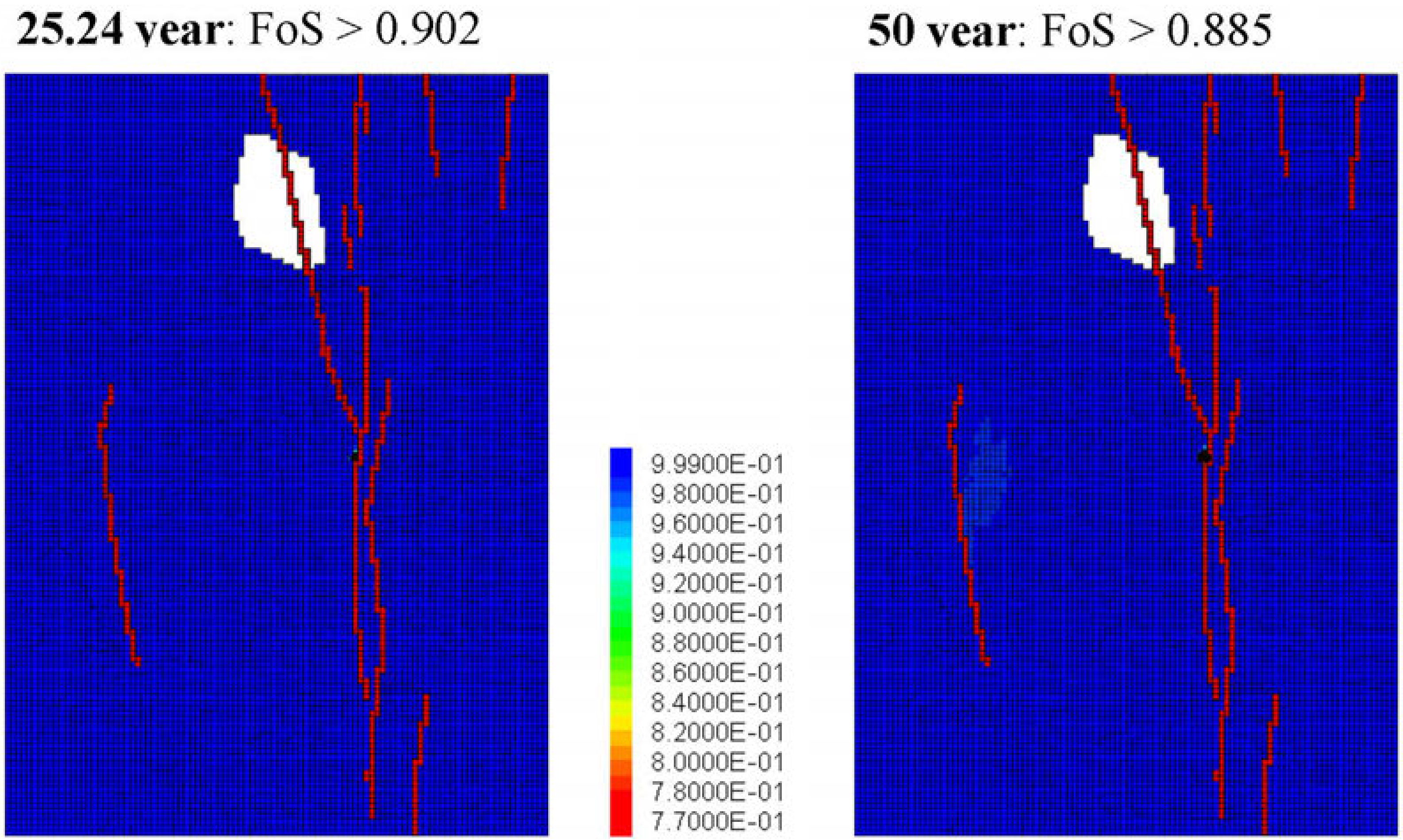
# Pinion Ridge – heave – $\alpha < 1$




Contours of surface heave [m] – 25.24 y

Contours of surface heave [m] – 50 y

# Pinion Ridge - FoS Index – $\alpha < 1$




Contours of FoS Index < 1 in Leadville

# Numerical predictions

| Pinion Ridge | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| 25.24year | 8.34 | 5.42 | 0.998 | 0.902 |
| 50 year | 14.65 | 9.39 | 0.989 | 0.885 |

Slip predicted to occur,
based on elastic stress state in the model.

# Summary – 25.24 year

| | **Maximum heave [cm]** | | **Minimum FoS** | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| PVU-1 | 3.49 | 2.10 | 0.860 | 0.794 |
| BIF-1 | 2.60 | 1.59 | 0.882 | 0.816 |
| BIF-2 | 2.76 | 1.73 | 0.964 | 0.891 |
| Mesa-1 | 4.86 | 3.12 | 0.990 | 0.986 |
| Mesa-2 | 3.64 | 2.30 | 0.917 | 0.844 |
| Pinion Ridge | 8.34 | 5.42 | 0.998 | 0.902 |

# Summary – 50 year

| | Maximum heave [cm] | | Minimum FoS | |
|---|---|---|---|---|
| | Alpha = 1 | Alpha < 1 | Alpha = 1 | Alpha < 1 |
| PVU-1 | 7.89 | 4.94 | 0.845 | 0.774 |
| BIF-1 | 5.31 | 3.39 | 0.866 | 0.780 |
| BIF-2 | 5.64 | 3.60 | 0.946 | 0.869 |
| Mesa-1 | 8.60 | 5.50 | 0.975 | 0.967 |
| Mesa-2 | 6.58 | 4.21 | 0.910 | 0.832 |
| Pinion Ridge | 14.65 | 9.39 | 0.989 | 0.885 |

# Observations - a

The Paradox model simulation results show:

- a smaller maximum predicted surface heave for smaller alpha value, as expected.
- a higher potential for slip at smaller alpha value, due to the comparatively lower increase in confinement induced by injection.

# Observations - b

Well locations, in predicted order of increasing potential for:

**WHP**:

Mesa-2
Mesa-1
PVU-1
BIF-2
Pinion Ridge
BIF-1

**‘Far Field’ slip** (*):

Pinion Ridge /Mesa-1
BIF-2
Mesa-2
BIF-1
PVU-1

**Surface heave** (**):

BIF-1
BIF-2
PVU-1/Mesa-2
Mesa-1
Pinion Ridge

(*) as measured by the minimum FoS Index in the simulations
(**) measured by the maximum surface heave in the model

# THANK YOU!

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# Appendix G
## Preliminary Identification of Aquatic Resources Report

wood.

# Preliminary Identification of Aquatic Resources Report

Paradox Valley
Montrose County, Colorado
Project No. GSA314C004

Prepared for:

**Bureau of Reclamation**

Upper Colorado Region, Western Colorado Area Office
445 W. Gunnison Ave., Suite 221
Grand Junction, CO 81501-5711

7/25/2018

# Preliminary Identification of Aquatic Resources Report

Paradox Valley
Project Location
Project No. GSA314C004

**Prepared for:**

Bureau of Reclamation
Upper Colorado Region, Western Colorado Area Office
445 W. Gunnison Ave., Suite 221
Grand Junction, CO 81501-5711

**Prepared by:**

Wood Environment & Infrastructure Solutions, Inc.
[Comments]

**7/25/2018**

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## List of Acronyms

| | |
|---|---|
| AMSL | Above Mean Sea Level |
| cfs | Cubic Feet per Second |
| EIS | Environmental Impact Statement |
| ESRI | Environmental Systems Research Institute |
| FEMA | Federal Emergency Management Agency |
| GIS | Geographic Information System |
| GNSS | Global Navigation Satellite System |
| GPS | Geographic Positioning System |
| LRR | Land Resource Region |
| MLRA | Major Land Resource Areas |
| NAIP | National Agriculture Imagery Program |
| NHD | National Hydrography Dataset |
| NRCS | Natural Resources Conservation Service |
| NWPL | National Wetland Plant List |
| OHWM | Ordinary High Water Mark |
| PEM | Palustrine Emergent Wetland |
| PVU | Paradox Valley Unit |
| SWReGAP | Southwest Regional GAP Analysis Program |
| USDA | US Department of Agriculture |
| USGS | US Geological Service |
| USACE | US Army Corps of Engineers |
| USFWS | US Fish and Wildlife Service |
| WETS | Wetlands Climate Table |
| WUS | Jurisdictional Waters of the US |

# 1.0 Introduction

The purpose of this field investigation is to complete a preliminary identification of aquatic resources that might be jurisdictional waters of the United States (WUS), including wetlands, relevant for the alternatives identified in a Draft Environmental Impact Statement (EIS) for a proposed action in the Paradox Valley by the US Bureau of Reclamation (Reclamation). The US Army Corps of Engineers (USACE) is serving as one of 18 cooperating agencies in the EIS process and requires a preliminary identification of aquatic resources in order to provide informed comments related to potential WUS under each alternative analyzed in the Draft EIS.

Reclamation currently operates the Paradox Valley Unit (PVU) in western Colorado. The PVU is the largest single contributor to the salinity control program in the Colorado River Basin. Reclamation's proposed action is to continue to construct, operate, and maintain facilities for the collection and disposal of saline ground water of the Paradox Valley, as mandated by Title II, Section 202(a)(1), of the Colorado River Basin Salinity Control Act. The PVU has injected naturally-occurring brine from the Paradox Valley since 1996,but may be nearing the end of its useful life. Therefore, Reclamation is investigating three action alternatives for brine disposal to replace or supplement the existing brine injection well (USBR 2017). Alternative B includes two site alternatives. The action alternatives are identified as the following: Alternative B1 – New Deep Injection Well ("BIF site"), Alternative B2 – New Deep Injection Well ("Monogram Mesa site"), Alternative C – Evaporation Ponds, and Alternative D – Zero-Liquid Discharge Technology.

This report discusses the proposed methodology for the preliminary field efforts to identify aquatic resources and categorizes the types of aquatic resources, including wetlands and streams present within the boundaries of each alternative. Field investigations identified aquatic resources and potential WUS following USACE guidance; however, not every aquatic resource was subject to a full WUS delineation. Once a final alternative is identified, formal delineations of all WUS will be completed for the selected alternative.

# 2.0 Location and Description

The project is in Montrose County, Colorado near Bedrock, CO (Figure 1). The alternative acreages and latitude and longitude in decimal degrees are provided in Table 1.

**Table 1. Survey Area for Each Alternative**

| Alternative | Latitude | Longitude | Acres |
|---|---|---|---|
| Alternative B1 | 38.283629 | -108.896076 | 400 |
| Alternative B2 | 38.26973 | -108.774426 | 810 |
| Alternative C | 38.290357 | -108.823571 | 1,530 |
| Alternative D | 38.264183 | -108.767416 | 480 |
| Note: For this analysis, acres include the maximum external boundaries of each alternative and associated facilities. The actual footprint of any alternatives, if implemented, would likely be less than this amount. | | | |

# 3.0 Methods

## 3.1 Desktop Review

A desktop review of available information was performed prior to conducting field surveys. The desktop review included the following data sources for information on vegetation patterns, topography, drainage, and potential or known wetlands in the project vicinity:

- Aerial Imagery – Aerial imagery from Environmental Systems Research Institute (ESRI) Basemap, US Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) dated 7/26/2014, and GoogleEarth© were reviewed.
- Topographic map – US Geological Service (USGS) 7.5-minute quadrangles were reviewed online at the USGS National Map Viewer (http://viewer.nationalmap.gov/viewer/) (USGS 2018a). A topographic map of the Survey Area is included in Figure 1, Appendix A.
- National Wetlands Inventory (NWI) data - US Fish and Wildlife Service (USFWS) Wetlands Mapper database (http://www.fws.gov/wetlands/Data/Mapper.html) (USFWS 2018). The NWI data is presented with survey results and National Hydrography Dataset (NHD) data in Figure 2, Appendix A .
- Soils data – USDA –Natural Resources Conservation Service (NRCS) online Web Soil Survey (http://websoilsurvey. nrcs.usda.gov/app/HomePage.htm) (NRCS 2017, 2018). Soils data for the Survey Area are included in Section 4.2.3 and Figure 3, Appendix A.
- Climate Data, Wetlands Climate Table (WETS) tables (http://agacis.rcc-acis.org/06105/wets) (ACIS 2018).
- General ecological description of Western Range and Irrigated Region (D-35), Land Resource Region (LRR) and Major Land Resource Areas (MLRA) of the United States, the Caribbean and the Pacific Basin from the USDA Handbook 296 (NRCS 2006).

Preliminary data based on these sources was entered into the USACE Sacramento Office Aquatic Resource spreadsheet (Appendix F) and compiled into GIS data. In addition, aerial images were inspected and any areas that appeared to contain a potential wetland or other WUS was marked and entered into the table and GIS data. Areas identified as high priority for field verification were identified. Personnel with the USACE Colorado West Regulatory Branch reviewed the maps and agreed with the areas identified as high priority for field verification.

## 3.2 Field Methods

On May 8 - 10, 2018, Wood conducted field investigations within the Survey Area. USACE Colorado West Regulatory Branch personnel met Wood personnel during one day of the field investigation. The USACE personnel double checked field methods and reviewed potential wetland areas. Data were collected using a Trimble® R1 Global Navigation Satellite System (GNSS) Receiver handheld Global Positioning System (GPS) unit capable of submeter accuracy. GPS data was imported into ArcGIS. The features were overlaid on topographic and aerial imagery and adjusted using field notes and measurements. All figures were created in ArcGIS 10.4. All field data was recorded in World Geodetic System 1984 (WGS 1984), and field maps were generated using North American Datum 1983, State Plane Colorado South FIPS 0503 (US feet); Linear Units: Feet. The following describes the methodology used during the field survey.

As a preliminary field investigation, not every aquatic resource was fully delineated. In some cases, only a visual inspection was performed. However, representative streams, wetlands, and open water were documented using the appropriate methods (as described below). Any aquatic resources that were visually inspected were matched to a representative site with similar characteristics.

### 3.2.1 Wetlands

For every type of Cowardin classification (e.g. Palustrine Emergent Wetland, Scrub-Shrub Wetland) observed in the field, paired wetland sample points, following the 1987 USACE Delineation Manual and the Arid West Regional Supplement (Version 2), were collected (Cowardin et al. 1979; Environmental Laboratory 1987; USACE 2008). Any sites with this full delineation were considered representative sites and used as baseline sample points for each Cowardin classification. Data was recorded on an Arid West electronic Wetform or an Arid West Determination datasheet hard copy. Data collected at each paired sample point included:

a. Vegetation - 2016 National Wetland Plant List and the USDA Plants Database (Lichvar et al. 2016; USDA 2018)
b. Soils - Field Indicator of Hydric Soils, Version 8.1 2017 (NRCS 2016)
c. Hydrology
d. GPS data of paired sample points and wetland boundary
e. Site photographs - Minimum of a photo in each cardinal direction

Potential wetlands that exhibit the same visual signature as the representative wetlands were documented. Visual inspections documented vegetation, hydrology where practical, and landscape position. Each aquatic resource was given a unique number. In addition, documentation was recorded to identify which representative wetland sample point contained similar characteristics to the aquatic resource. Dominant vegetation and photos in each of the cardinal directions were recorded. For each visually inspected wetland, a GPS point or polygon was collected based on a visual determination of the boundary, and the type of wetland (i.e., Cowardin classification) was recorded.

### 3.2.2 Streams and Open Water

Throughout the survey areas, streams (and open water, if any) were visually inspected. Existing NHD data and aerial imagery were verified in the field. Areas with noticeable discrepancies were prioritized for field verification over those areas that appeared to match up well with the existing NHD data. For the purposes of this report, intermittent and ephemeral streams were not differentiated and were assumed to be ephemeral based on visual observations of the absence of riparian or other vegetation with a wetland indicator status. The USACE defines intermittent streams as “having flow during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow. Ephemeral streams have flowing water only during, and for a short duration after, precipitation events in a typical year. Runoff from rainfall is the primary source of water for stream flow (USACE 2017). For representative stream channels, the following data was collected:

a. The Ordinary High Water Mark (OHWM) data sheet was completed, and in the case of ephemeral streams, the Arid West Ephemeral and Intermittent Streams OHWM Datasheet was used (Lichvar & McColley 2008; Curtis & Lichvar 2010);
b. GPS data was collected on the channel centerline and/or the OHWM and an average width was recorded for the channel reach within the Survey Area; and

c. Photos were collected that represent the upstream and downstream channel.

At a minimum, representative stream channels were recorded for each type of stream (i.e., perennial, intermittent, and ephemeral) throughout the Survey Area. In areas with perennial streams, the OHWM was walked. If an area could not be walked due to safety concerns, OHWM points were collected within accessible areas and refined within ArcMap during post-processing.

Where time allowed, channel OHWMs/centerlines and culvert crossings were recorded. When time was limited, field sample points were collected to sufficiently delineate channels off aerial imagery in ArcMap during post-processing:

a. Assumptions on channel width, connectivity, and OHWMs were based off field observations within the area; and

b. Assumptions were made regarding culvert crossings.

## 3.3 Post-Processing and Finalization

GPS data were verified and finalized in ArcMap, extrapolating where needed based on aerial imagery and other data. Maps for wetlands were created using representative wetland sample points, delineated wetland boundaries, and estimated wetland boundaries. Maps for streams were created using the approximate OHWM and stream type (e.g. perennial, ephemeral).

Data were overlaid on an aerial image, and the Sacramento District's Map and drawing standards for the South Pacific Division Regulatory Program were followed, where feasible. Where mapping efforts deviated from the map standards:

a. Areas are estimates

b. Aquatic resources were mapped within the maximum external boundaries of each alternative, including associated facilities. Final impacts to each aquatic resource will be identified once a preferred alternative is selected.

c. Most wetland boundaries are based on visual observations of hydrophytic vegetation and correlated with the representative wetland and do not contain paired sample points.

d. An OHWM data sheet was not recorded for all channels within the Survey Area.

e. OHWM widths, characteristics, and connectivity are estimates

f. Cross section maps are not included.

g. Data represents a combination of GIS desktop resources and field observations. The data does not represent all channel meanders, either natural or with man-made features (e.g. culvert crossings).

The following items were prepared based on the field methods and post-processing. These items are included in the delineation report prepared for the USACE and Reclamation.

1. Aquatic Resource map identifying potential WUS, including wetlands
2. Aquatic Resources Excel spreadsheet (Appendix F)
    a. Created based on desktop review and revised based on field data and observations

   b. In addition to the standard columns, a column indicates whether a full delineation was completed (either wetland or OHWM) or only a visual inspection was completed (e.g. data point in the field).
3. Arid West Determination forms of representative wetlands
4. OHWM Datasheets of representative channels
5. Photolog
   a. Representative images of wetlands depicting soils, vegetation, and landscape position
   b. Representative images of perennial, intermittent, and ephemeral channels

# 4.0 Existing Conditions

## 4.1 Landscape Setting

General knowledge of the Survey Area assists in identifying water features that may constitute potentially jurisdictional WUS, prior to performing the site visit. The following paragraphs describe the general land uses, geology and hydrogeology, and climate identified within the Survey Area.

The USDA NRCS completed a detailed report documenting the general conditions of land resource areas in the Land Resource Regions (LRR) and MLRA of the United States, the Caribbean, and the Pacific Basin (NRCS 2006). According to the report, the Survey Area falls within LRR D – Western Range and Irrigated Region and MLRA 36 – Southwestern Plateaus, Mesas, and Foothills (NRCS 2006).

The Southwestern Plateaus, Mesas, and Foothills area is on the Intermontane Plateaus and mainly in Canyon Lands and Navajo Sections of the Colorado Plateaus Province on top of sedimentary rock formations (NRCS 2006). Elevation within the system generally ranges from 4,600 to 8,500 feet above mean sea level (AMSL) (NRCS 2006). Elevation across the Survey Area site ranges from 4,950 to 6,994 feet AMSL.

Geology of this MLRA is affected by erosion of Jurassic, Cretaceous, and Tertiary sedimentary rocks (NRCS 2006). The area is comprised of horizontal beds of sedimentary rocks with representative formations including the Morrison Formation, Dakota Sandstone, Cliff House Sandstone, and other members of the Mesa Verde group (NRCS 2006). Formations have been eroded into plateaus, mesas, hills, and canyons, which are evident throughout the Survey Area.

### 4.1.1 Land Use

Land use within the MLRA consists of grasslands and shrublands primarily used for grazing, forest, or irrigated crops such as alfalfa, hay, and wheat (NRCS 2006). The majority of the Survey Area consists of shrubland managed by BLM for grazing, open land, and recreation.

### 4.1.2 Regional Hydrology and Climate

Paradox, Colorado has a 20-year normal temperature range from 15°F to 94°F and an average annual precipitation of approximately 13.32 inches (ACIS 2018). Current data from the US Drought Monitor shows the Survey Area is in a D3 drought level which is considered extreme drought (NOAA 2018). The Bedrock, Colorado USGS Dolores River stream gauge (09169500) data for 2014 - 2018 shows that the river consistently fluctuates between 100 cubic feet per second (cfs) in January to an average peak of 1,000 cfs in the spring (USGS 2018b). Provisional gauge data for 2018 shows the river level at approximately 60 cfs in January and 6 cfs in June. A copy of the gauge data is attached to the OHWM datasheet for the Dolores River in Appendix E.

The Federal Emergency Management Agency (FEMA) mapping for the Project Area is designated as Zone D (FEMA 2018). The Zone D designation is used in areas where there are possible but undetermined flood hazards, and no analysis of floods hazards has occurred.

### 4.1.3 Survey Area Hydrology

The Survey Area occurs predominantly within the Upper Dolores Watershed, with a small portion of the proposed natural gas pipeline of Alternative D within the San Miguel Watershed (USGS Hydrologic Unit Code 14030002, 14030003). The Alternatives contain portions of the Dolores River, one named stream East Paradox Creek, and numerous unnamed ephemeral streams. Hydrology within the Survey Area drains toward the Dolores River, with the exception of a one-mile portion of the proposed natural gas pipeline within Alternative D that flows east into the San Miguel River.

### 4.1.4 Topography and Site Drainage

The Survey Area is comprised of mesas, terraces, floodplains, and flat grassland and shrublands. Portions of Alternatives B1 and C lie within the Dolores River floodplain and terraces. The southern portion of Alternative B1 is on a ridge above the river floodplain. Surface water within Alternative B1 drains south to north toward the Dolores River. The dominant surface water drainage within Alternatives C and D flows east to west toward the Dolores River. Surface water drainage within Alternative B2 flows northeast to southeast.

## 4.2 Aquatic Resources

### 4.2.1 Wetlands

NWI data reviewed prior to field surveys identified two types of palustrine wetland habitats and four types of riverine habitats within the alternative boundaries (Table 2). The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergent vegetation, emergent mosses or lichens (Cowardin et al. 1979). The Riverine System includes all wetlands and deepwater habitats contained within a channel, unless the wetland is dominated by trees, shrubs, persistent emergent vegetation, emergent mosses, or lichens, and/or the habitats contain water with ocean-derived salts of 0.5 parts per thousand or greater (USFWS 2018). Figure 2 in Appendix A depicts the NWI data reviewed prior to the field surveys.

**Table 2. Mapped NWI Features by Alternative**

| Alternative | NWI Type | Cowardin Code | Cowardin Code Description |
|---|---|---|---|
| **Alternative B1** | Palustrine | PSAA | Palustrine Scrub-Shrub Temporary Flood |
| | | PABFh | Palustrine, Aquatic Bed, Semipermanently Flooded |
| | Riverine | R3USA | Riverine, Upper Perennial, Unconsolidated Shore, Temporary Flooded |
| | | R3USC | Riverine, Upper Perennial, Unconsolidated Shore, Seasonally Flooded |
| | | R3UBH | Riverine, Upper Perennial, Unconsolidated Bottom, Permanently Flooded |

| Alternative | NWI Type | Cowardin Code | Cowardin Code Description |
|---|---|---|---|
| **Alternative B2** | Riverine | R4SBA | Riverine, Intermittent, Streambed, Temporary Flooded |
| **Alternative C** | Riverine | R4SBA | Riverine, Intermittent, Streambed, Temporary Flooded |
| | Palustrine | PABFh | Palustrine, Aquatic Bed, Semipermanently Flooded |
| **Alternative D** | Riverine | R4SBA | Riverine, Intermittent, Streambed, Temporary Flooded |
| **Source:** (Cowardin 2011; USFWS 2018) | | | |

#### 4.2.1.1 Representative Wetlands

During field surveys, wetlands were identified adjacent to the Dolores River within the boundaries of Alternatives B1 and C. Within these areas, one wetland (Wetland 2) sample point and an upland (Upland 2) determination sample point were collected (Figure 4, Appendix D). Wetland Determination Data Forms are attached in Appendix D. Hydrophytic vegetation observed within the representative wetland sample point includes reed canarygrass (*Phalaris arundinacea*), saltgrass (*Distichlis spicata*), coyote willow (*Salix exigua*), muhly grass (*Muhlenbergia sp.*), watercress (*Nasturtium officinale*), broadleaf cattail (*Typha latifolia*), eastern cottonwood (*Populus deltoides*), and Siberian elm (*Ulmus pumila*). The hydric soil indicator within this area is sandy redox, and site hydrology within the wetland area includes saturation and a high water table. This wetland is classified as a Palustrine Emergent Wetland (PEM).

Vegetation within the upland sample point includes common reed (*Phragmites australis*), common threesquare (*Schoenoplectus pungens*), coyote willow, and tamarisk (*Tamarix sp*). This upland sample point does not contain hydric soil indicators but exhibits saturation and a water table at 11 inches below the surface.

A second upland sample point (Upland 1) was taken to determine if a willow community bordering the Dolores River qualified as a wetland. Hydrophytic vegetation is present but wetland hydrology is not present, so this point was determined to be an upland site. This point is located within a coyote willow-dominated area, and also contains tamarisk, field pennycress (*Thalspi arvense*), water sedge (*Carex aquatilis*), and timothy grass (*Phleum pratense*). The point did not contain wetland hydrology indicators, so soils were not evaluated.

#### 4.2.1.2 Delineated and Visually Inspected Wetlands

Three sites were evaluated for the presence of wetlands, and only one (Wetland 2) was determined to contain all three wetland indicators -- hydric soils, hydrophytic vegetation, and wetland hydrology (Figure 4, Appendix A). For the purposes of this project, an estimated three-foot wetland buffer was assumed along each bank of the Dolores River within the Survey Area. This assumption was discussed and agreed upon during the site visit with the USACE. The three-foot buffer was created using GPS field data, existing GIS data, and aerial imagery within ArcGIS. The wetlands within this area are consistent with sample point Wetland 2, which is dominated by reed canarygrass, common threesquare, and saltgrass. The Dolores River within the Survey Area is incised approximately four feet on average. The incised banks of the Dolores River, combined with relatively low water levels within the river channel, are limiting factors for wetland development beyond the three-foot buffer. Hydrophytic vegetation was observed in areas outside the three-foot wetland buffer but those areas lacked hydric soil indicators and wetland hydrology. Figures are provided in Appendix A.

**Table 3. Wetlands Identified in Survey Area**

| Alternative | Cowardin Code | Cowardin Description | Size (acres) | Method (Delineation or Visual) | Wetland Description |
|---|---|---|---|---|---|
| **Alternative B1 (Figure 5)** | PEM | Palustrine, Emergent | 1.47 | Delineation and Visual | 3-foot buffer adjacent to the Dolores River |
| **Alternative C (Figure 7)** | PEM | Palustrine, Emergent | 0.10 | Delineation and Visual | 3-foot buffer adjacent to the Dolores River |

### 4.2.2 Streams and Open Water

The majority of the streams within the Survey Area consist of ephemeral washes. The NHD data commonly identified these as intermittent streams, but field conditions indicated that the streams were primarily ephemeral, unless otherwise noted. Common OHWM indicators used to identify the OHWM were bed and bank, sediment sorting, mudcracks, and vegetation zonation. Typically, the active channel was devoid of vegetation, with upland species such as sagebrush and cheatgrass on adjacent terraces.

#### 4.2.2.1 Representative Delineated Streams

Within each alternative boundary, an OHWM datasheet was completed for one or more representative stream channels. For ephemeral/intermittent streams, an *Arid West Ephemeral and Intermittent Streams OHWM Datasheet* was completed. For the Dolores River, a perennial river, an *OHWM Delineation Datasheet* was completed. These data were collected to provide the USACE information on representative channels within each alternative and assist with the refinement of the desktop GIS data. These can be found in Appendix E, with photographs of representative channels in Appendix B. Figure 4 in Appendix A and Table 4 identify the representative stream locations. Vegetation is discussed in Section 4.2.4 and in Appendix C.

The representative stream within Alternative B1 is the Dolores River. The river is categorized within the Cowardin classification system as an Unconsolidated bottom, Lower perennial, Riverine system (R2UB). The channel averages 30 feet wide at the OHWM, with an incised stream bank and an unconsolidated bottom. Vegetation adjacent to the Dolores River is dominated by herbaceous plants with a small percentage of shrubs.

The representative stream within Alternative B2 is an unnamed ephemeral stream. The Cowardin classification for channels within Alternative B2 is R6 (i.e., a wetland, spring, stream, river, pond or lake that only exists for a short period). The channel is unvegetated and the typical sediment texture is silt. The average width of the channel at the OHWM is approximately four feet.

The representative stream within Alternative C is East Paradox Creek, which is an ephemeral stream based on visual observations, particularly the absence of riparian or other vegetation with a wetland indicator status. In addition, data indicate that the groundwater table in this area is 400-600 feet deep. The Cowardin classifi.cation for East Paradox Creek is R6. The typical sediment texture consists of a fine silty sand with smaller gravel within the channel. The average width of East Paradox Creek at the OHWM is approximately six feet. The active floodplain is sparsely vegetated, with approximately ten percent herbaceous upland cover.

The representative stream within Alternative D is an unnamed ephemeral stream. The Cowardin classification for the stream is R6. The typical sediment texture is sandy with cobble within the channel. The average width of the channel is ten feet at the OHWM. Vegetation cover within the active floodplain consists of about 30 percent herbaceous upland plants.

**Table 4. Representative Stream Locations**

| Alternative | Sample Point | Latitude | Longitude | Channel Type |
|---|---|---|---|---|
| **Alternative B1** | OWUS 4 | 38.307966 | -108.889829 | Perennial: Dolores River |
| **Alternative B2** | OWUS 2 | 38.199611 | -108.772728 | Ephemeral |
| **Alternative C** | OWUS 1 | 38.277653 | -108.763058 | Ephemeral: East Paradox Creek |
| **Alternative D** | OWUS 3 | 38.32053 | -108.844370 | Ephemeral |

### 4.2.2.2 Visually Inspected Streams

A total of 16 acres and more than 80,000 linear feet of stream channels were identified within the Survey Area (

Table 5). The majority of streams within the Survey Area are ephemeral including East Paradox Creek, and one perennial stream (Dolores River). Visually inspected stream channels are similar in characteristics to the representative streams discussed in Section 4.2.2.1.

The observed ephemeral streams are typically sandy, unvegetated, narrow channels averaging two feet wide. There are a few exceptions within Alternative B2, where bedrock is shallow and exposed in the channel bed in some of the streams. When vegetation did occur, it was upland herbaceous or shrub species.

East Paradox Creek, an ephemeral stream, occurs within the northern portion of Alternative C. This channel was predominantly bare of vegetation. OHWM characteristics were the same as observed in the ephemeral channels; however, the channel was wider, sediment particles were larger, and there was evidence of sand bars.

The Dolores River is a perennial stream located within Alternatives B1 and C. The river channel is approximately 30 feet wide at the OHWM and is severely incised. The channel bed is approximately four feet lower than the low terrace. OHWM characteristics within Alternatives B1 and C are the presence of a defined bed and bank, vegetation zonation, benches, soil development, and drift lines and/or debris. Figures 5 through 8 depict the streams identified for each alternative.

**Table 5. Streams Identified in Survey Area**

| Alternative | Cowardin Code | Cowardin Description | Area: Acres (Length: feet) | Method (Delineation, Visual) | Water Description |
|---|---|---|---|---|---|
| **Alternative B1 (Figure 5)** | R2UB | Unconsolidated Bottom, Lower Perennial, Riverine | 10.64 (10,973) | Delineation and Visual | Dolores River |
| | R6 | A wetland, spring, stream, river, pond or lake that only exists for a short period | 0.08 (3,612) | Visual | Unnamed ephemeral streams |
| **Alternative B2 (Figure 6)** | R6 | A wetland, spring, stream, river, pond or lake that only exists for a short period | 0.40 (5,783) | Delineation and Visual | Unnamed ephemeral stream |
| **Alternative C (Figure 7)** | R2UB | Unconsolidated Bottom, Lower Perennial, Riverine | 0.63 (587) | Visual | Dolores River |
| | R6 | A wetland, spring, stream, river, pond or lake that only exists for a short period | 3.71 (53,747) | Delineation and Visual | East Paradox Creek & Unnamed ephemeral streams |
| **Alternative D (Figure 8)** | R6 | A wetland, spring, stream, river, pond or lake that only exists for a short period | 0.37 (5,832) | Delineation and Visual | Unnamed ephemeral streams |

#### 4.2.2.3 Open Water

A 0.03-acre stock pond classified as L1UB (Unconsolidated Bottom, Limnetic, Lacustrine) occurs within Alternative B2 (Figure 6, Appendix A). Several other potential stock ponds or excavated detention areas were found within other alternatives, but these did not contain water or wetland vegetation.

### 4.2.3 Soils

Table 6 lists the results of the NRCS Web Soil Survey, which identified 19 mapped soil types in the 2,906 acres of Survey Area (Figure 3, NRCS 2018). These soils are predominantly Paradox fine sandy loam, 1 to 4 percent slopes (26 percent of the Survey Area); Barx fine sandy loam, 3 to 6 percent slopes (16 percent of Survey Area); and Gypsiorthids, 3 to 25 percent slopes (14 percent of Survey Area). Rock outcrops (3 percent) and water (1 percent) make up a small portion of the Survey Area. The majority of soils within the Survey Area are well-drained sandy loams (NRCS 2018). Within the Survey Area, only the Fluvaquents, 0 to 6 percent slopes, frequently flooded (2 percent) soil is hydric (NRCS 2018).

**Table 6. Soil Units within the Survey Area**

| Map Unit Symbol | Map Unit Name | Landform | Runoff Class | Natural Drainage | Acres in Survey Area |
|---|---|---|---|---|---|
| 14 | Barx fine sandy loam, 1 to 3 percent slopes | Mesa, terraces | Low | Well drained | 26.9 |
| 15 | Barx fine sandy loam, 3 to 6 percent slopes | Terraces | Medium | Well drained | 458.7 |
| 17 | Barx-Progresso complex, 3 to 12 percent slopes | Mesa, terraces | Medium | Well drained | 4.6 |
| 18 | Begay fine sandy loam, 1 to 6 percent slopes | Terraces | Very low | Well drained | 175.7 |
| 23 | Bodot, dry-Ustic Torriorthents complex, 5 to 50 percent slopes | Structural benches, terraces, landslides | Very high | Well drained | 115.4 |
| 43 | Fluvaquents, 0 to 6 percent slopes, frequently flooded | Flood plains, terraces | Low | Somewhat poorly drained | 46.5 |
| 45 | Gladel-Bond-Rock outcrop complex, 1 to 50 percent slopes | Escarpments, mesas, structural benches | Very high | Well drained | 59.7 |
| 49 | Gypsiorthids, 3 to 25 percent slopes | Valley floors, terraces | Medium | Well drained | 415.0 |
| 50 | Gypsum land | Knobs on valley floors | No data | No data | 215.5 |
| 59 | Mivida fine sandy loam, 5 to 15 percent slopes | Alluvial fans, terraces | Low | Well drained | 14.2 |
| 60 | Monogram loam, 1 to 8 percent slopes | Mesas, structural benches | High | Well drained | 126.8 |
| 73 | Paradox fine sandy loam, 1 to 4 percent slopes | Alluvial fans, valley floors | Low | Well drained | 752.6 |
| 75 | Pinon-Bowdish-Progresso loams, cool, 1 to 12 percent slopes | Mesas, ridges | Very high | Well drained | 102.5 |
| 76 | Pinon-Bowdish-Rock outcrop complex, 3 to 30 percent slopes | Structural benches, escarpments, mesas | Very high | Well drained | 68.6 |
| 79 | Pojoaque-Chilton complex, 5 to | Alluvial fans, hills | Medium | Well drained | 160.7 |

| Map Unit Symbol | Map Unit Name | Landform | Runoff Class | Natural Drainage | Acres in Survey Area |
|---|---|---|---|---|---|
| | 30 percent slopes, extremely stony | | | | |
| 87 | Rock outcrop | Mesas, canyons | Very high | N/A | 97.5 |
| 88 | Rock outcrop-Orthents complex, 40 to 90 percent slopes | Structural benches, canyons | High | Well drained | 20.8 |
| 95 | Skein-Rock outcrop complex, 3 to 65 percent slopes | Mesas, canyons | Very high | Well drained | 3.1 |
| 112 | Water | | | | 40.6 |
| **Totals for Area of Interest** | | | | | 2,905.5 |
| Source: (NRCS 2018) | | | | | |

### 4.2.4 Plant Communities

The majority of the Survey Area is dominated by the Inter-Mountain Basins Big Sagebrush Shrubland community, with smaller areas of Colorado Plateau Pinyon-Juniper Shrubland, Invasive Annual Grassland, and Invasive Southwest Riparian Woodland and Shrubland as defined by the Southwest Regional Gap Analysis Program (SWReGAP) (SWReGAP 2004; Lowry et al. 2005). As a result of the drought, the majority of the vegetation was stunted or desiccated. The Inter-Mountain Basins Big Sagebrush Shrubland, Colorado Plateau Pinyon-Juniper Shrubland, and Invasive Annual Grassland communities are similar in composition with differences in dominant vegetation.

Dominant vegetation identified in the Survey Area includes Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), rubber rabbitbrush (*Ericameria nauseosa*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), Russian knapweed (*Acroptilon repens*), and cheatgrass (*Bromus tectorum*). Additional species include oneseed juniper (*Juniperus monosperma*), Indian ricegrass (*Achnatherum hymenoides*), greasewood (*Sarcobatus vermiculatus*), field pennycress (*Thlaspi arvense*), and crested wheatgrass (*Agropyron cristatum*). A full list of species observed within the Survey Area is in Appendix C.

Areas along the Dolores River are within the SWReGAP community Invasive Southwest Riparian Woodland and Shrubland. This community was identified adjacent to the Dolores River within Alternative B1. Vegetation observed within this area includes reed canarygrass, saltgrass, coyote willow, common reed, tamarisk, eastern cottonwood, single-leaf ash (*Fraxinus anomala*), and Siberian elm (*Ulmus pumila*). Most of the ephemeral stream channels found throughout the Survey Area are devoid of vegetation. Areas adjacent to the channels are typically dominated by Wyoming big sagebrush, cheatgrass, and Russian knapweed.

# 5.0 Conclusions

This preliminary investigation of aquatic resources yielded the following potential aquatic resources by alternative under consideration. These aquatic resources would need to be formally delineated prior to any action or permitting. The attached Aquatic Resources Spreadsheet (Appendix F) identifies each individual aquatic resource by alternative.

- Under Alternative B1, there are approximately 1.5 acres of emergent wetlands, 11 (10,973 feet) acres of perennial stream, and less than 0.1 acres (3,612 feet) of ephemeral streams.
- Under Alternative B2, there are approximately 0.4 acres (5,783 feet) of ephemeral streams.
- Under Alternative C, there are approximately 0.1 acres of emergent wetlands, 0.6 acres (587 feet) of perennial stream, and 3.7 acres (53,747 feet) of ephemeral streams.
- Under Alternative D, there are approximately 0.4 acres (5,832 feet) of ephemeral streams.

# 6.0 References

ACIS. 2018. AgACIS for Montrose County: Paradox 2N, CO. National Oceanic & Atmospheric Administration Regional Climate Centers, ACIS. Available from http://agacis.rcc-acis.org/?fips=08085 (accessed June 7, 2018).

CDA. 2018. Noxious Weed Species | Department of Agriculture – Conservation Services. Colorado Department of Agriculture. Available from https://www.colorado.gov/pacific/agconservation/noxious-weed-species (accessed June 21, 2018).

Cowardin, LM. 2011. Wetlands and Deepwater Habitats Classification Chart. Available from https://www.fws.gov/wetlands/documents/Wetlands-and-Deepwater-Habitats-Classification-chart.pdf (accessed June 8, 2018).

Cowardin LM, Carter V, Golet FC, LaRoe ET. 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. US Fish and Wildlife Service, Washington DC.

Curtis KE, Lichvar RW. 2010. Updated Datasheet for the Identification of the Ordinary High Water Mark (OHWM) in the Arid West Region of the Western United States. TN-10-1. 20 pages. Cold Regions Research and Engineering Laboratory, US Army Engineer Research and Development Center.

Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. 143 pages. Technical Report Y-87-1. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss. Available from http://www.lrh.usace.army.mil/Portals/38/docs/USACE%2087%20Wetland%20Delineation%20Manual.pdf (accessed December 6, 2017).

FEMA. 2018. FEMA Flood Map Service Center |Montrose County Unincorporated Areas. Federal Emergency Management Agency. Available from https://msc.fema.gov/portal/search#searchresultsanchor (accessed June 8, 2018).

Lichvar R, McColley S. 2008. A Field Guide to the Identification of the OHWM in the Arid West: A Delineation Manual. ERDC/CRREL TR-08-12. Cold Regions Research and Engineering Laboratory, US Army Engineer Research and Development Center, Hanover, NH. Available from http://www.spk.usace.army.mil/Portals/12/documents/regulatory/pdf/Ordinary_High_Watermark_Manual_Aug_2008.pdf (accessed June 6, 2018).

Lichvar RW, Kirchner WN, Melvin NC. 2016. The National Wetland Plant List: 2016 Wetland Ratings. *Phytoneuron* **30:1–17**. Available from http://wetland-plants.usace.army.mil/nwpl_static/home/home.html (accessed June 20, 2018).

Lowry J et al. 2005. Southwest Regional Gap Analysis Project: Final Report on Land Cover Mapping Methods. GIS Laboratory Utah State University, Logan, Utah. Available from http://www.gapserve.ncsu.edu/swgap/swgap/ (accessed June 19, 2018).

NOAA. 2018. United States Drought Monitor > Current Map > State Drought Monitor. National Weather Service, National Oceanic and Atmospheric Administration and The National Drought Mitigation Center, University of Nebraska at Lincoln, Lincoln, NE. Available from http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?CO (accessed June 7, 2018).

NRCS. 2006. NRCS MLRA Explorer. USDA Agriculture Handbook. US Department of Agriculture, Natural Resources Conservation Service. Available from http://apps.cei.psu.edu/mlra/ (accessed June 6, 2018).

NRCS. 2016. Field Indicators of Hydric Soils in the United States, Version 8.0. US Department of Agriculture, Natural Resources Conservation Service.

NRCS. 2017. Web Soil Survey. Soil Survey Staff, Natural Resources Conservation Service, US Department of Agriculture. Available from https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed June 4, 2018).

NRCS. 2018. Custom Soil Resource Report for San Miguel Area, Colorado, Parts of Dolores, Montrose, and San Miguel Counties: PVU. US Department of Agriculture, Natural Resources Conservation Service, Washingson, D.C. Available from https://websoilsurvey.sc.egov.usda.gov/WssProduct/5mm3uim032yeixfn1w1h5z0a/GN_00000/20180608_09522709511_63_Soil_Report.pdf (accessed June 8, 2018).

SWReGAP. 2004. Southwest Regional GAP Analysis Project - Land Cover Descriptions. USGS, Natureserve, Utah State University. Available from http://swregap.nmsu.edu/AssociatedProducts.htm (accessed August 15, 2016).

USACE. 2008. ERDC/EL TR-08-28, Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Arid West Region (Version 2.0). ERDC/EL TR-08-28. US Army Engineer Research and Development Center, Vicksburg, MS. Available from http://www.usace.army.mil/Portals/2/docs/civilworks/regulatory/reg_supp/trel08-28.pdf (accessed October 8, 2015).

USACE. 2017. Nationwide Permits, Conditions, District Engineer's Decision. Further Information, and Definitions. US Army Corps of Engineers.

USBR. 2017. Paradox Valley Unit Environmental Impact Statement. Available from https://www.usbr.gov/uc/wcao/progact/paradox/index.html#EIS (accessed June 6, 2018).

USDA. 2018. The PLANTS Database. US Department of Agriculture, National Plant Data Team, Greensboro, NC. Available from http://plants.usda.gov/java/nameSearch (accessed June 8, 2018).

USFWS. 2018. National Wetlands Inventory - Wetlands Mapper. US Fish and Wildlife Service. Available from https://www.fws.gov/wetlands/data/Mapper.html (accessed June 18, 2018).

USGS. 2018a. The National Map: TNM Download. US Geologic Survey. Available from https://viewer.nationalmap.gov/basic/ (accessed June 5, 2018).

USGS. 2018b. USGS Current Conditions for USGS 09169500 DOLORES RIVER AT BEDROCK, CO. US Geologic Survey. Available from https://nwis.waterdata.usgs.gov/co/nwis/uv?cb_00060=on&format=gif_default&site_no=09169500&period=&begin_date=2018-01-01&end_date=2018-06-19 (accessed June 19, 2018).

# APPENDIX A: FIGURES

Figure 1: Project Overview

Figure 2: NWI and NHD Data

Figure 3: Soils Data

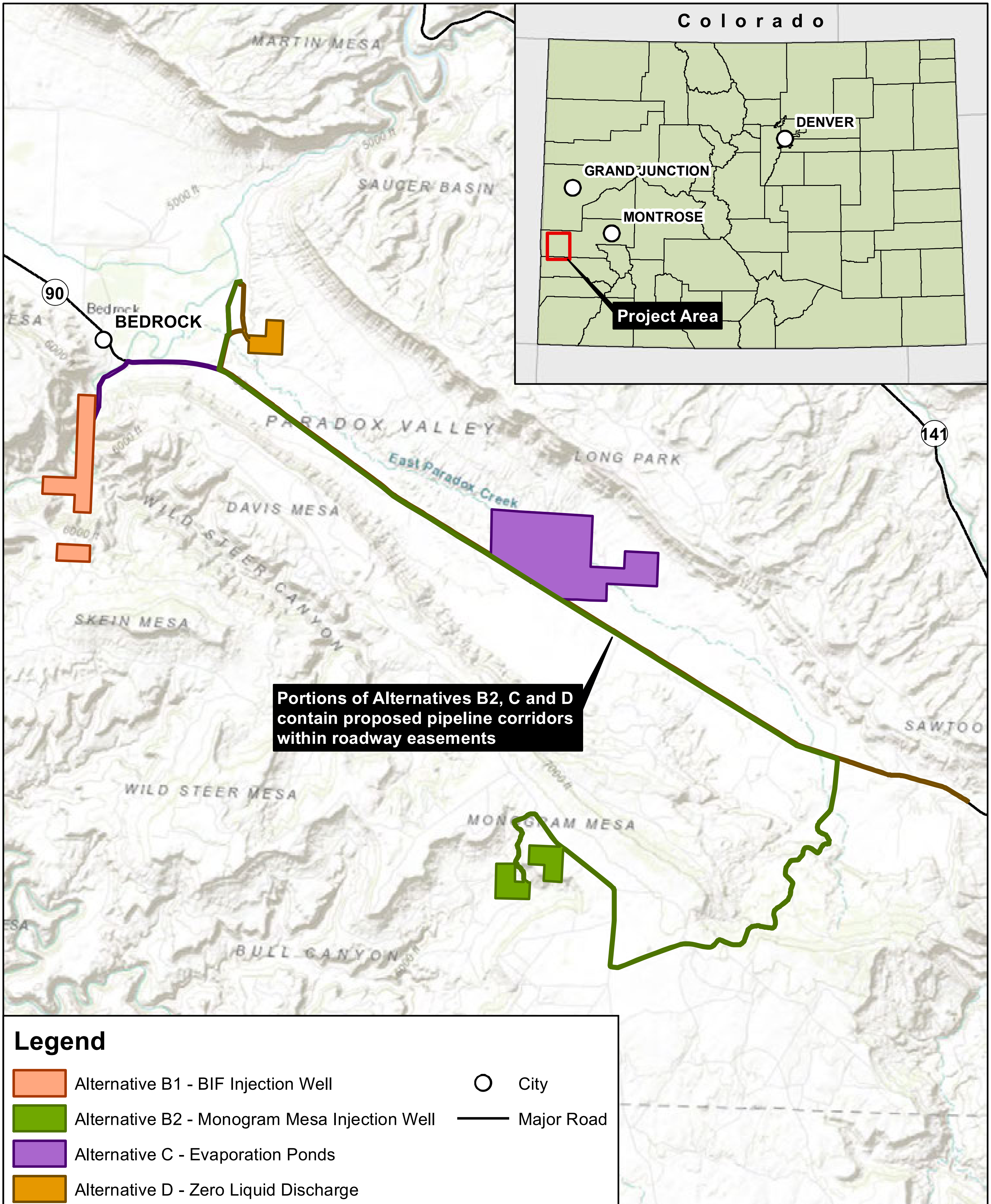
Figure 4: Field Data Points

Figure 5: Alternative B1 (multi-part maps)

Figure 6: Alternative B2 (multi-part maps)

Figure 7: Alternative C (multi-part maps)

Figure 8: Alternative D (multi-part maps)

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**Project Overview Map**

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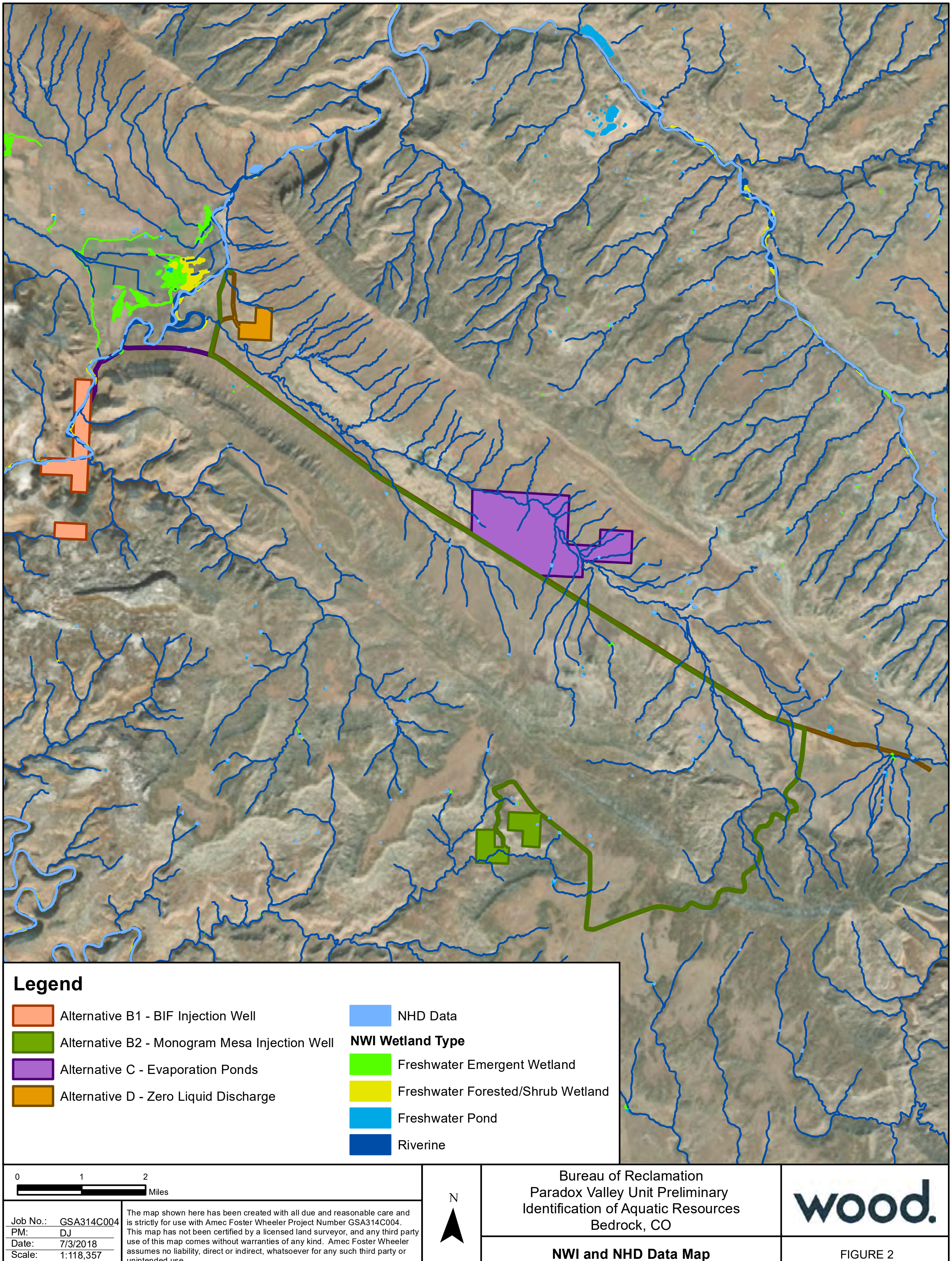
FIGURE 1

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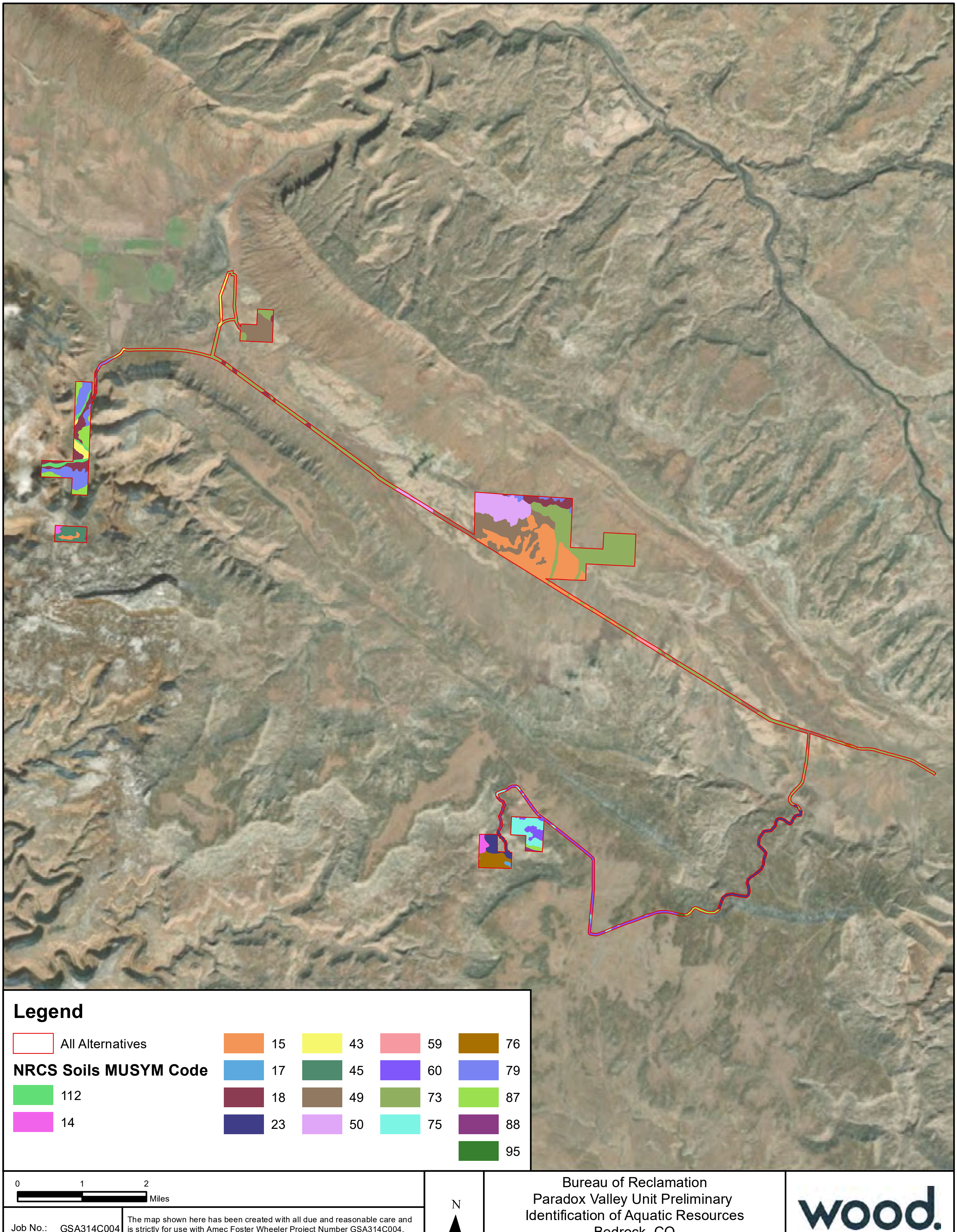
**NWI and NHD Data Map**

FIGURE 2

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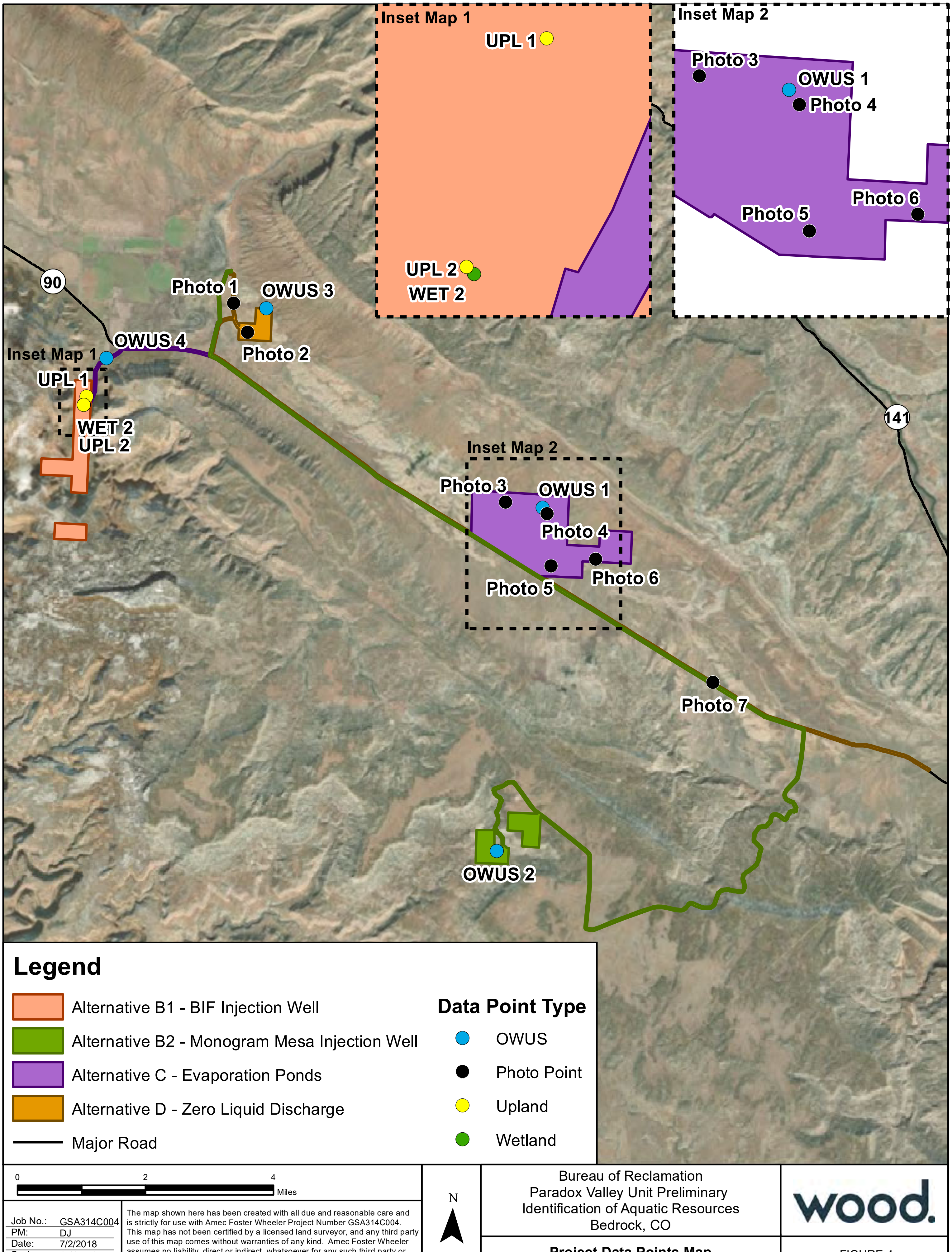
**NRCS Soils Data Map**

FIGURE 3

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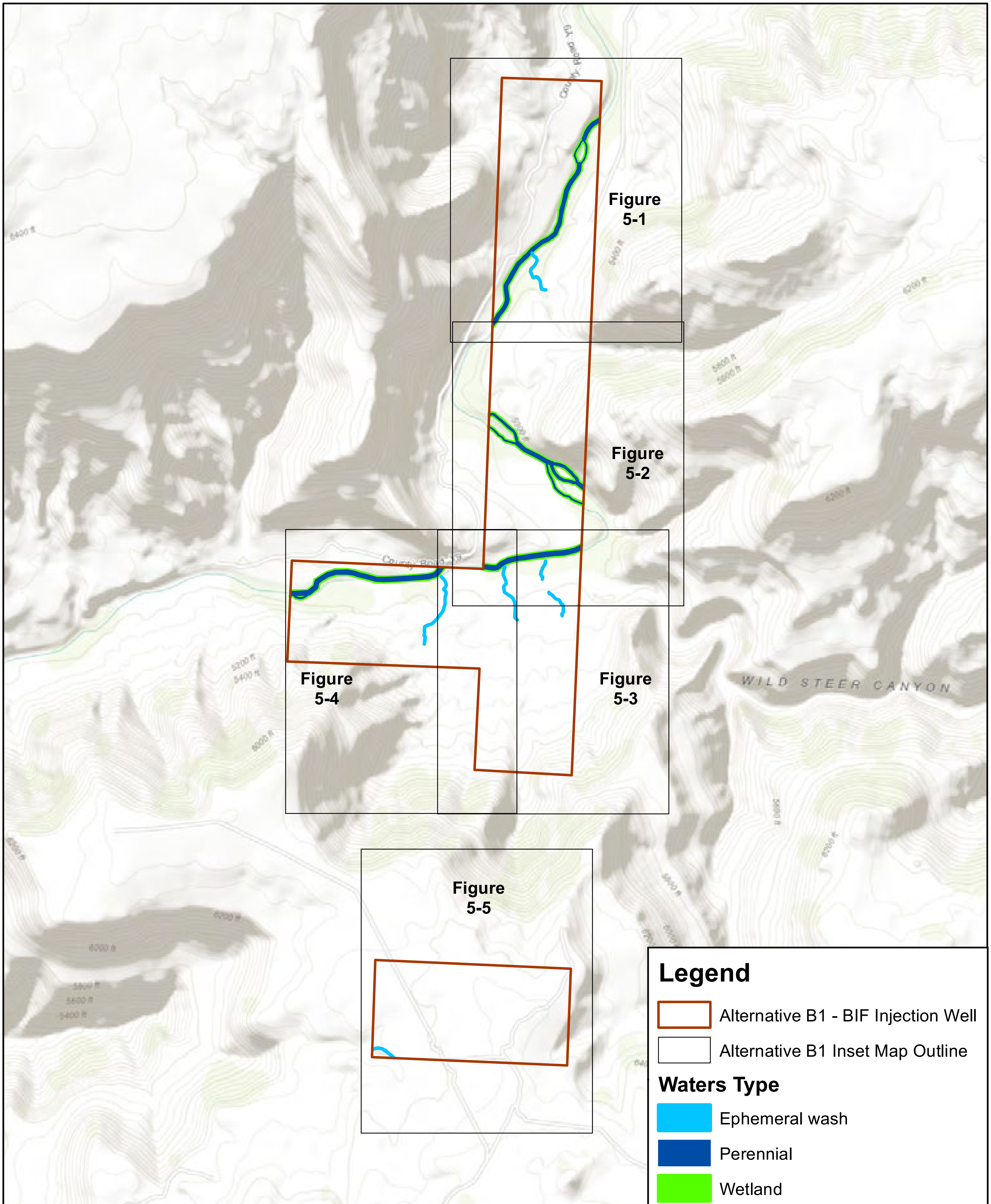
**Project Data Points Map**

FIGURE 4

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**Alternative B1 Waters Overview Map**

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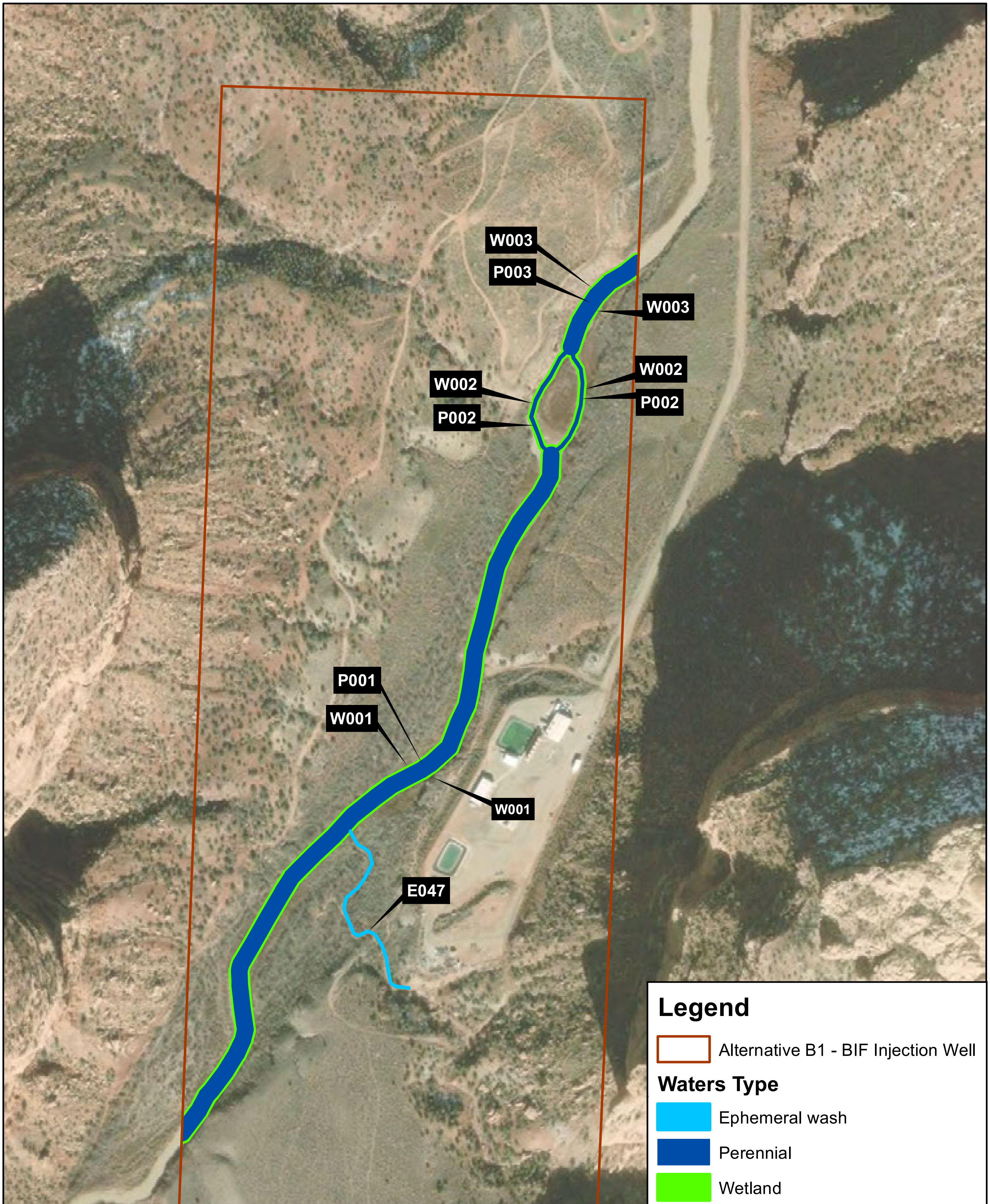
FIGURE 5

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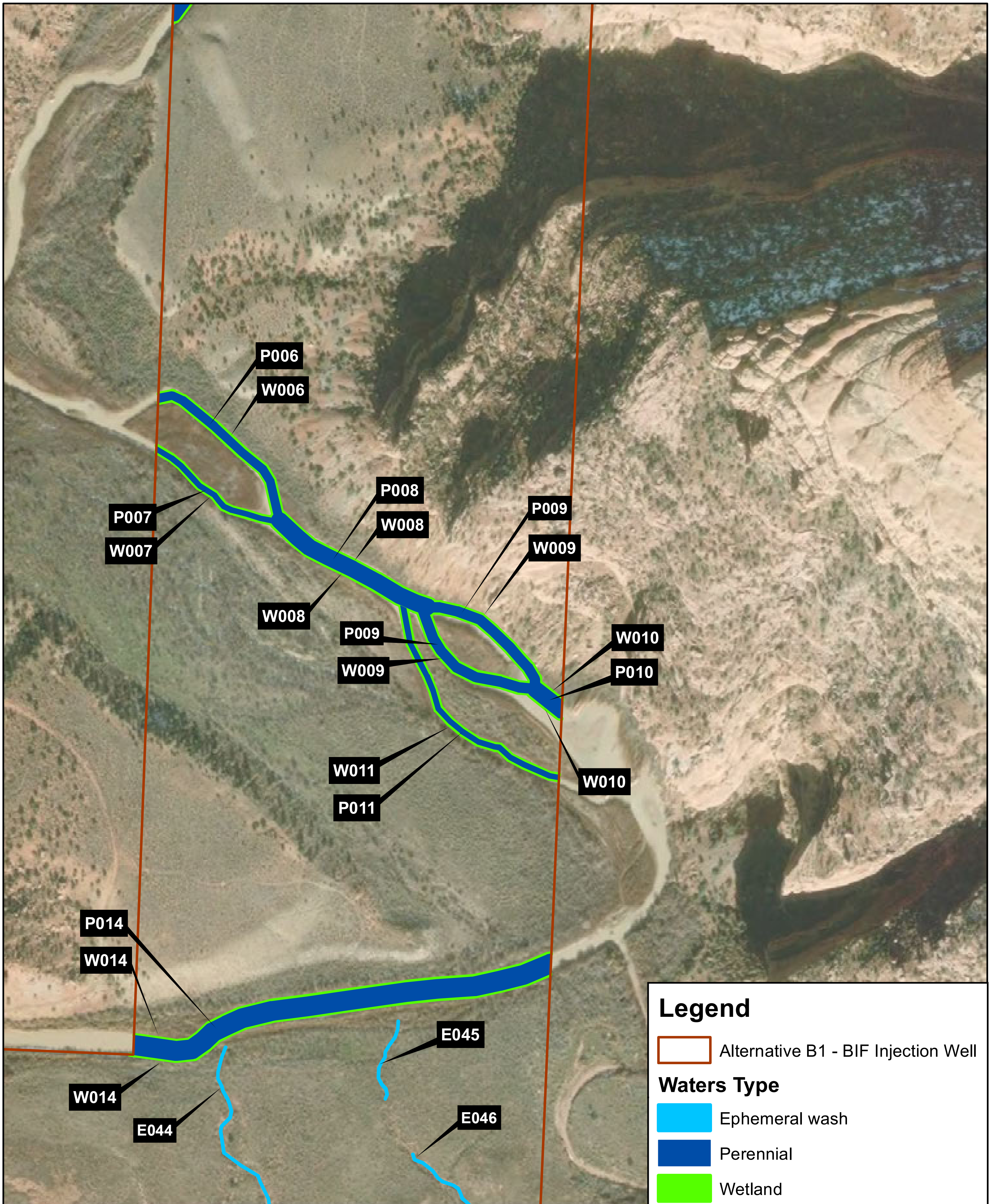
**Alternative B1 Waters Map**
**Page 1 of 5**

wood.

FIGURE 5-1

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**Alternative B1 Waters Map**
**Page 2 of 5**

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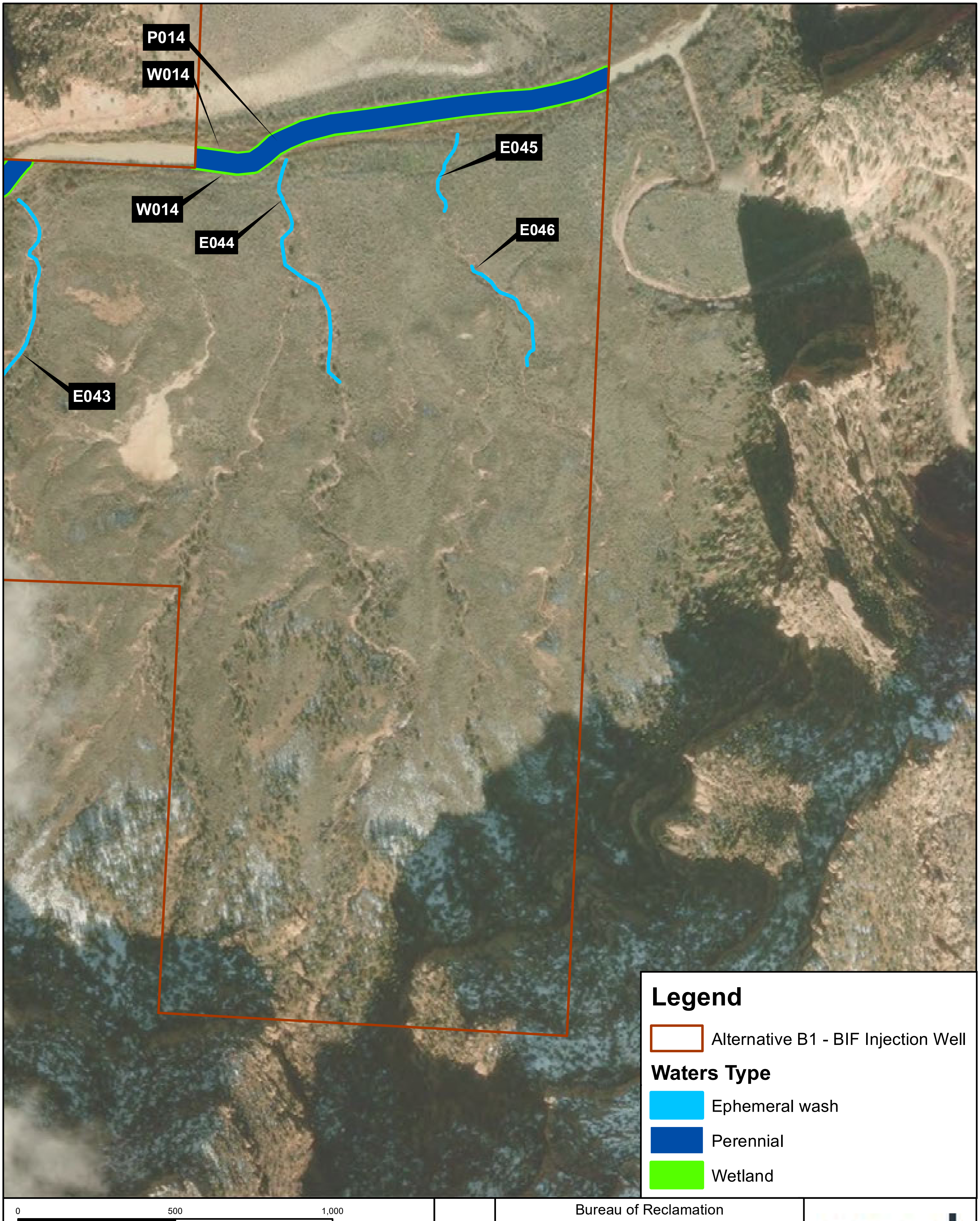
FIGURE 5-2

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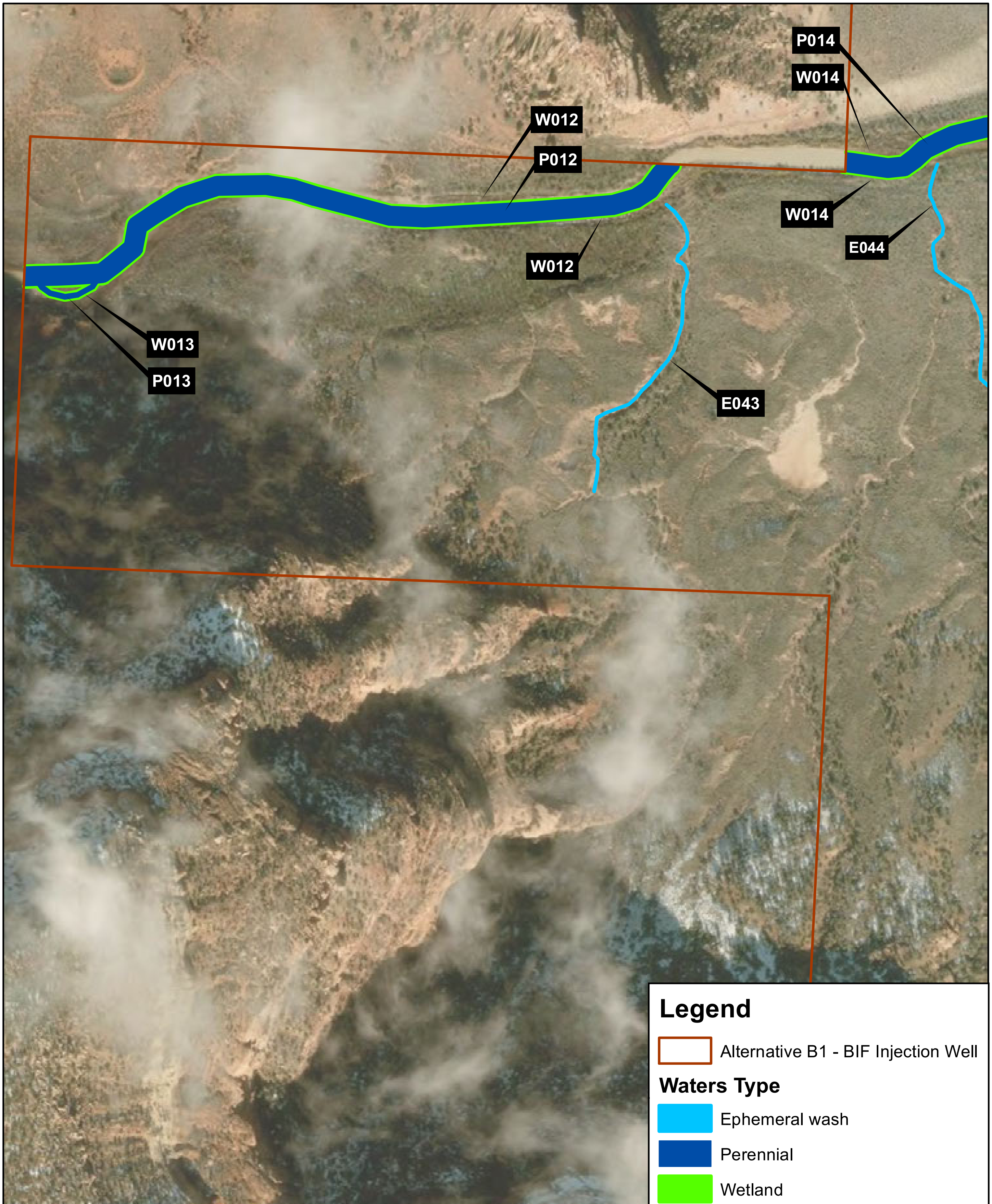
**Alternative B1 Waters Map**
**Page 3 of 5**

FIGURE 5-3

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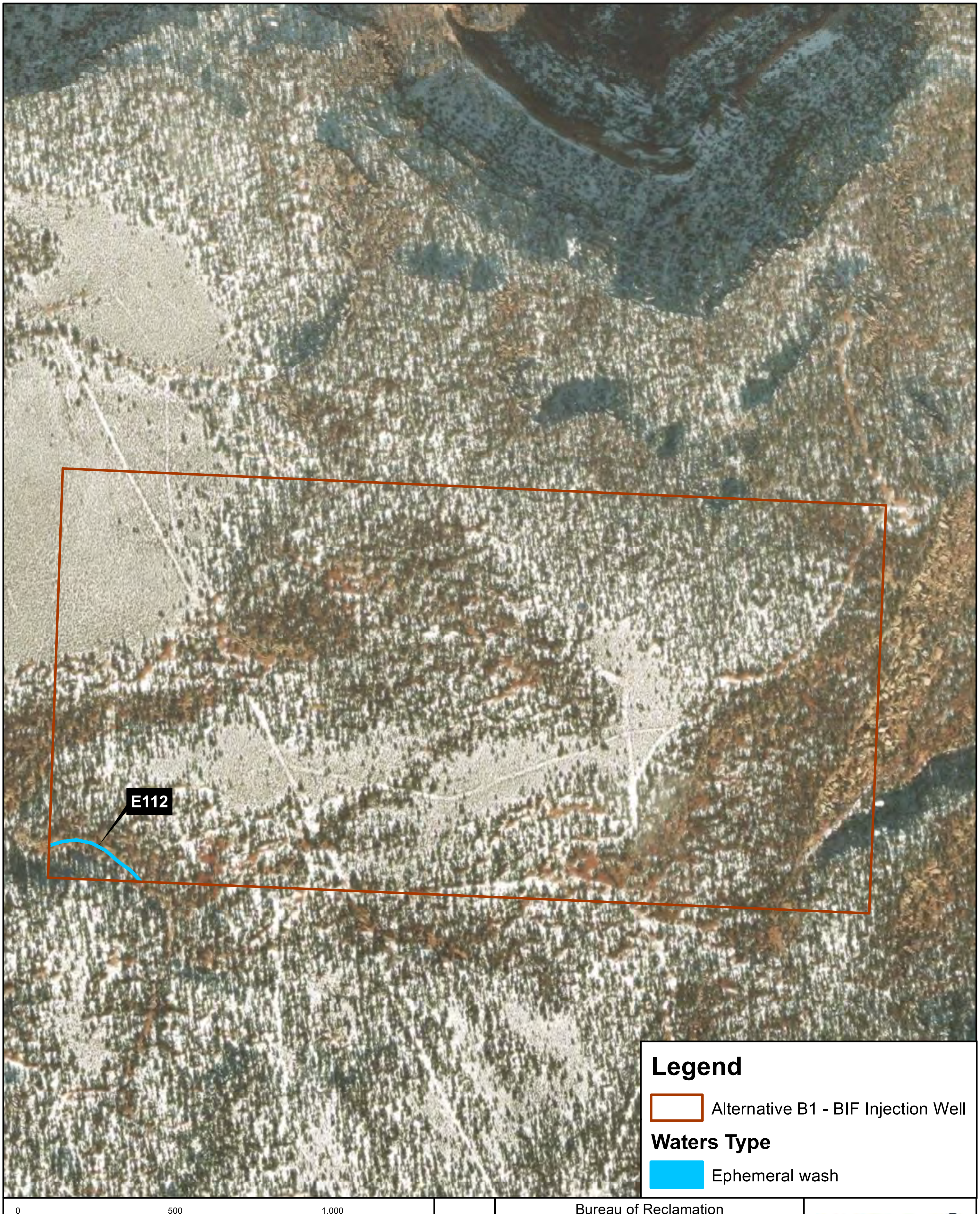
**Alternative B1 Waters Map**
**Page 4 of 5**

wood.

FIGURE 5-4




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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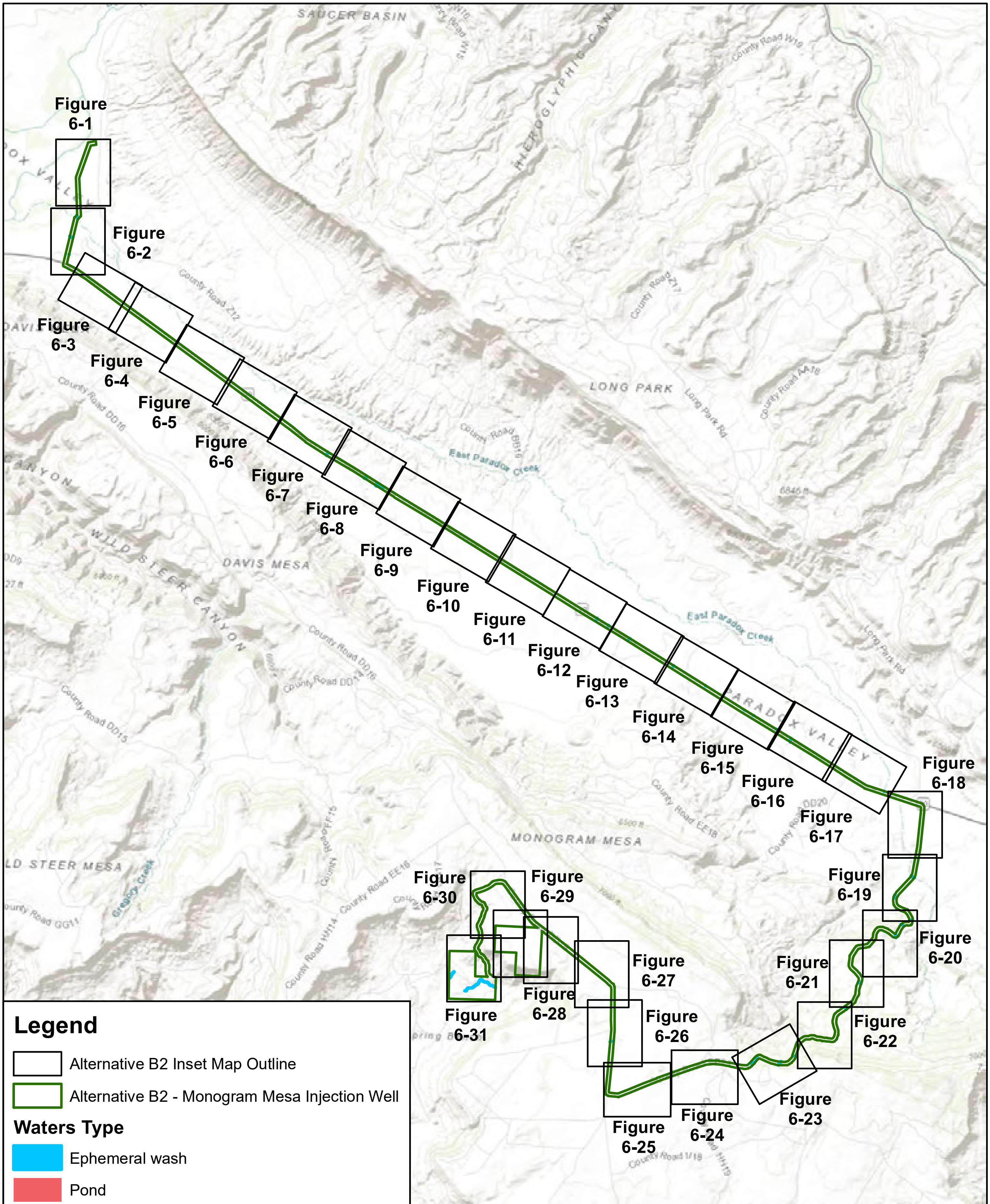
Bedrock, CO

**Alternative B1 Waters Map**
**Page 5 of 5**

wood.

FIGURE 5-5




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:85,279 |

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**Alternative B2 Waters Overview Map**

wood.

FIGURE 6


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PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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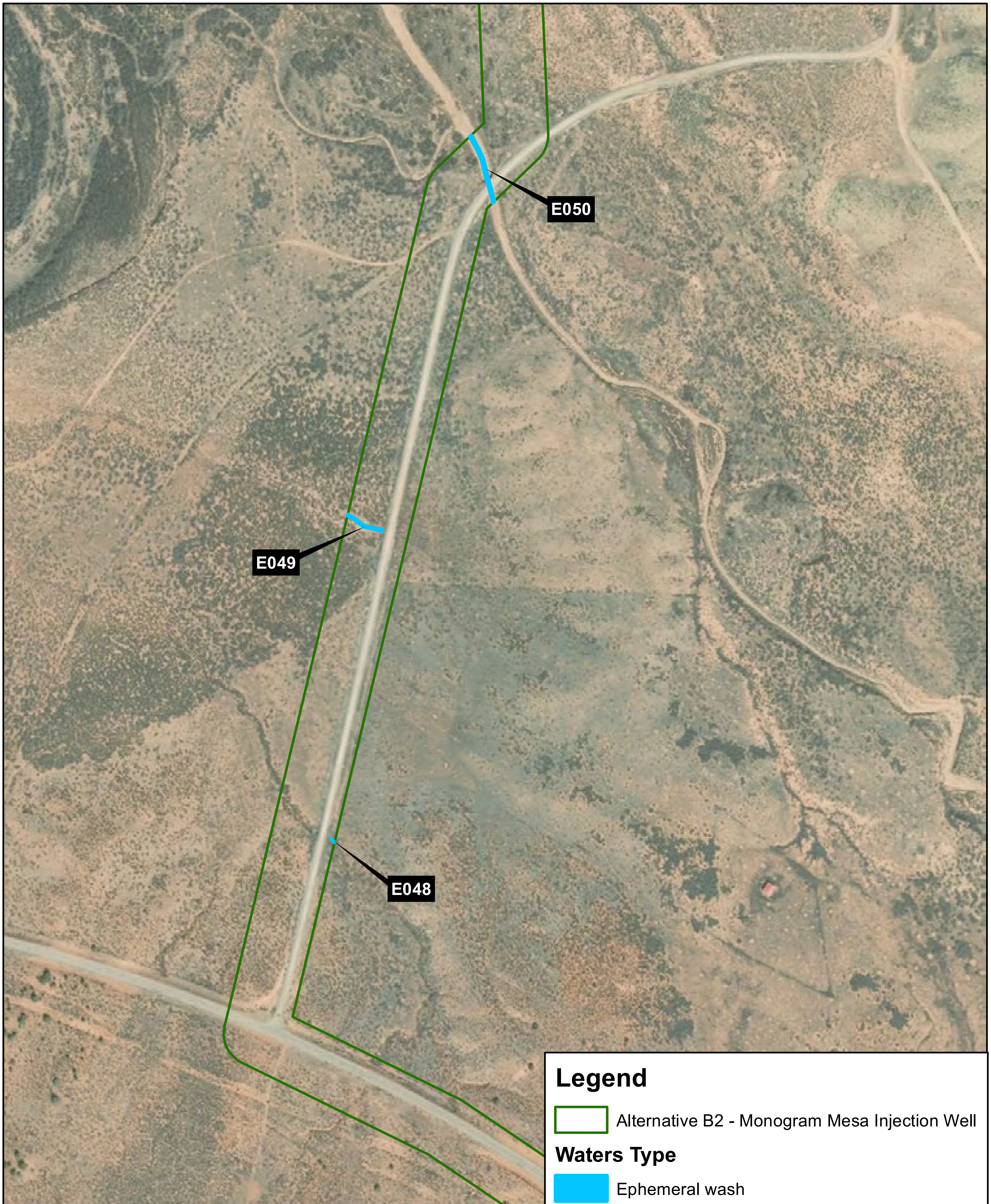
**Alternative B2 Waters Map**
**Page 1 of 31**

FIGURE 6-1




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

**Alternative B2 Waters Map**
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FIGURE 6-2


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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**Alternative B2 Waters Map**
**Page 3 of 31**

wood.

FIGURE 6-3

## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative B2 Waters Map**
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FIGURE 6-4


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative B2 Waters Map**
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FIGURE 6-5

## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000
Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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N

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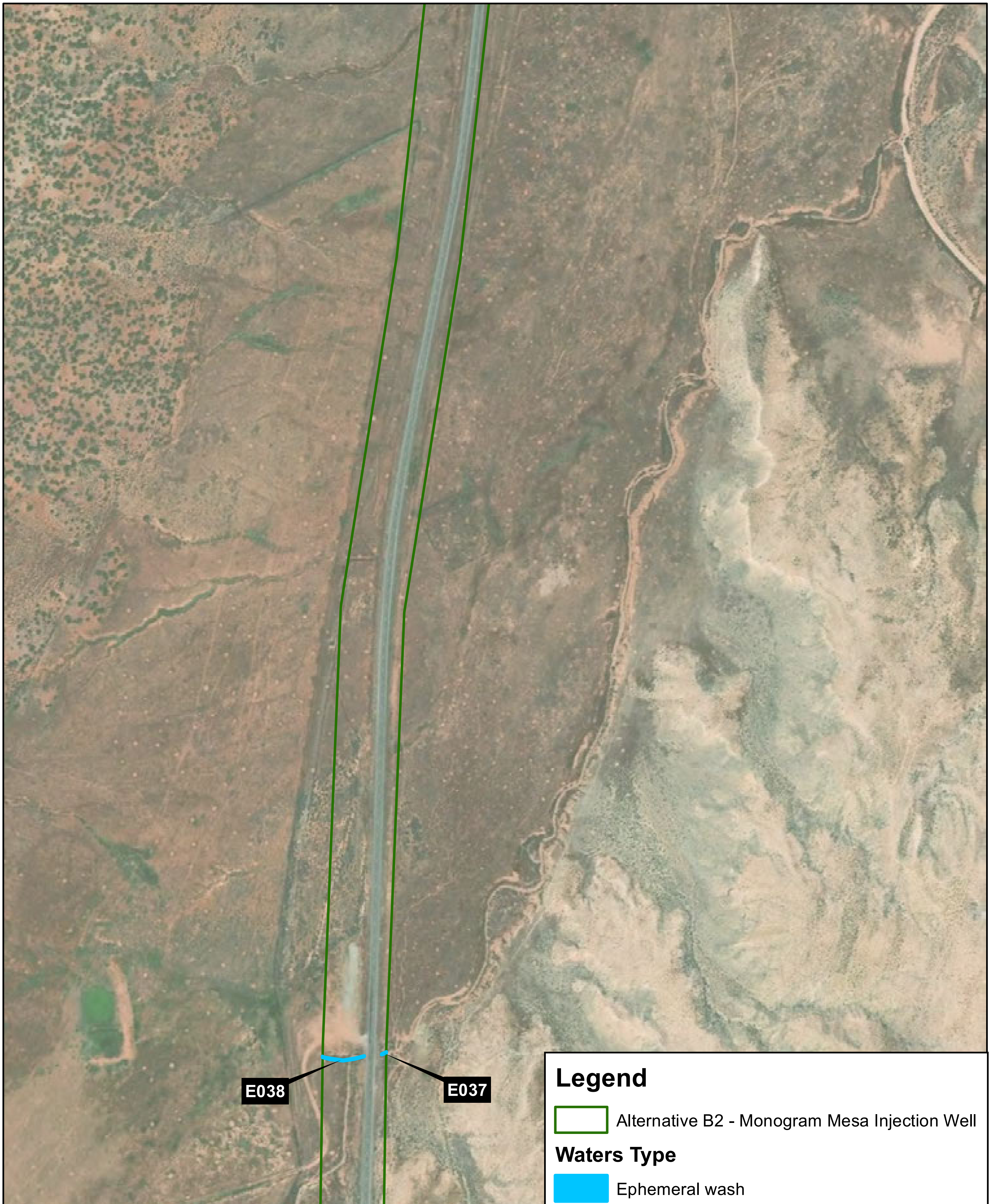
**Alternative B2 Waters Map**
**Page 6 of 31**

wood.

FIGURE 6-6




# Legend

Alternative B2 - Monogram Mesa Injection Well

## Waters Type

Ephemeral wash

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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N

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Paradox Valley Unit Preliminary
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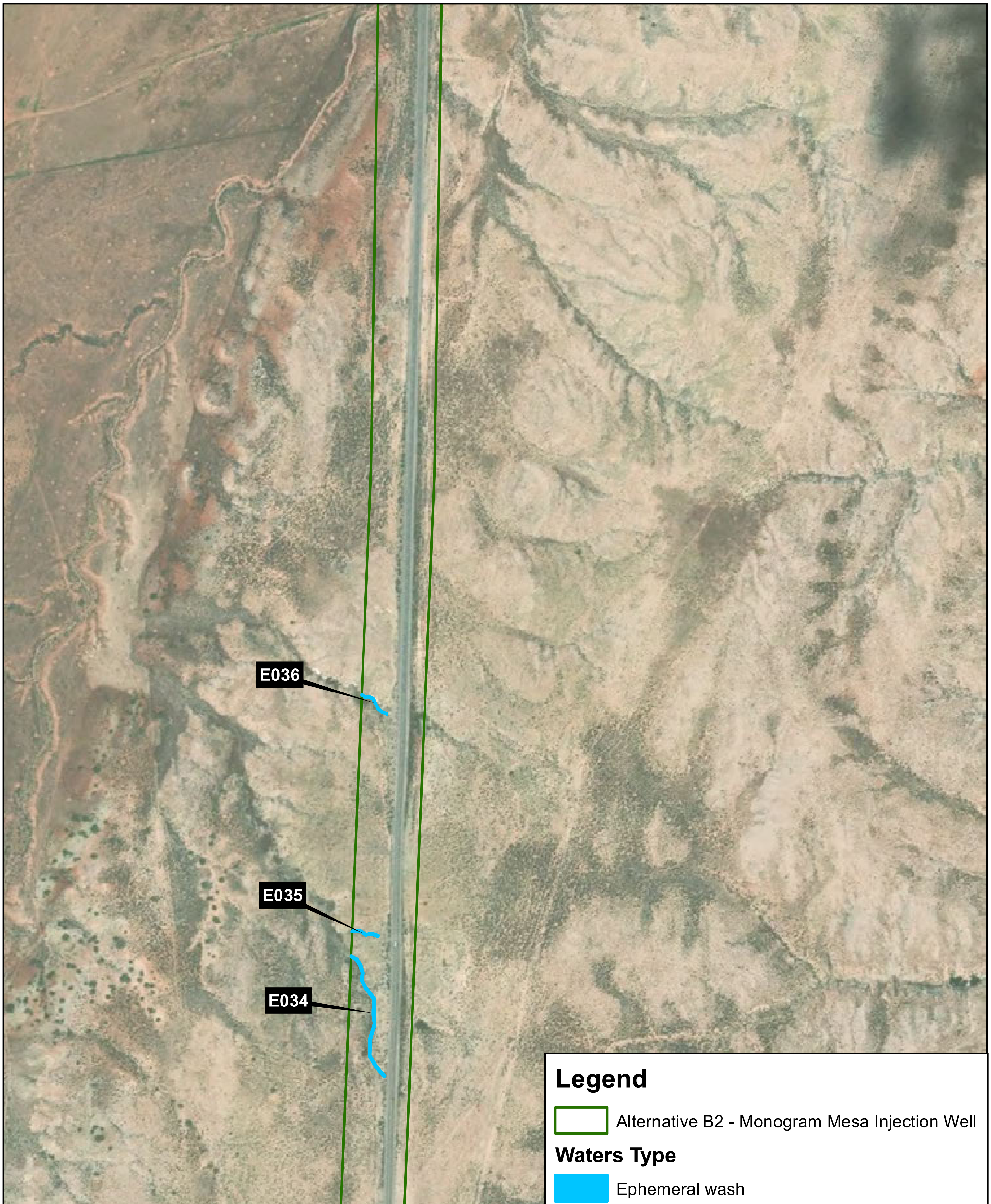
wood.

**Alternative B2 Waters Map**
**Page 7 of 31**

FIGURE 6-7




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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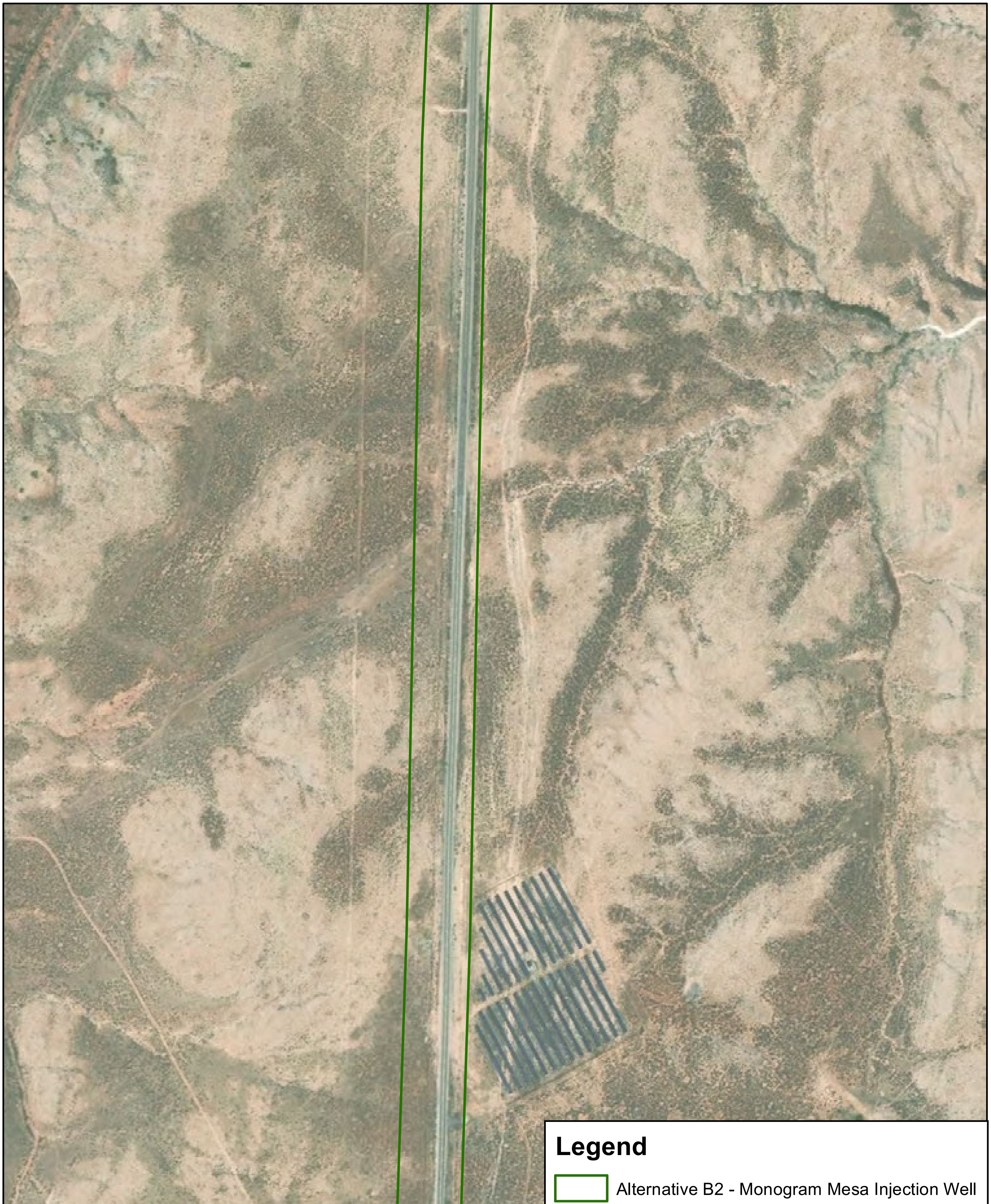
wood.

**Alternative B2 Waters Map**
**Page 8 of 31**

FIGURE 6-8



## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000
Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



Bureau of Reclamation
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wood.

**Alternative B2 Waters Map**
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FIGURE 6-9

## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



Bureau of Reclamation
Paradox Valley Unit Preliminary
Identification of Aquatic Resources
Bedrock, CO

wood.

**Alternative B2 Waters Map**


FIGURE 6-10

## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative B2 Waters Map**
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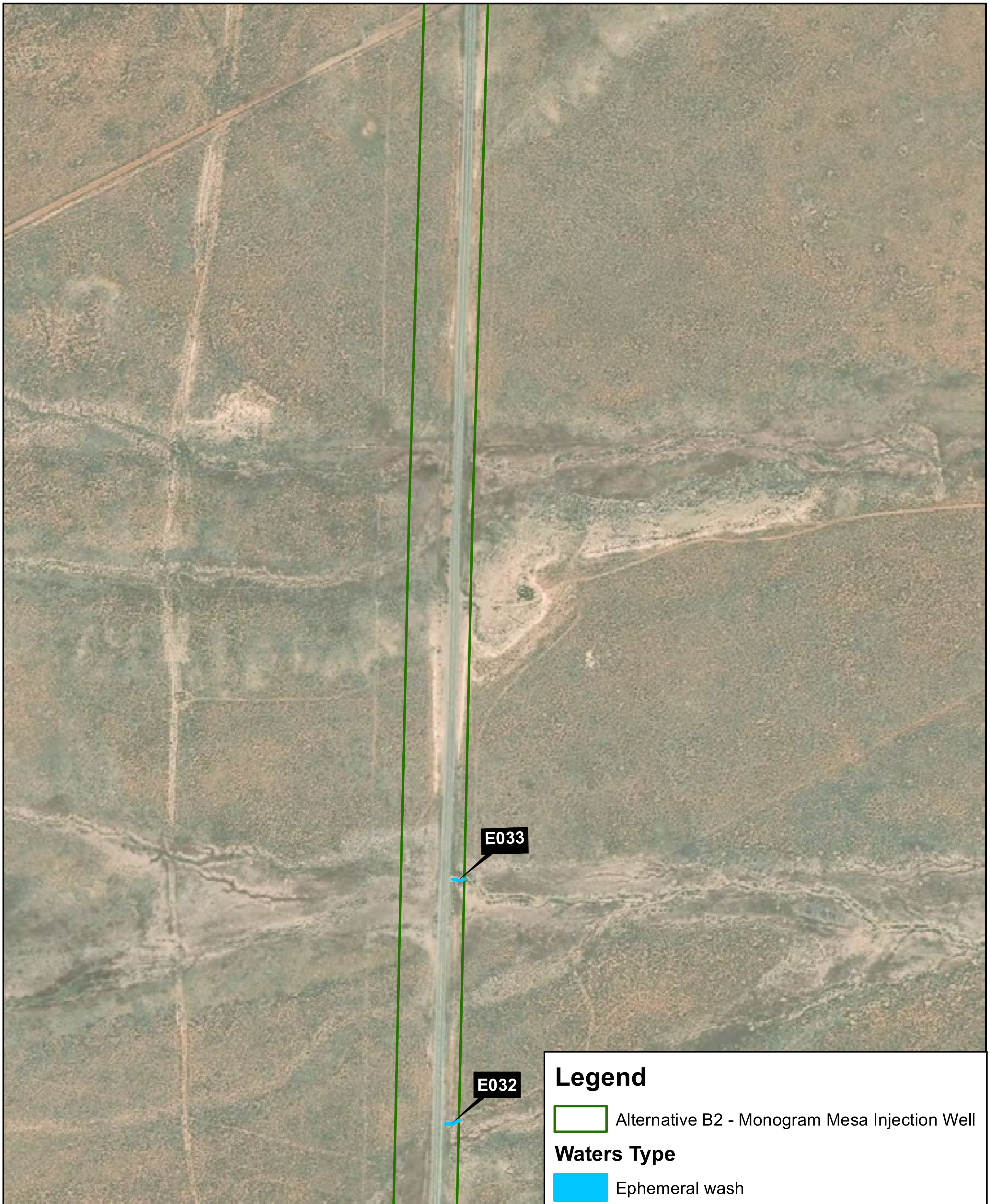
wood.

FIGURE 6-11




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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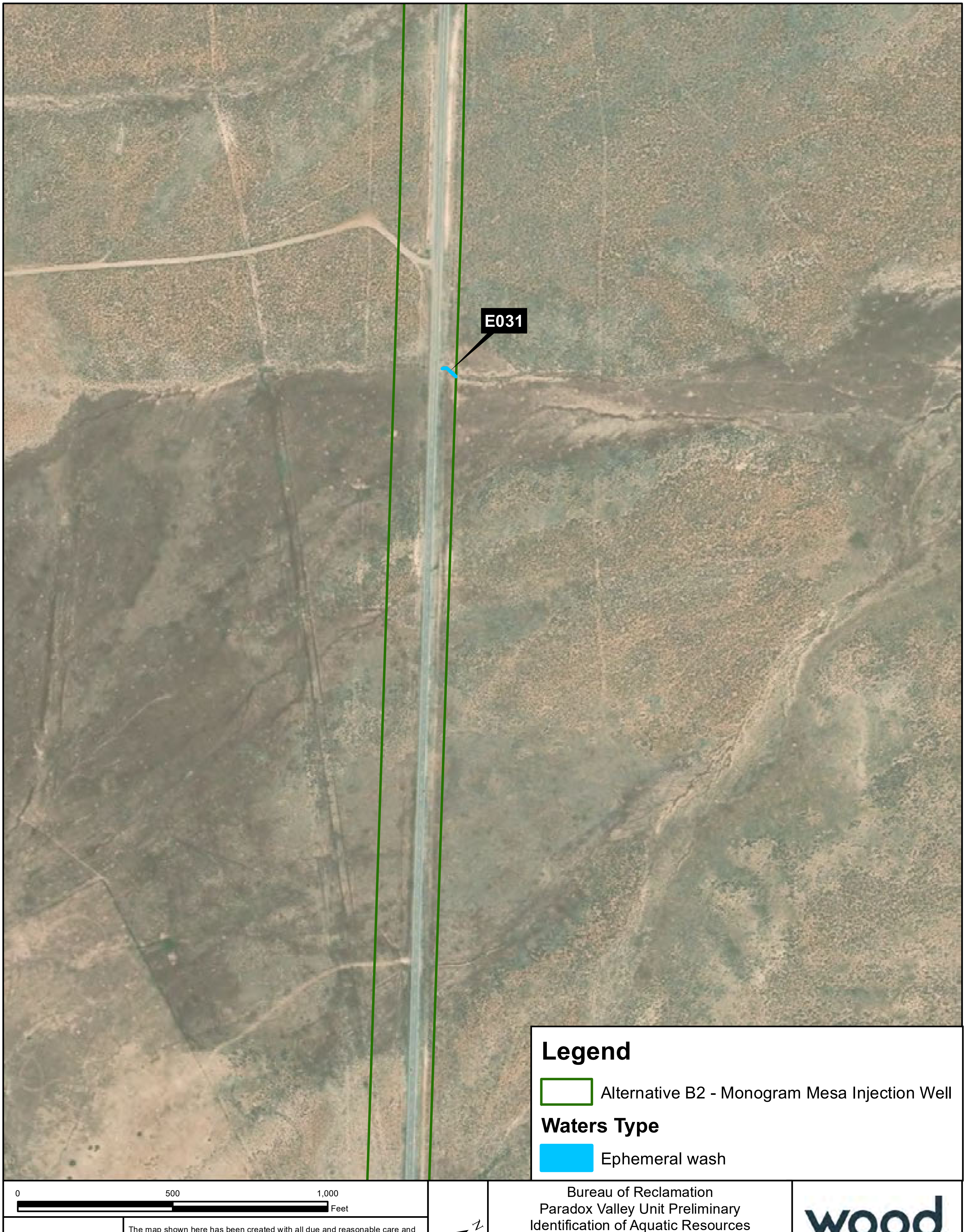
**Alternative B2 Waters Map**
**Page 12 of 31**

wood.

FIGURE 6-12




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative B2 Waters Map**
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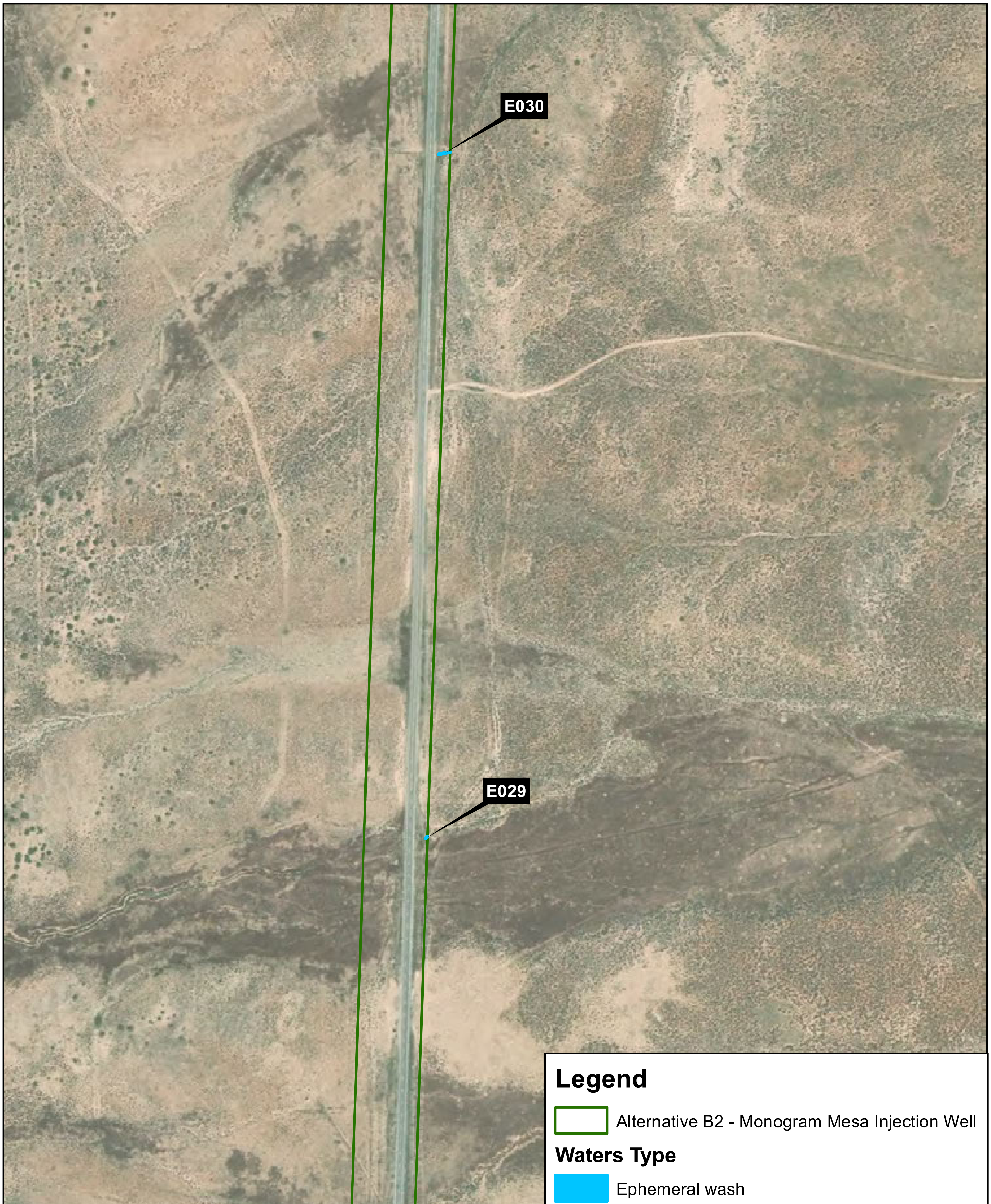
FIGURE 6-13




0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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N

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wood.

**Alternative B2 Waters Map**
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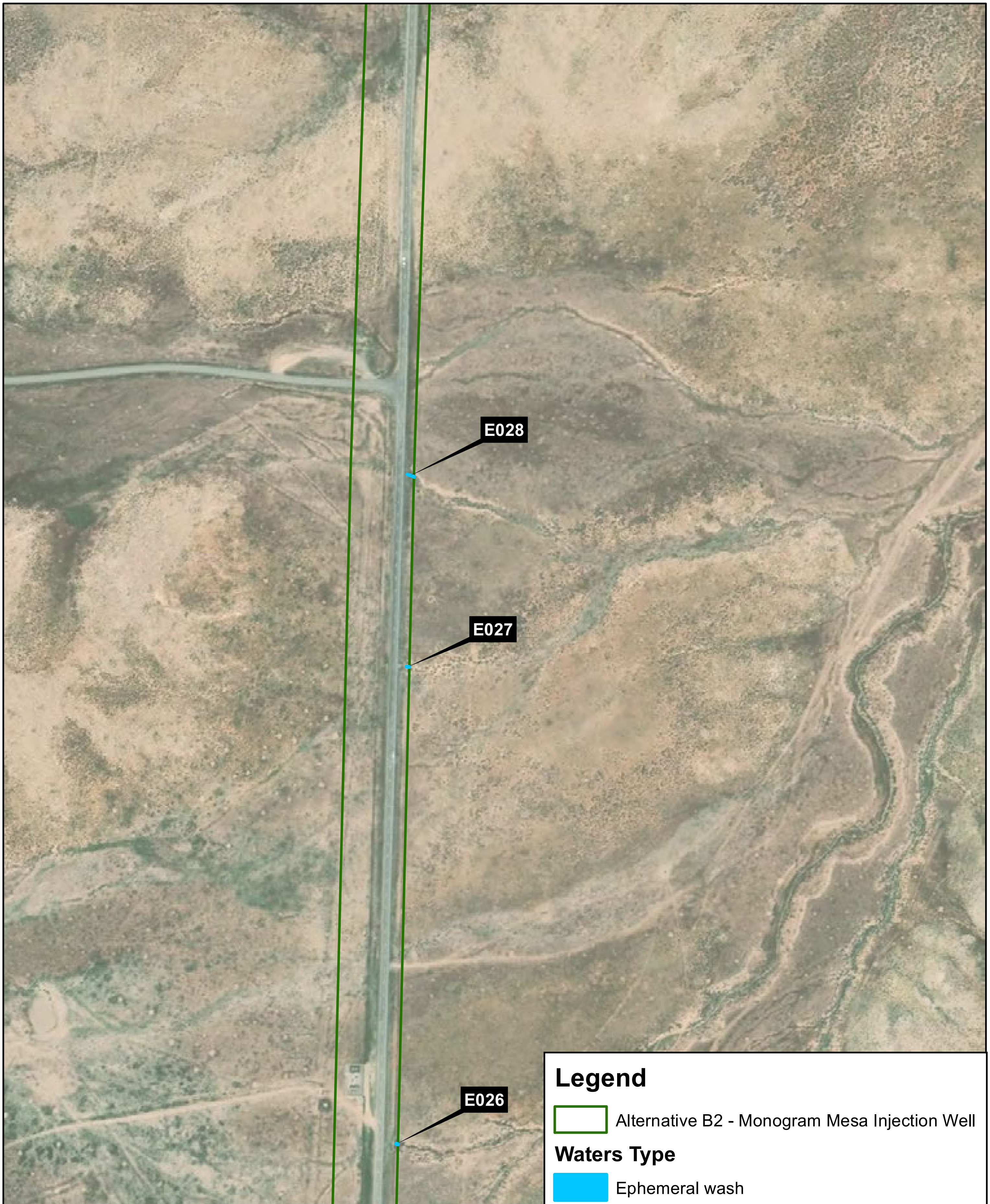
FIGURE 6-14




## Legend

Alternative B2 - Monogram Mesa Injection Well

**Waters Type**

Ephemeral wash

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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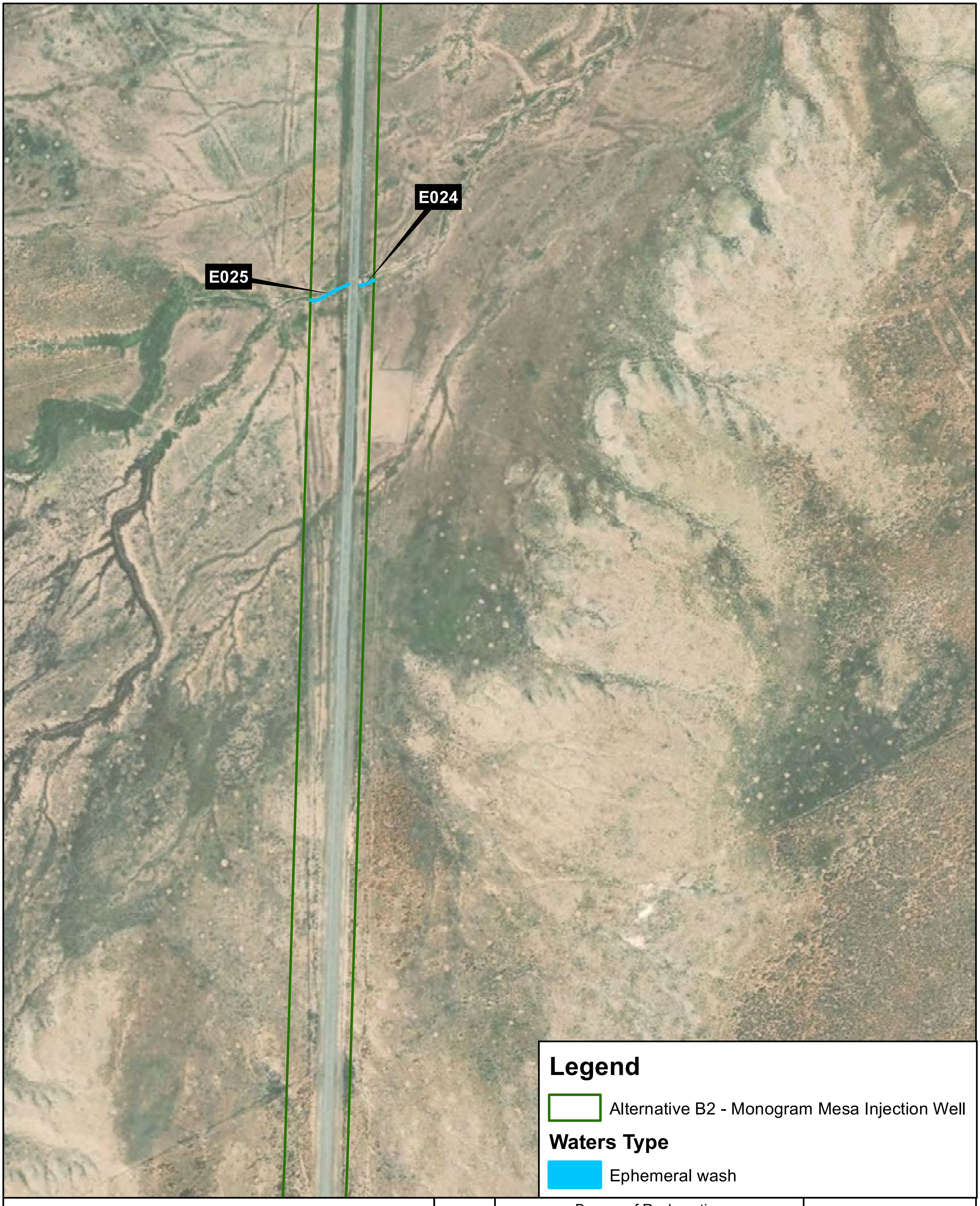
wood.

**Alternative B2 Waters Map**
**Page 15 of 31**

FIGURE 6-15




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative B2 Waters Map**
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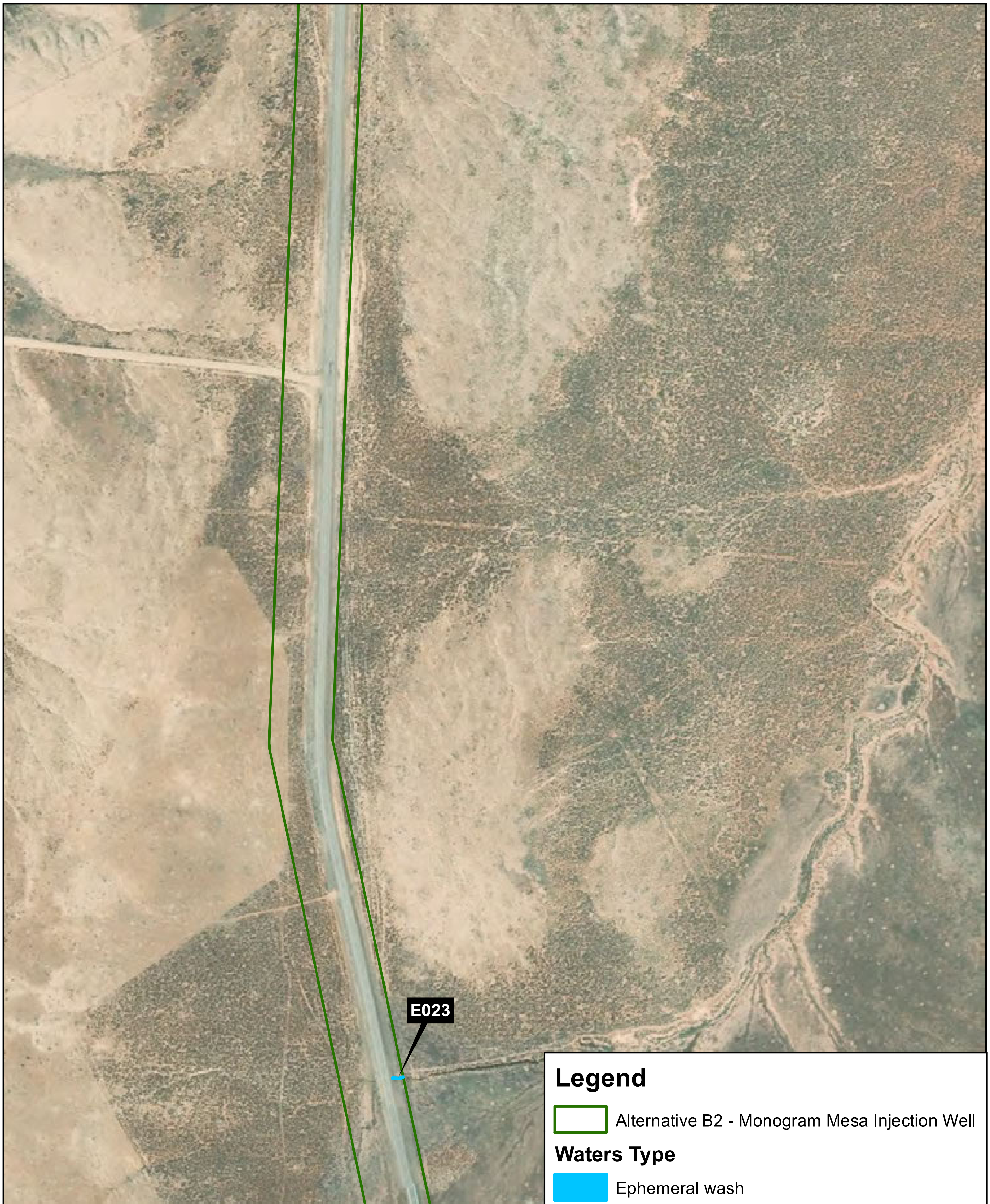
FIGURE 6-16




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,720 |



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**Alternative B2 Waters Map**
**Page 17 of 31**

wood.

FIGURE 6-17


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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**Alternative B2 Waters Map**
**Page 18 of 31**

wood.

FIGURE 6-18


## Legend

Alternative B2 - Monogram Mesa Injection Well

**Waters Type**

Ephemeral wash

0 500 1,000 Feet

N

Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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**Alternative B2 Waters Map**
**Page 19 of 31**

wood.

FIGURE 6-19


## Legend

Alternative B2 - Monogram Mesa Injection Well

**Waters Type**

Ephemeral wash

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative B2 Waters Map**
**Page 20 of 31**

wood.

FIGURE 6-20


## Legend

Alternative B2 - Monogram Mesa Injection Well

**Waters Type**

Ephemeral wash

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative B2 Waters Map**
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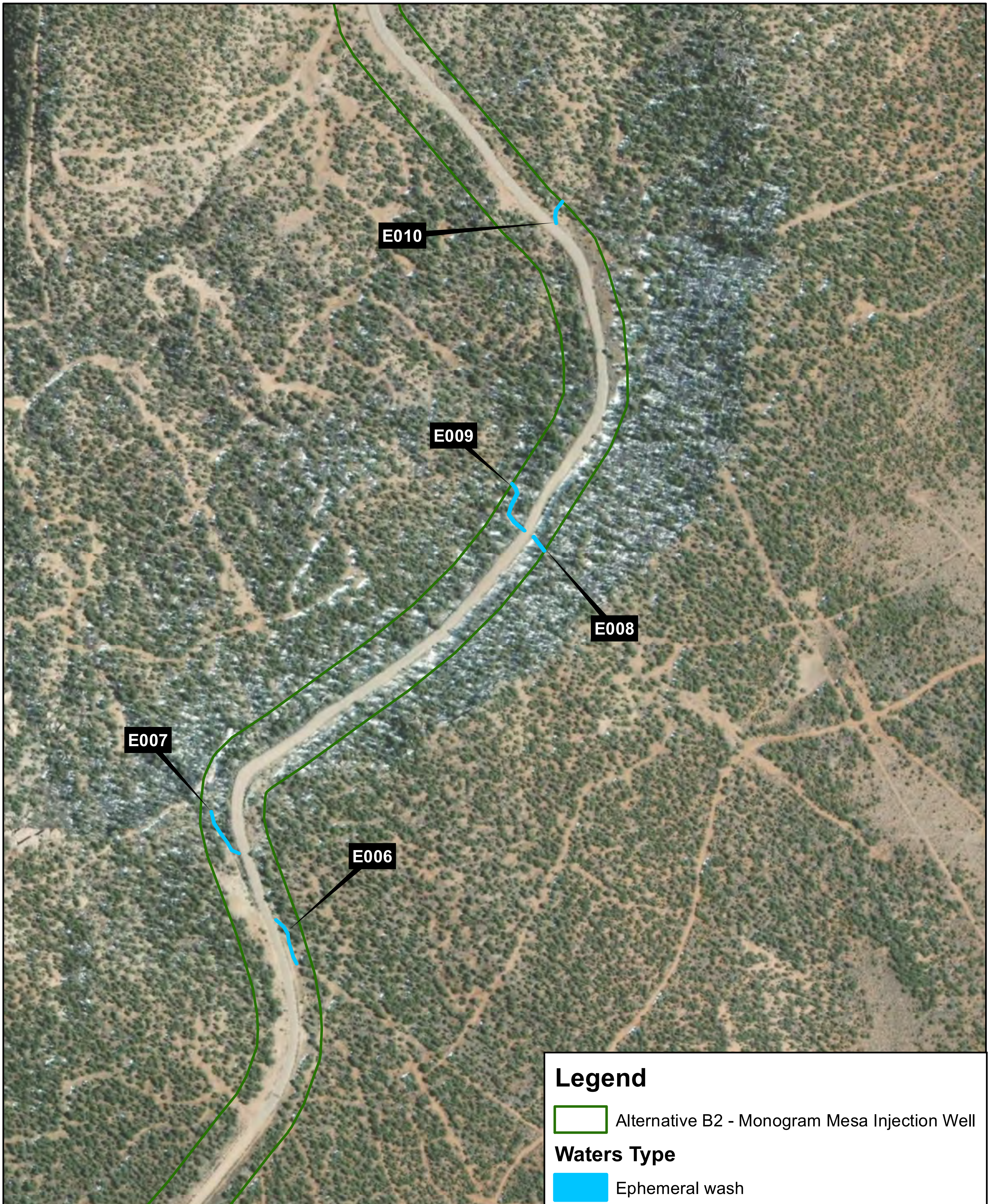
FIGURE 6-21




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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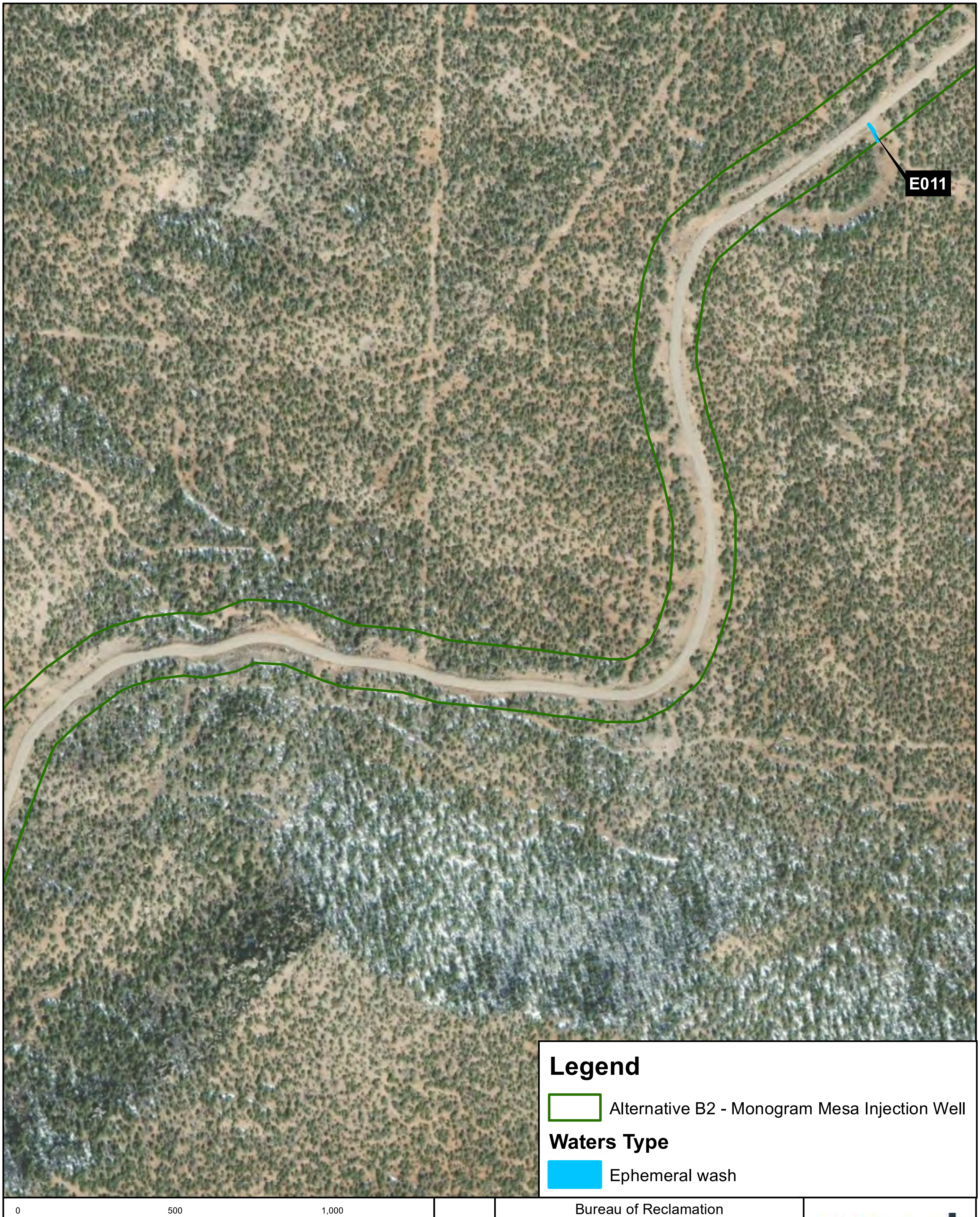
Bedrock, CO

wood.

**Alternative B2 Waters Map**
**Page 22 of 31**

FIGURE 6-23




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative B2 Waters Map**
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FIGURE 6-22



| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

**Alternative B2 Waters Map**
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FIGURE 6-24


Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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Identification of Aquatic Resources
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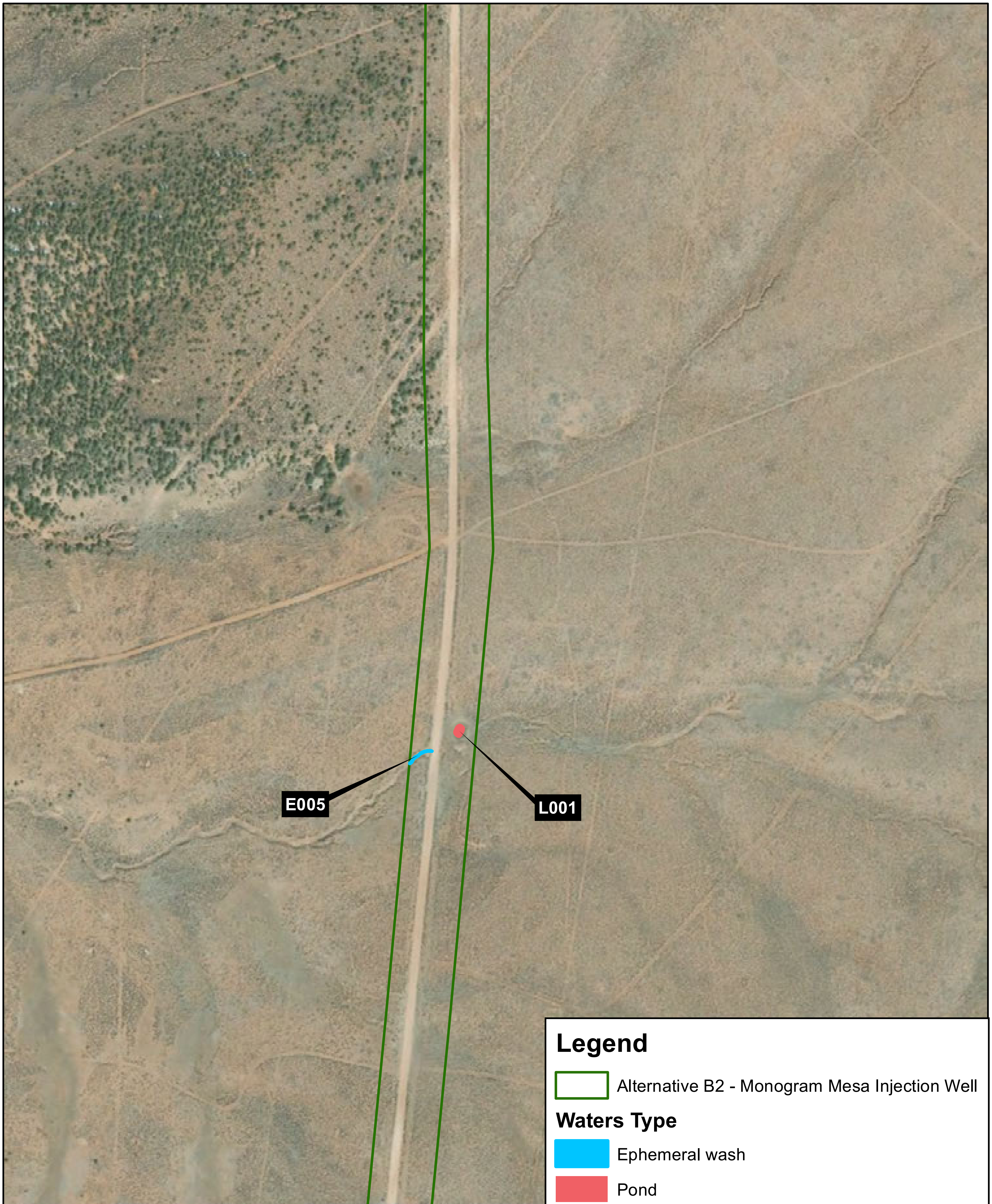
wood.

**Alternative B2 Waters Map**
**Page 25 of 31**

FIGURE 6-25




## Legend

Alternative B2 - Monogram Mesa Injection Well

**Waters Type**

Ephemeral wash

Pond

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative B2 Waters Map**
**Page 26 of 31**

wood.

FIGURE 6-26

## Legend

Alternative B2 - Monogram Mesa Injection Well

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

FIGURE 6-27


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



Bureau of Reclamation
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**Alternative B2 Waters Map**
**Page 28 of 31**

wood.

FIGURE 6-28



Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700



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**Alternative B2 Waters Map**
**Page 29 of 31**

wood.

FIGURE 6-29


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



Bureau of Reclamation
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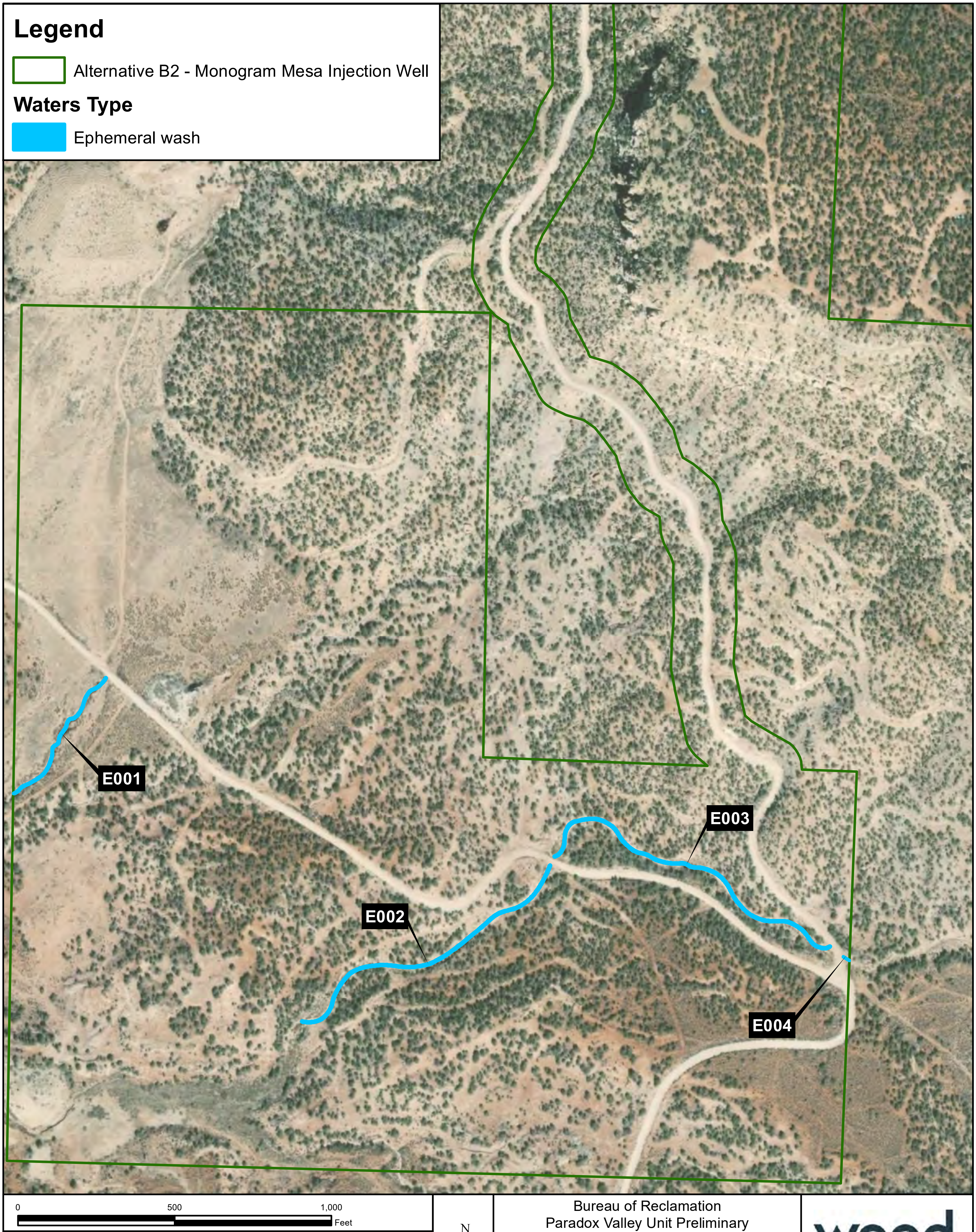
wood.

**Alternative B2 Waters Map**
**Page 30 of 31**

FIGURE 6-30




Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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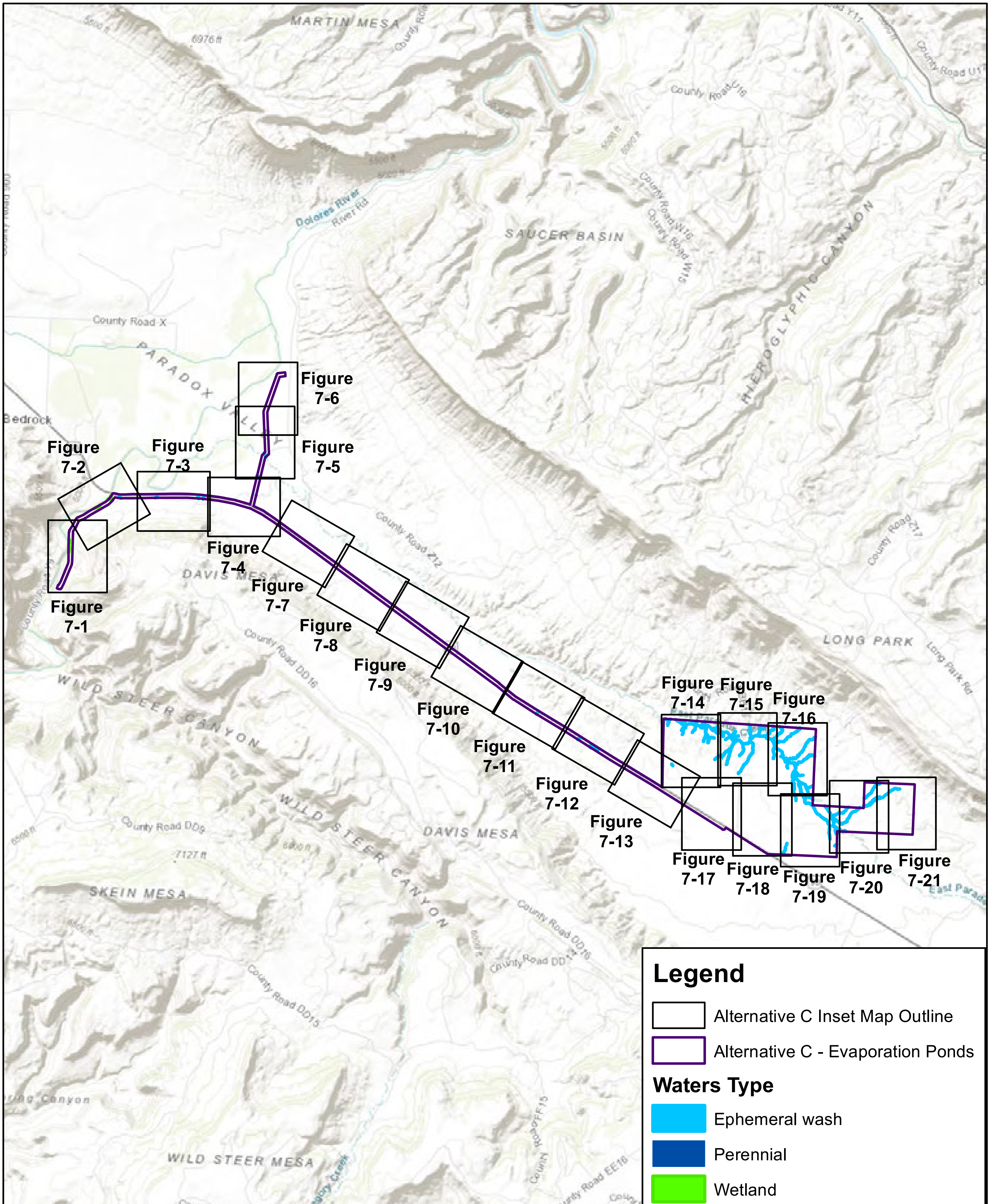
wood.

**Alternative B2 Waters Map**
**Page 31 of 31**

FIGURE 6-31




0 1 2 Miles

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:78,322 |

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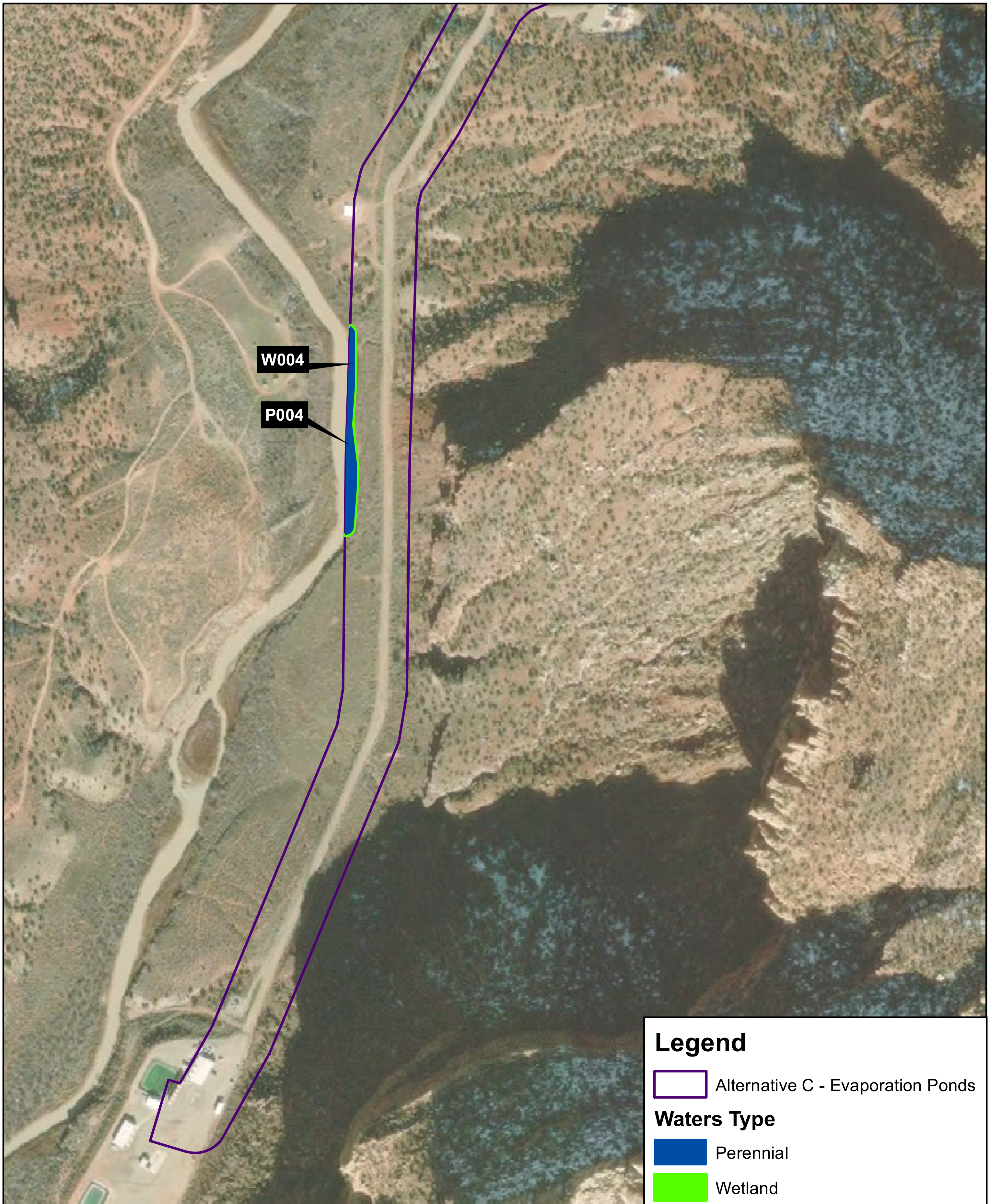
**Alternative C Waters Overview Map**

wood.

FIGURE 7




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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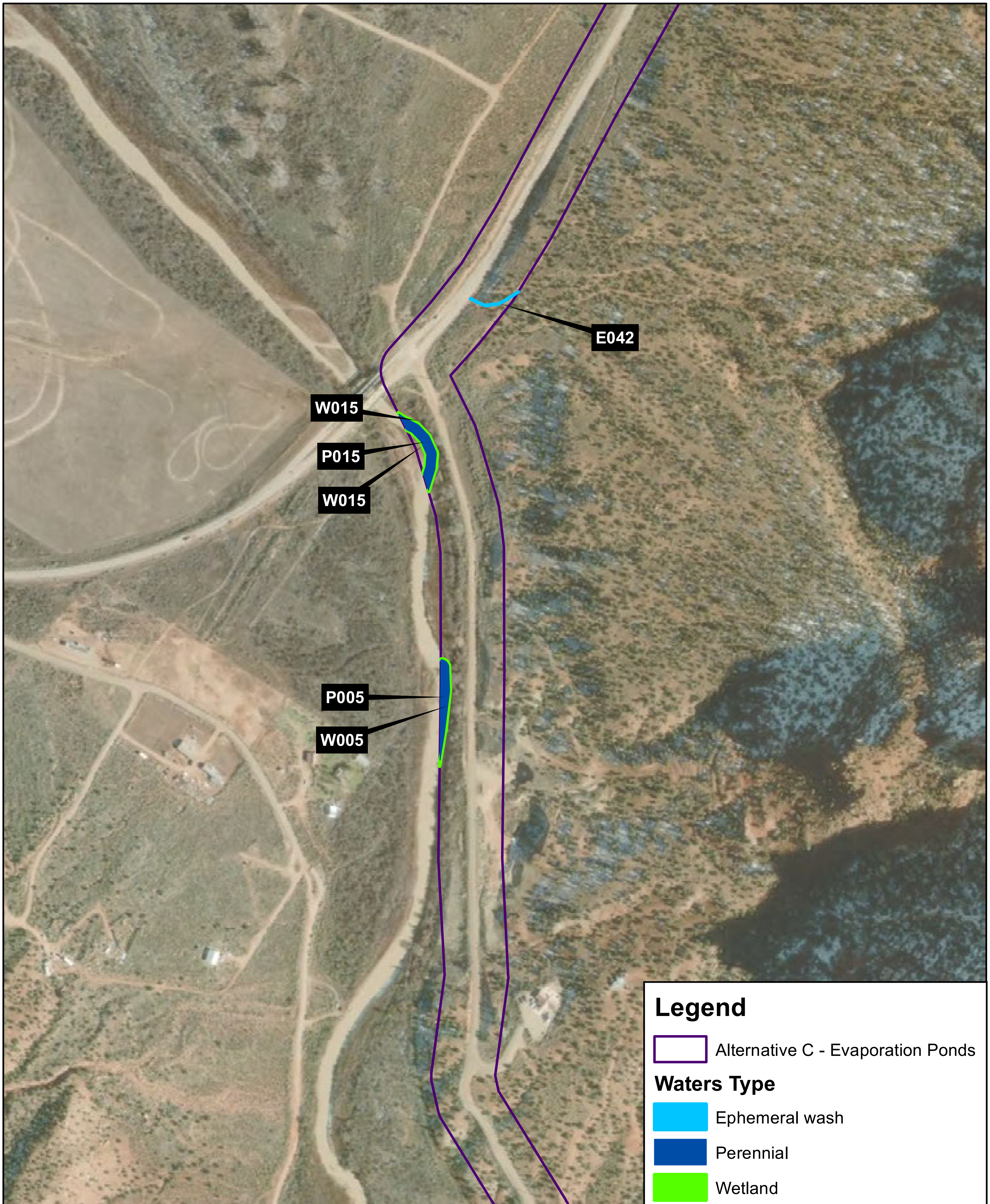
**Alternative C Waters Map**
**Page 1 of 21**

wood.

FIGURE 7-1




## Legend

Alternative C - Evaporation Ponds

**Waters Type**

Ephemeral wash

Perennial

Wetland

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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Identification of Aquatic Resources
Bedrock, CO

wood.

**Alternative C Waters Map**
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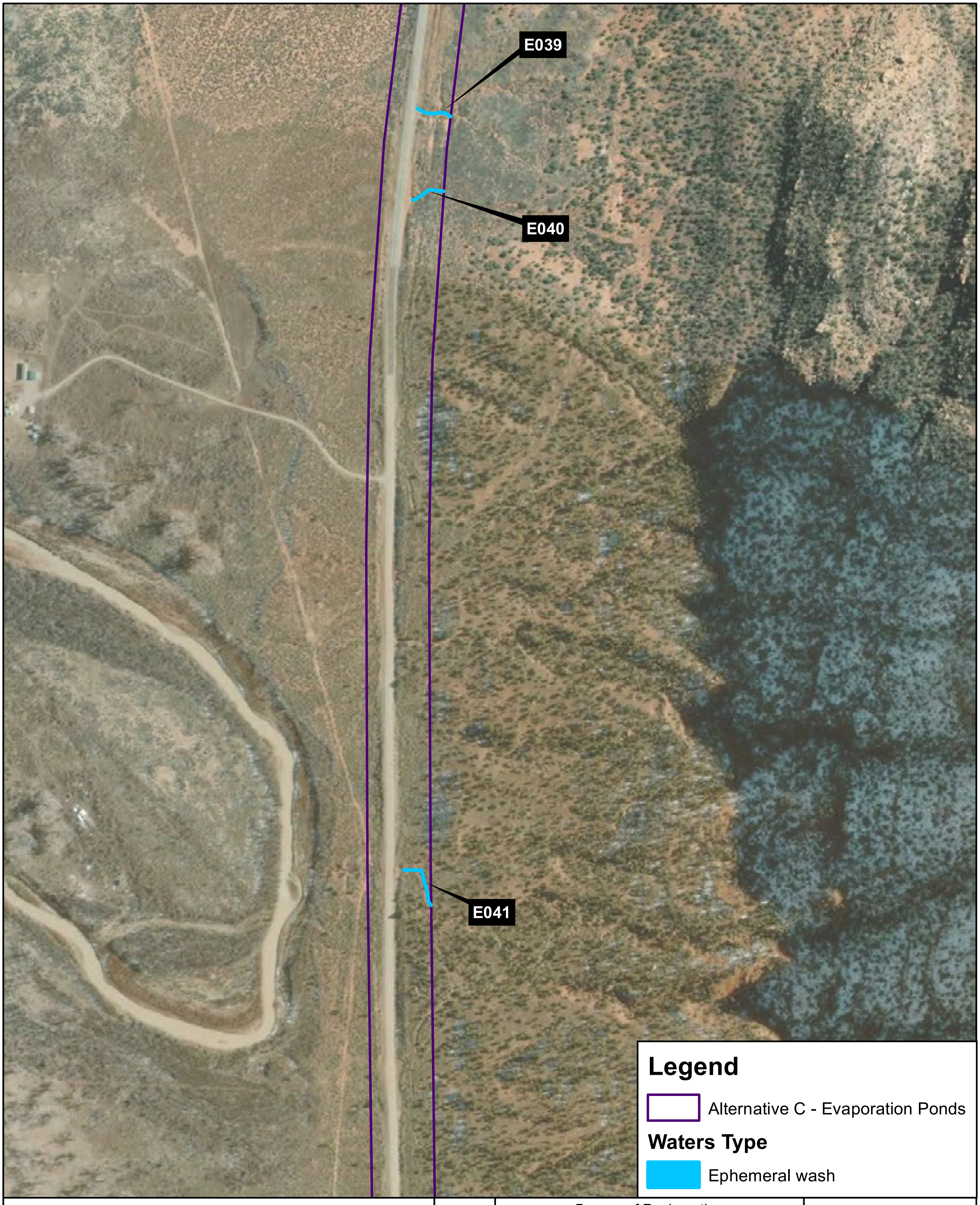
FIGURE 7-2




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

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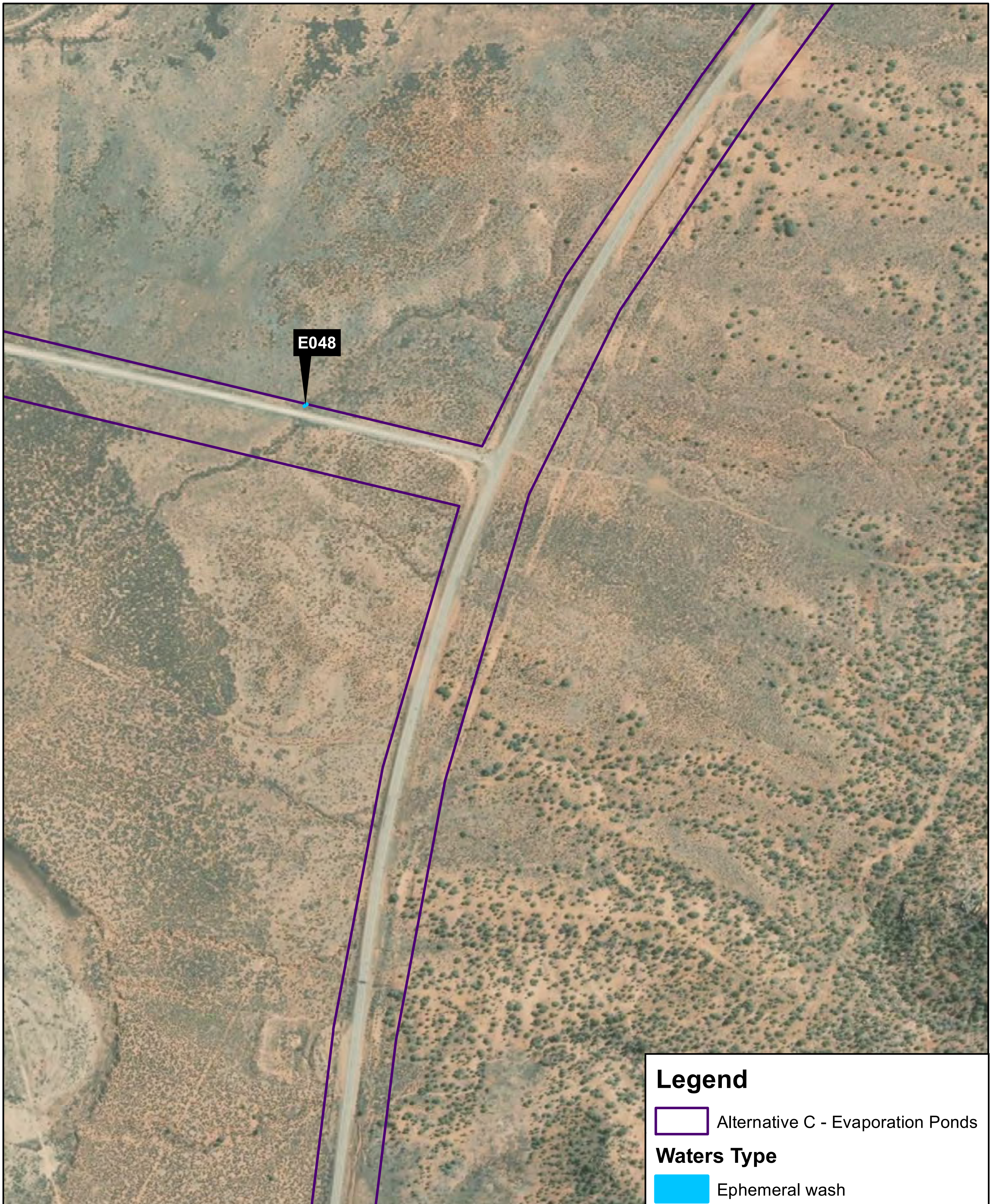
FIGURE 7-3




0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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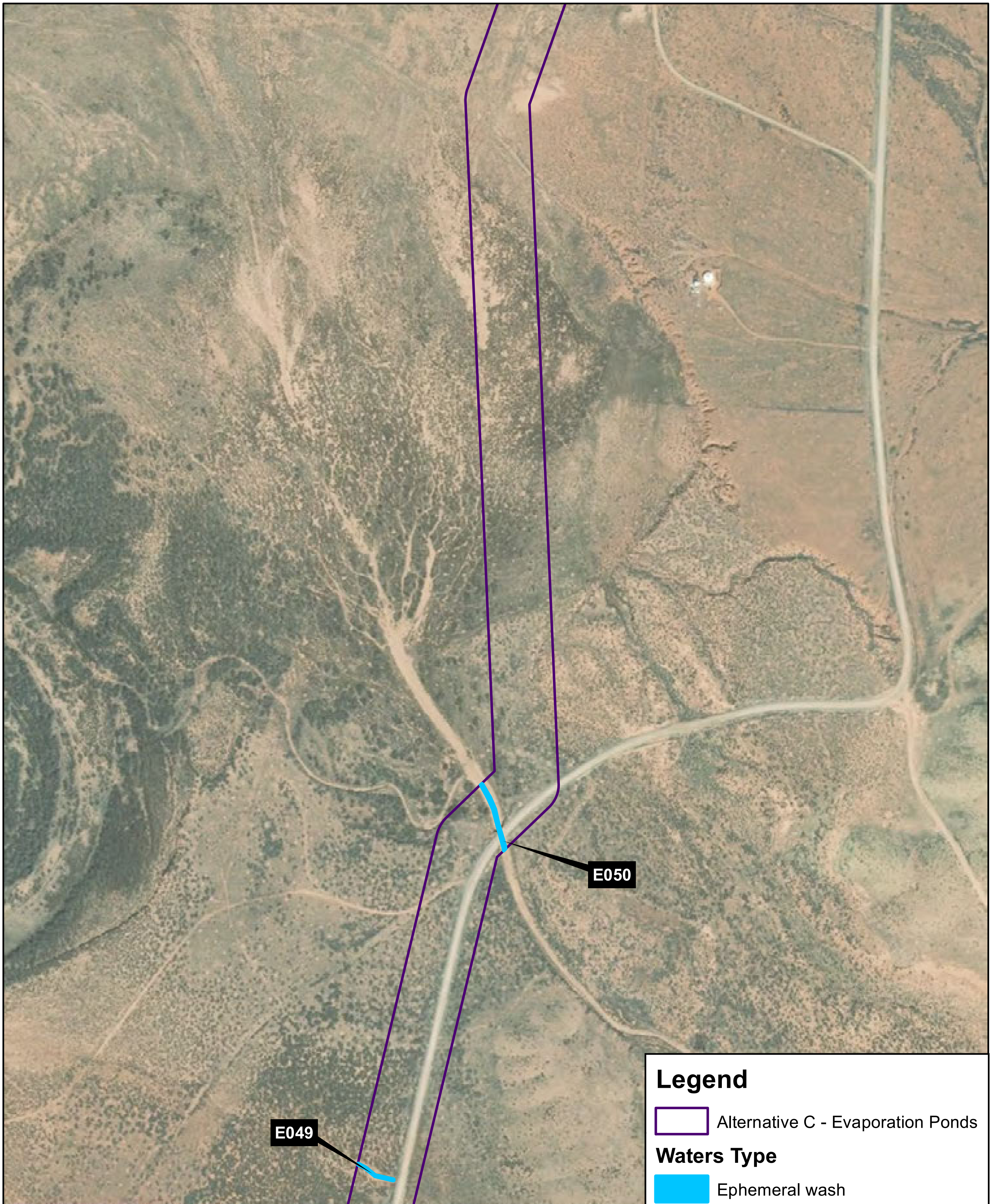
FIGURE 7-4




0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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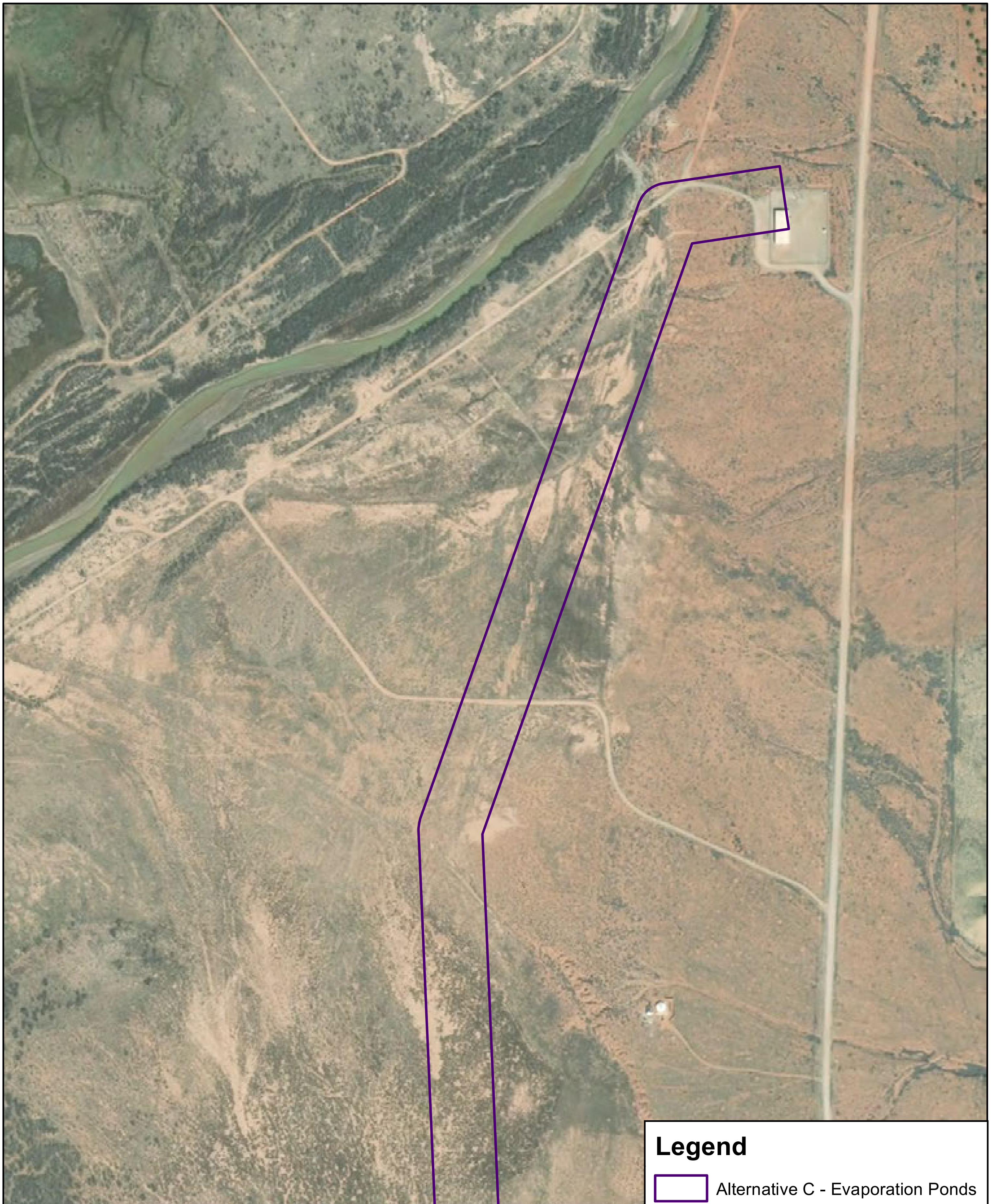
Bedrock, CO

**Alternative C Waters Map**
**Page 5 of 21**

wood.

FIGURE 7-5



## Legend

Alternative C - Evaporation Ponds

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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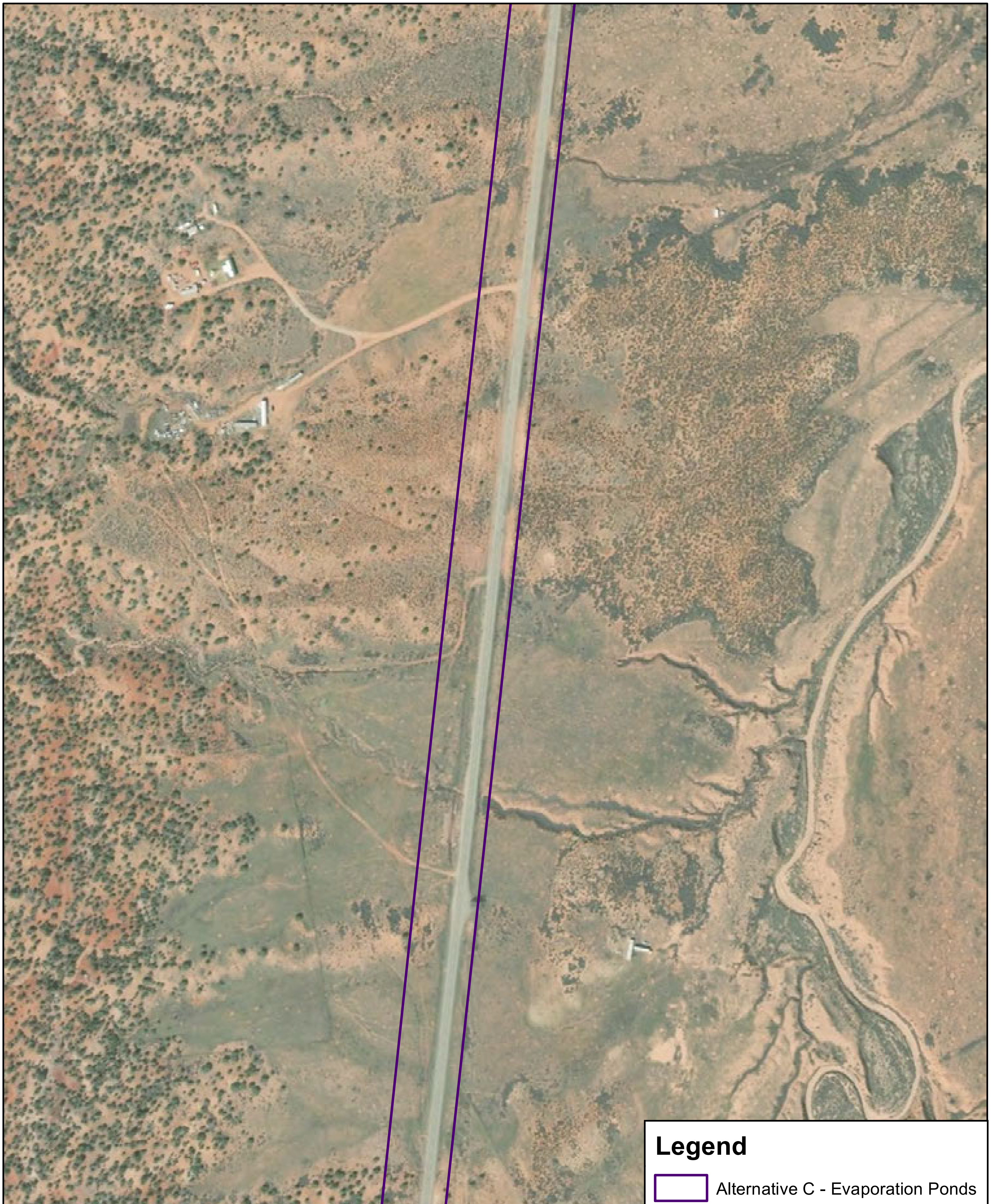
**Alternative C Waters Map**
**Page 6 of 21**

wood.

FIGURE 7-6



## Legend

Alternative C - Evaporation Ponds

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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N

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Identification of Aquatic Resources
Bedrock, CO

wood.

**Alternative C Waters Map**
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FIGURE 7-7


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative C Waters Map**
**Page 8 of 21**

wood.

FIGURE 7-8


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

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FIGURE 7-9


Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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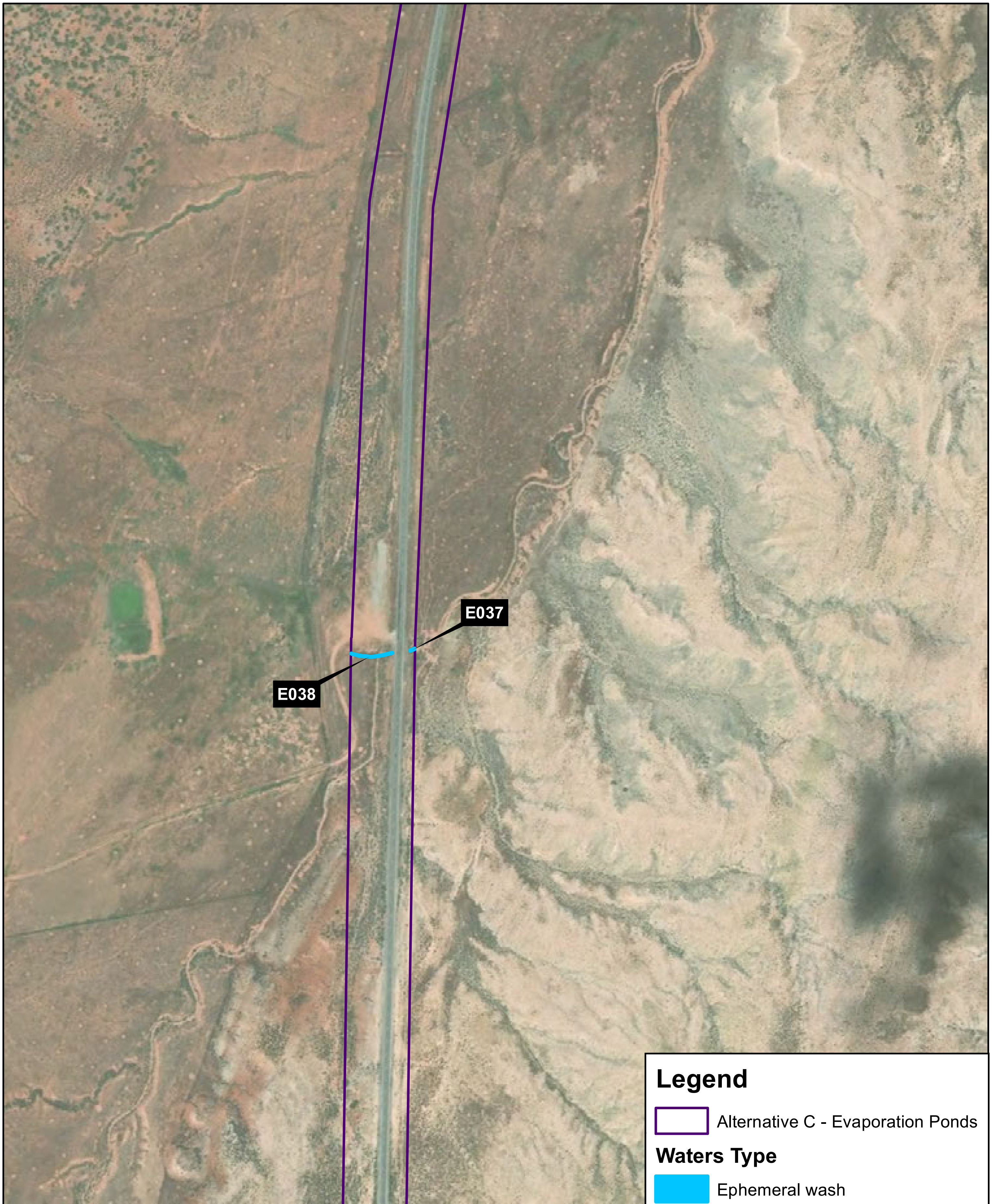
**Alternative C Waters Map**
**Page 10 of 21**

wood.

FIGURE 7-10




0 500 1,000 Feet

Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700



N

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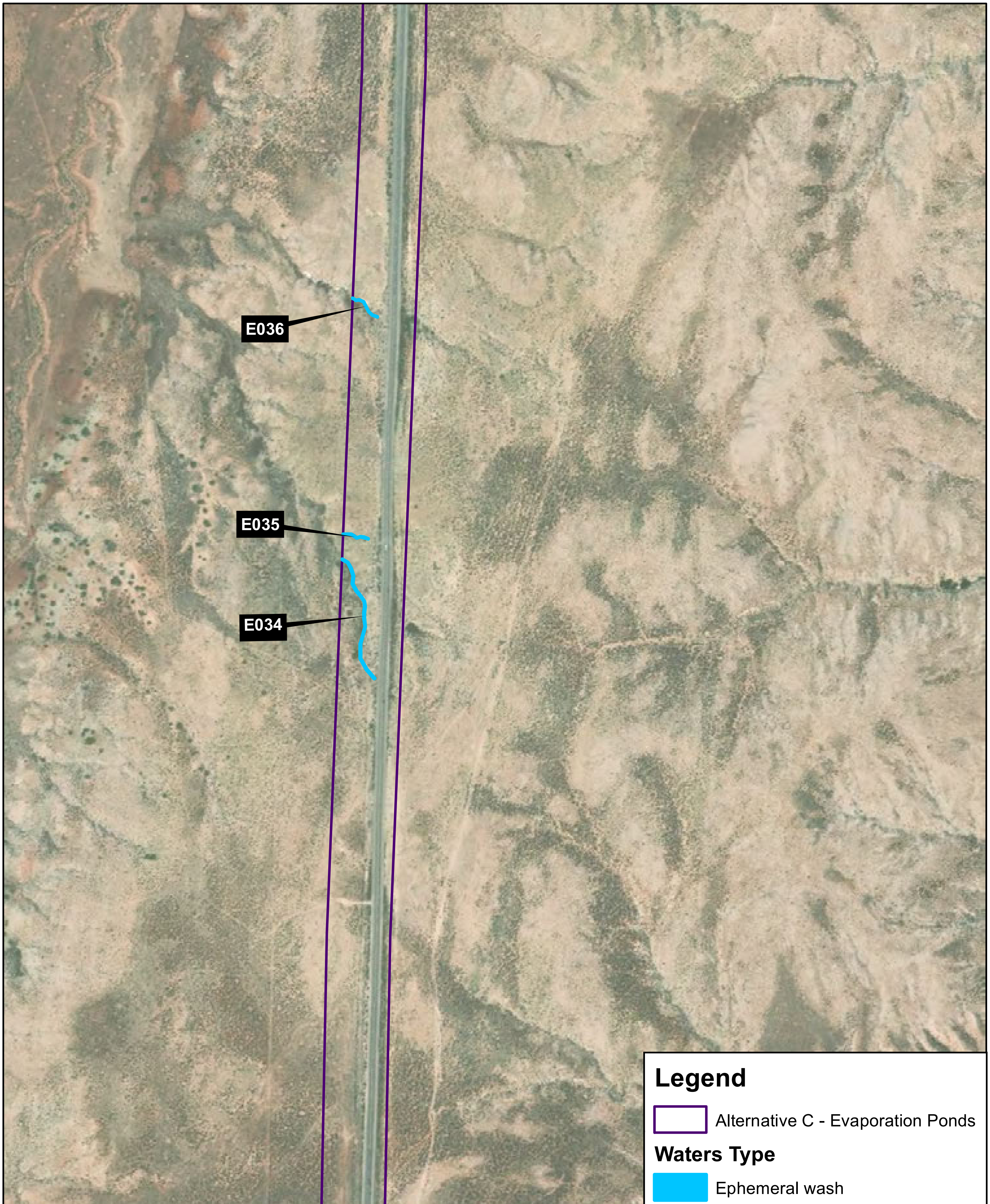
**Alternative C Waters Map**
**Page 11 of 21**

wood.

FIGURE 7-11




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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Bedrock, CO

wood.

**Alternative C Waters Map**
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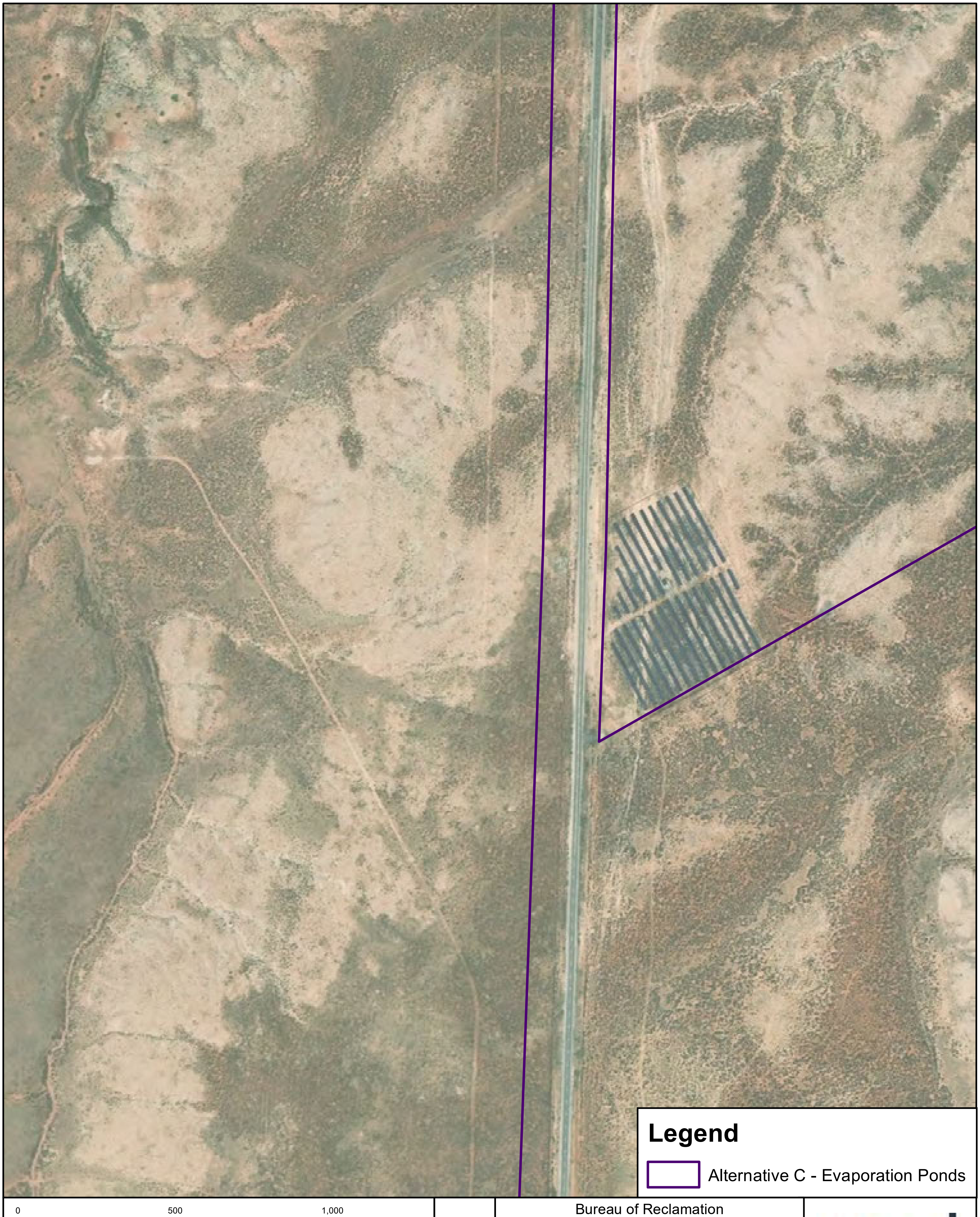
FIGURE 7-12




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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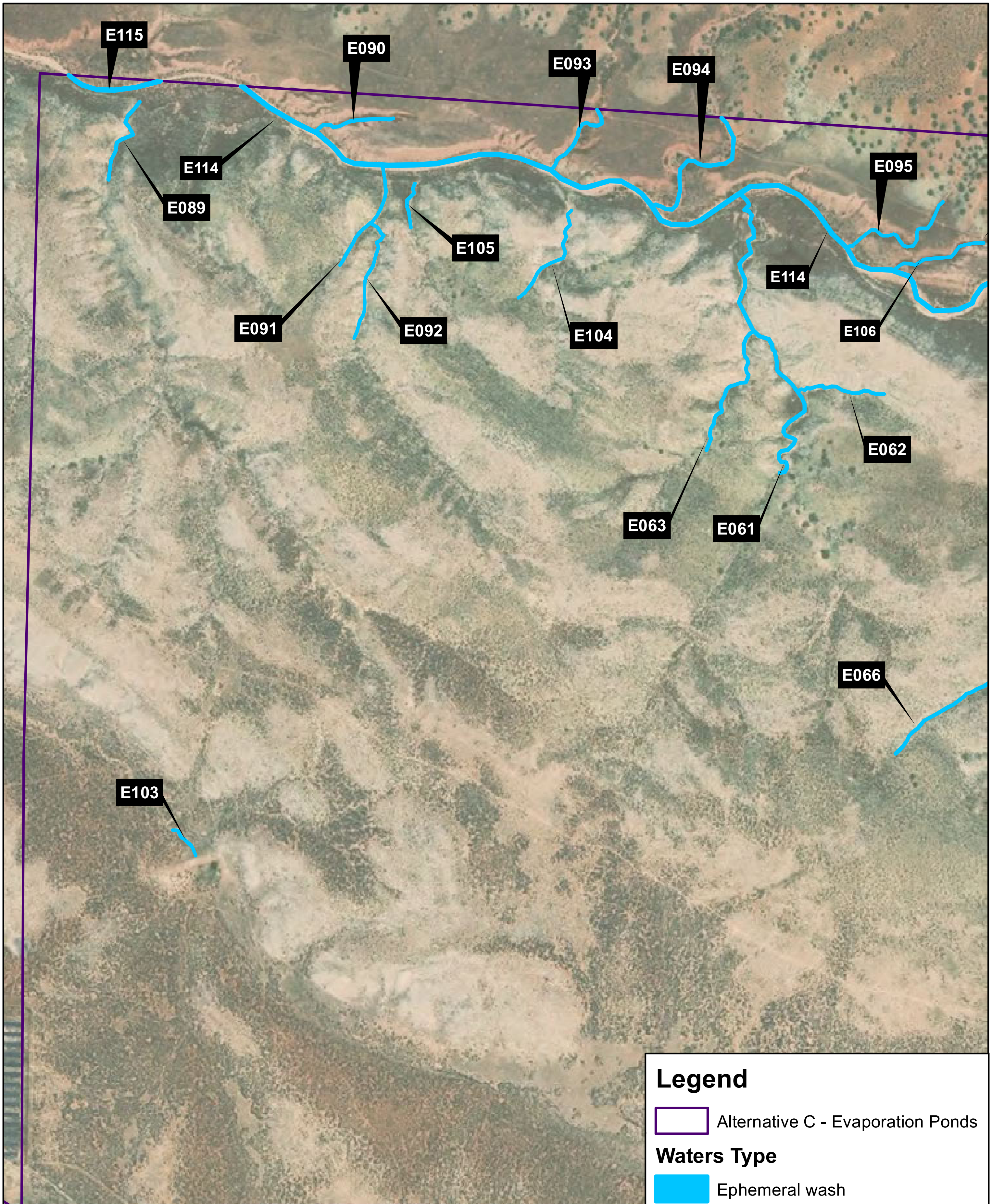
FIGURE 7-13




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative C Waters Map**
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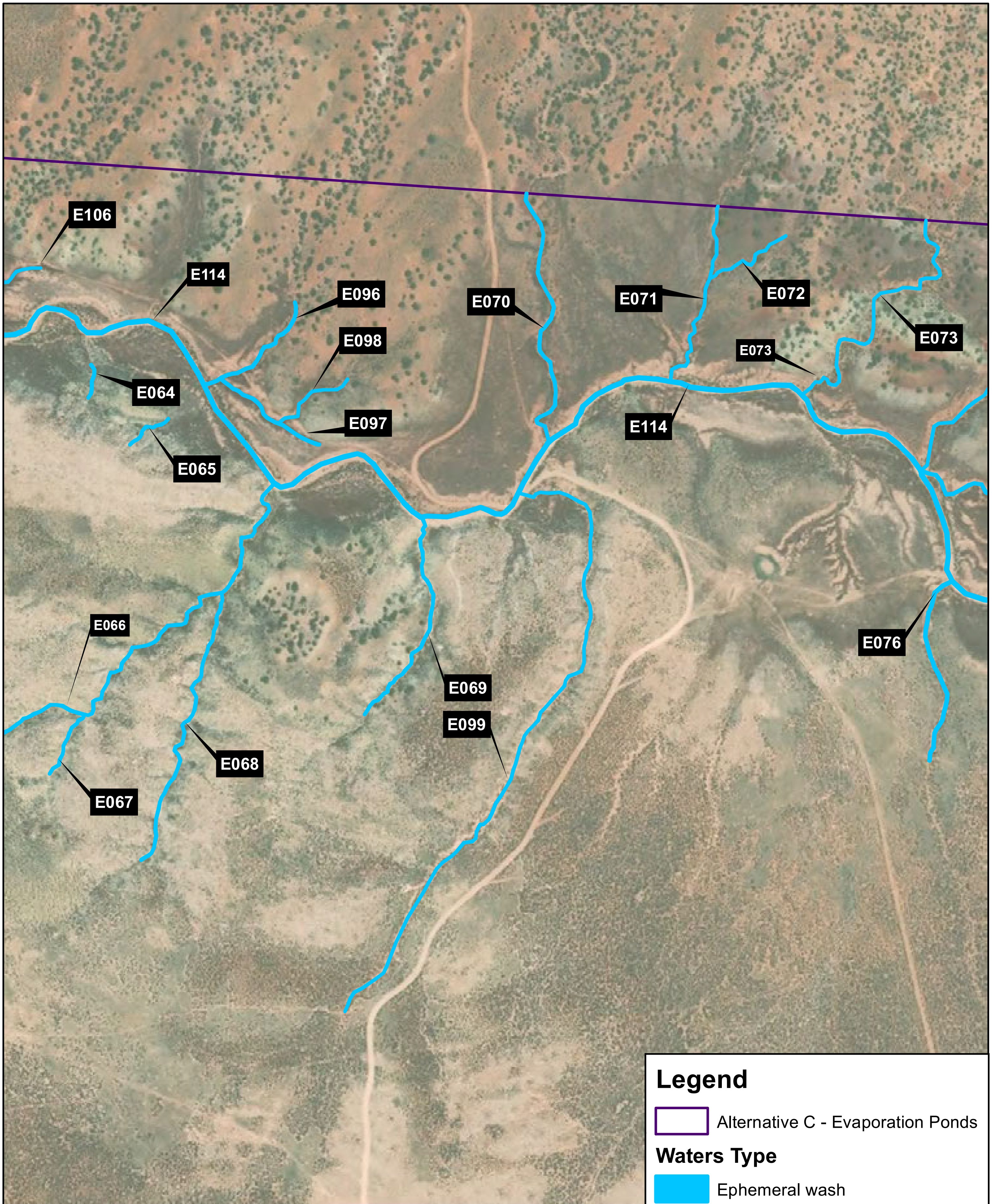
FIGURE 7-14




## Legend

Alternative C - Evaporation Ponds

### Waters Type

Ephemeral wash

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

**Alternative C Waters Map**
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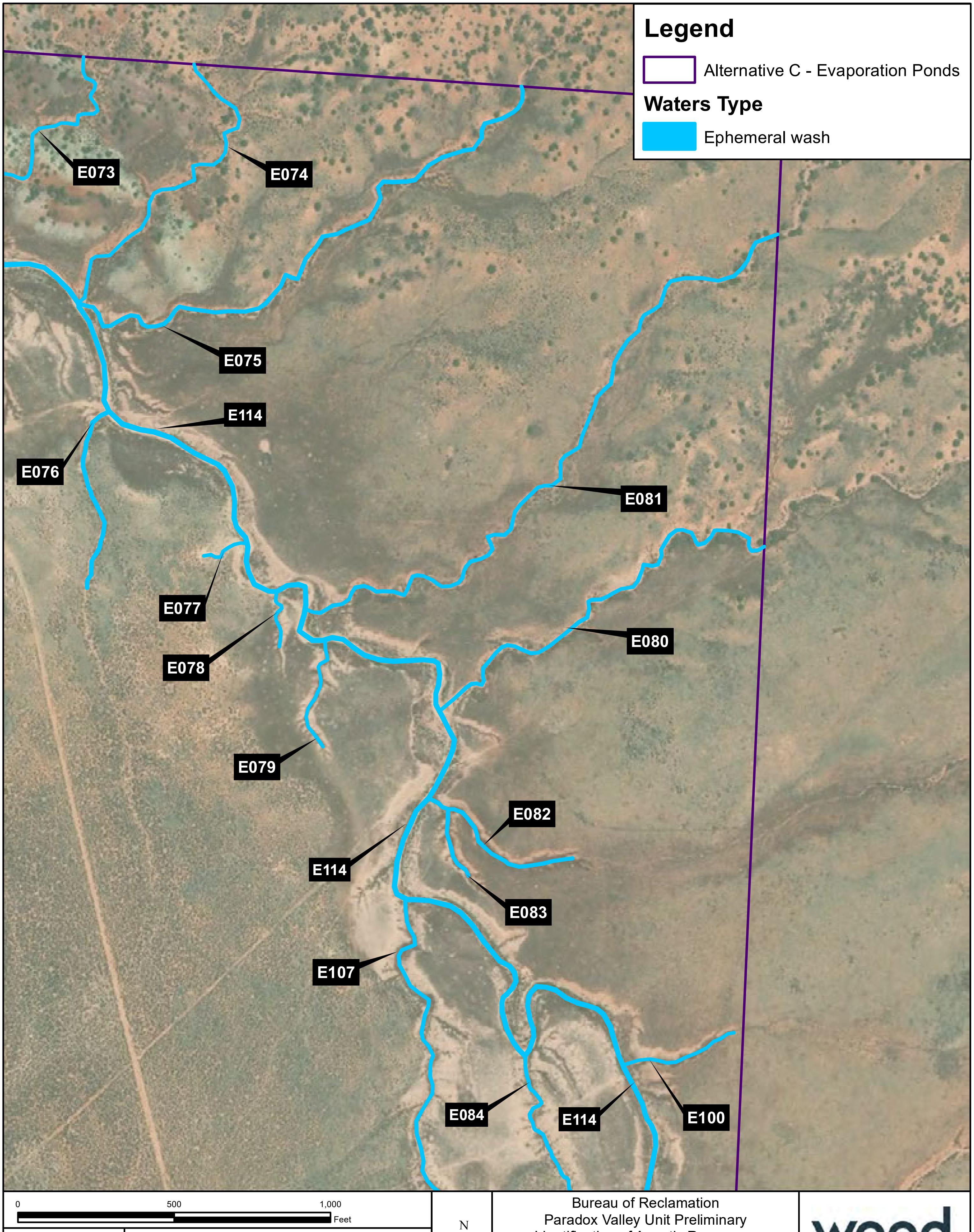
FIGURE 7-15




Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700

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wood.

**Alternative C Waters Map**
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FIGURE 7-16

## Legend

Alternative C - Evaporation Ponds

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative C Waters Map**
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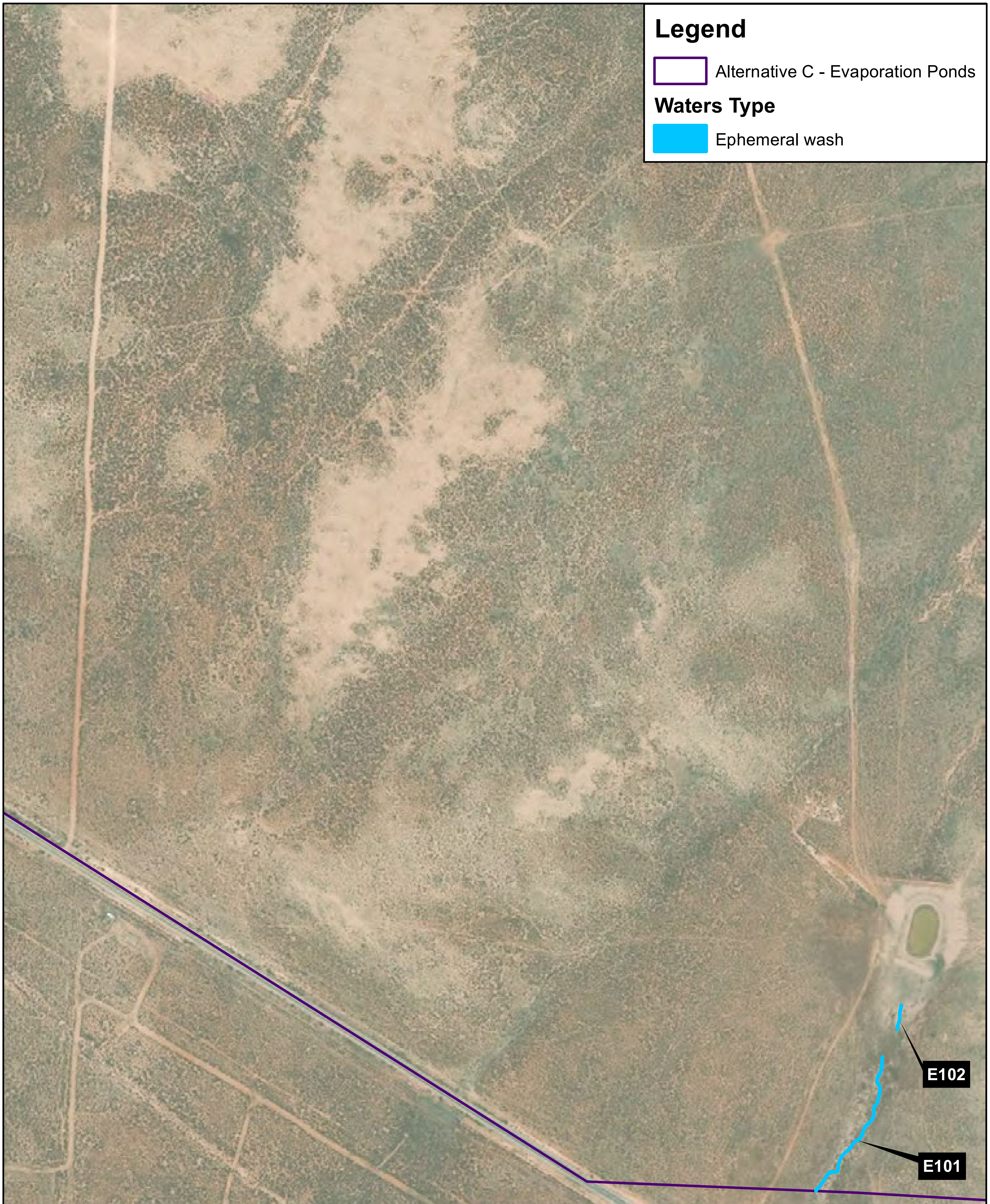
FIGURE 7-17




0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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N

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wood.

**Alternative C Waters Map**
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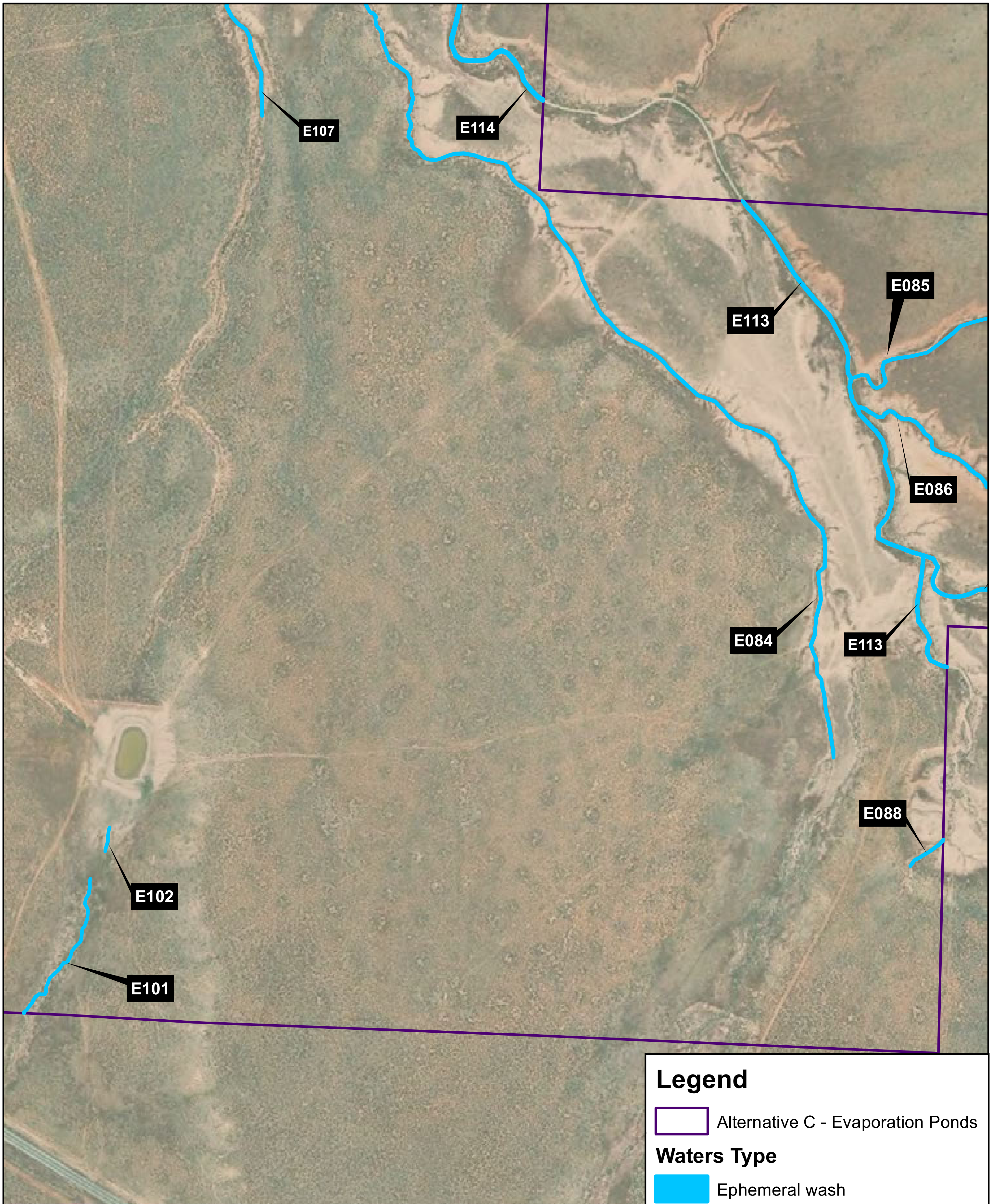
FIGURE 7-18




0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



N

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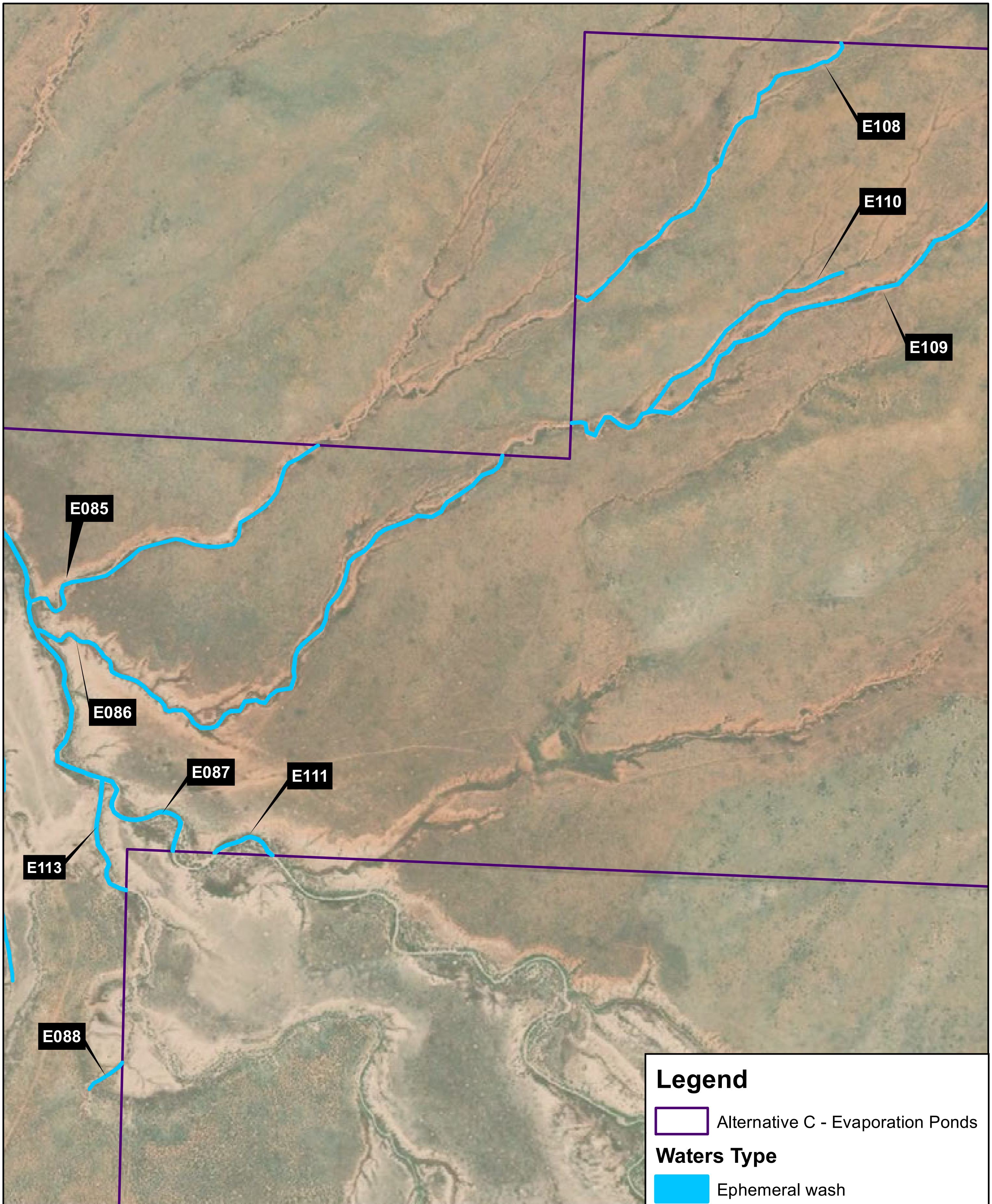
wood.

FIGURE 7-19




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative C Waters Map**
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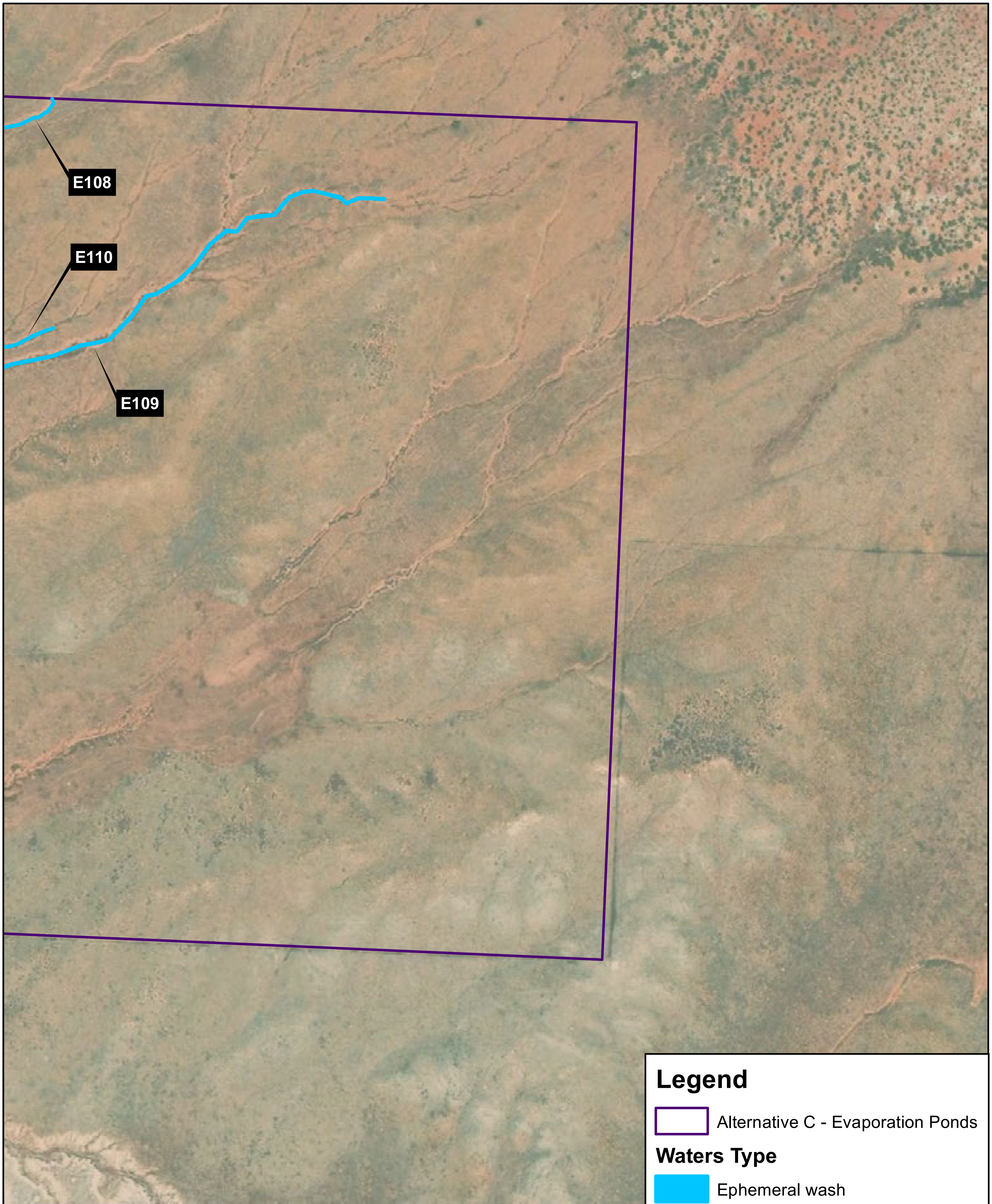
wood.

FIGURE 7-20




# Legend

Alternative C - Evaporation Ponds

## Waters Type

Ephemeral wash

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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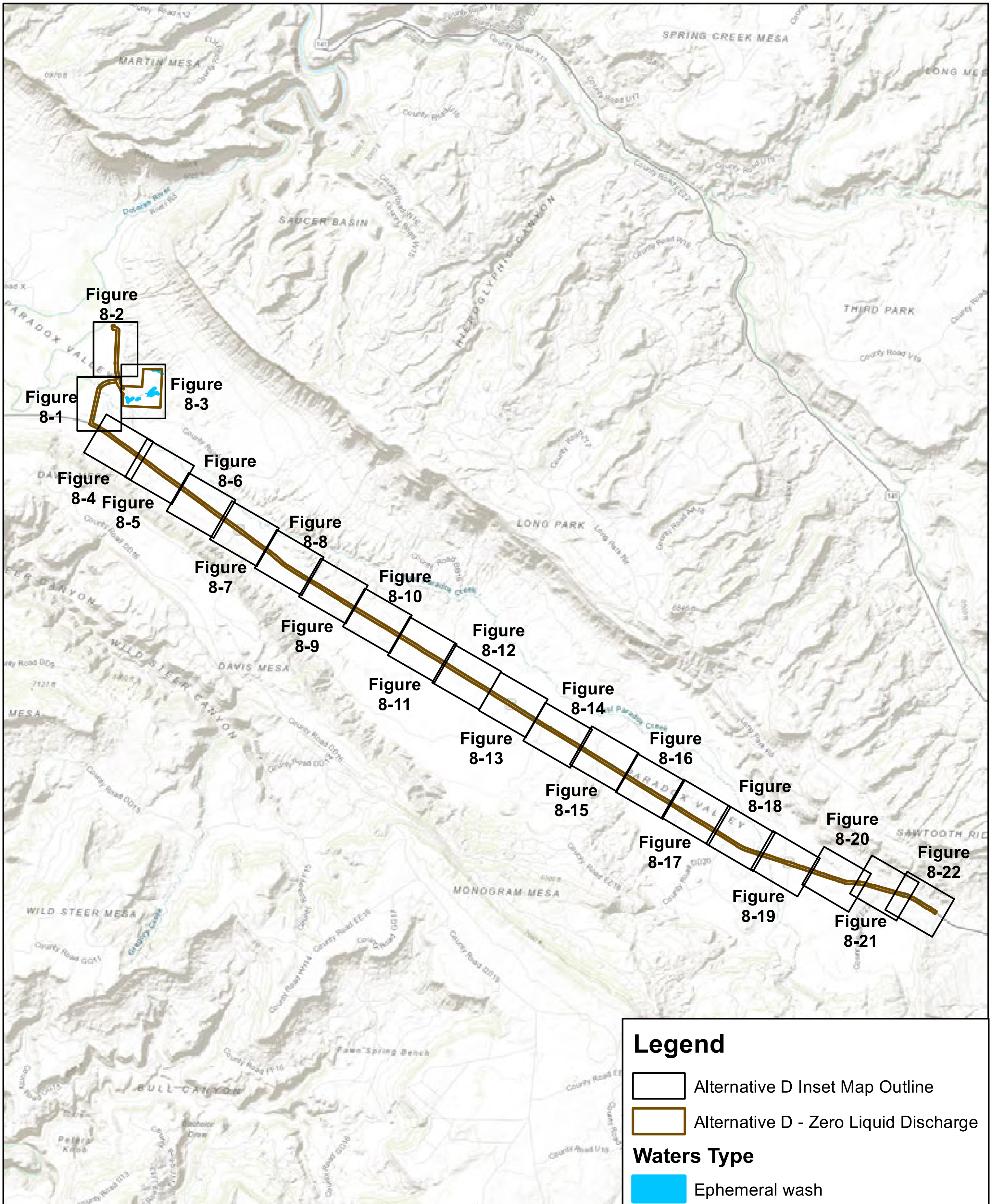
FIGURE 7-21




Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:104,839

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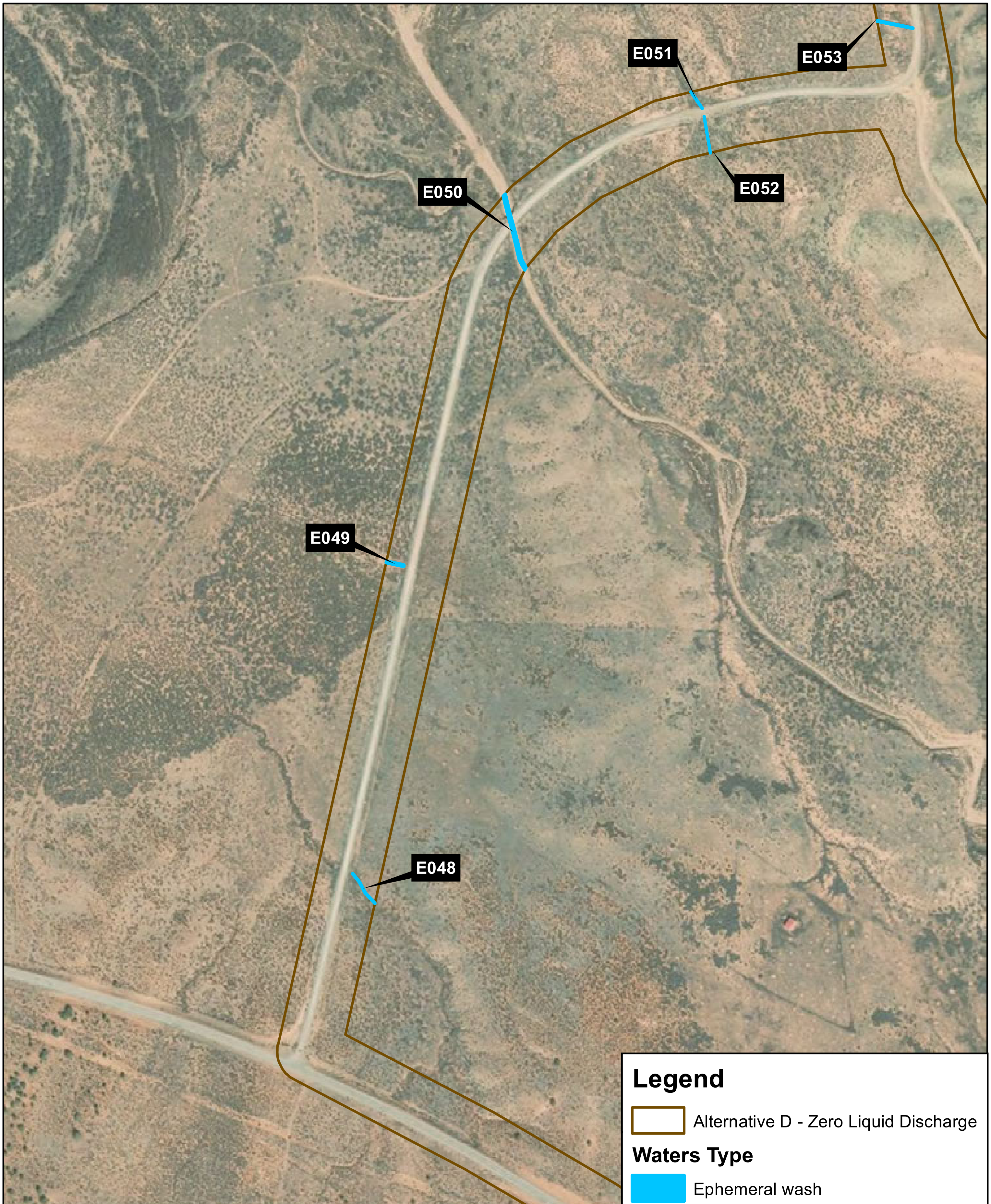
**Alternative D Waters Overview Map**

wood.

FIGURE 8




0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative D Waters Map**
**Page 1 of 22**

wood.

FIGURE 8-1


| | |
|---|---|
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| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

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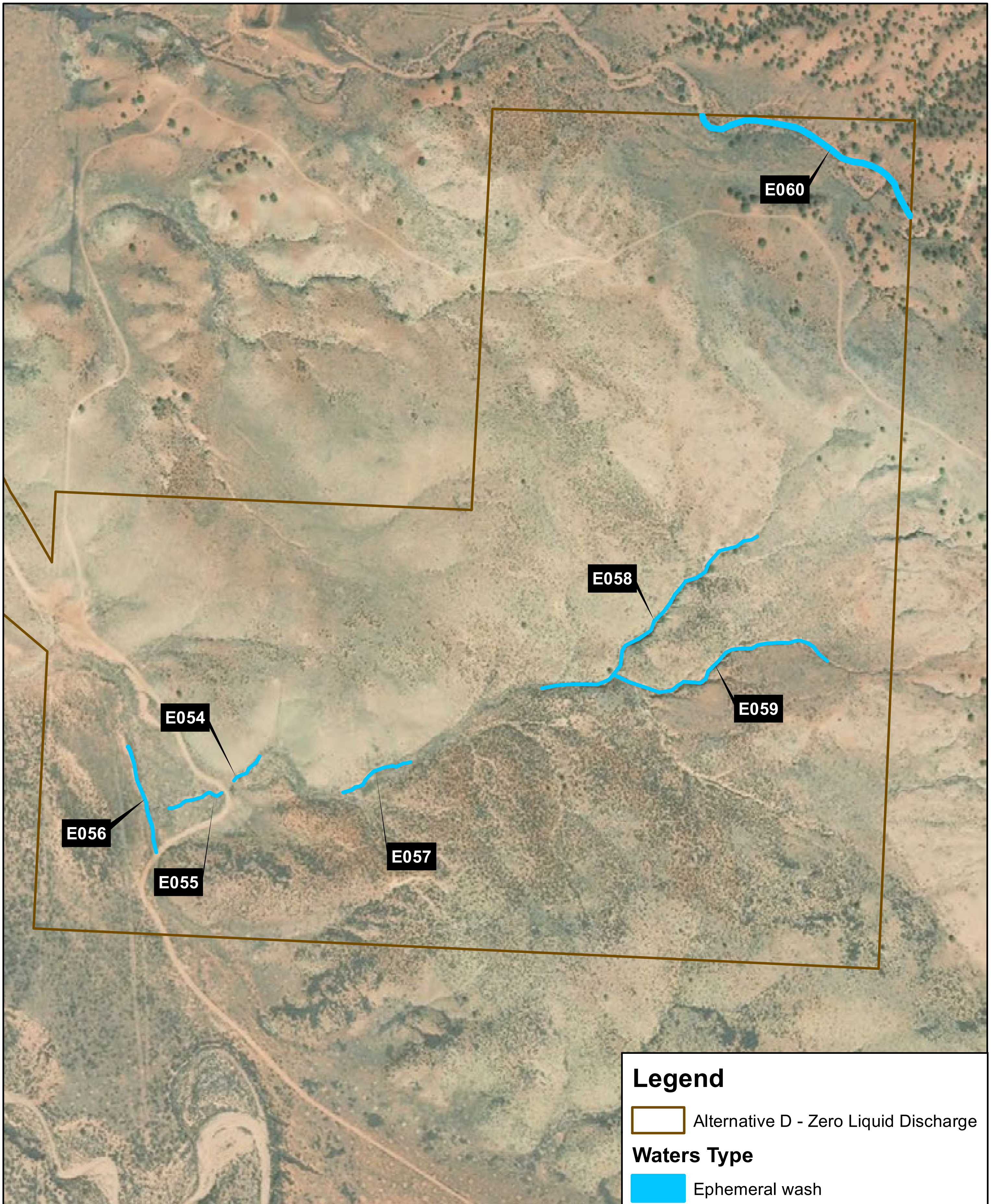
FIGURE 8-2




0 500 1,000
Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

**Alternative D Waters Map**
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FIGURE 8-2

## Legend

Alternative D - Zero Liquid Discharge

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative D Waters Map**
**Page 4 of 22**

FIGURE 8-4

## Legend

Alternative D - Zero Liquid Discharge

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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**Alternative D Waters Map**
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FIGURE 8-5


0 500 1,000
Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative D Waters Map**
**Page 6 of 22**

wood.

FIGURE 8-6

## Legend

Alternative D - Zero Liquid Discharge

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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**Alternative D Waters Map**
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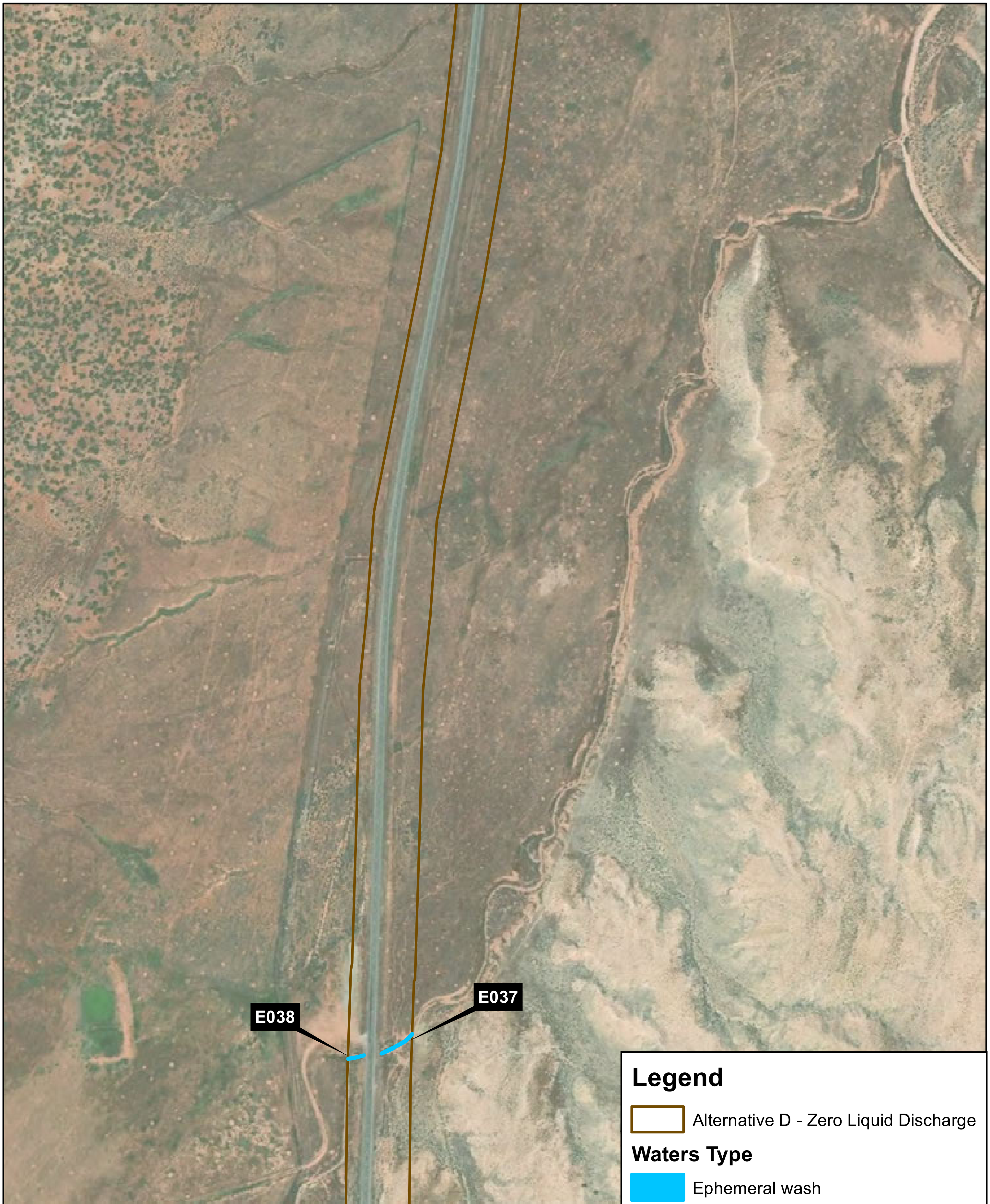
FIGURE 8-7




## Legend

Alternative D - Zero Liquid Discharge

**Waters Type**

Ephemeral wash

0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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**Alternative D Waters Map**
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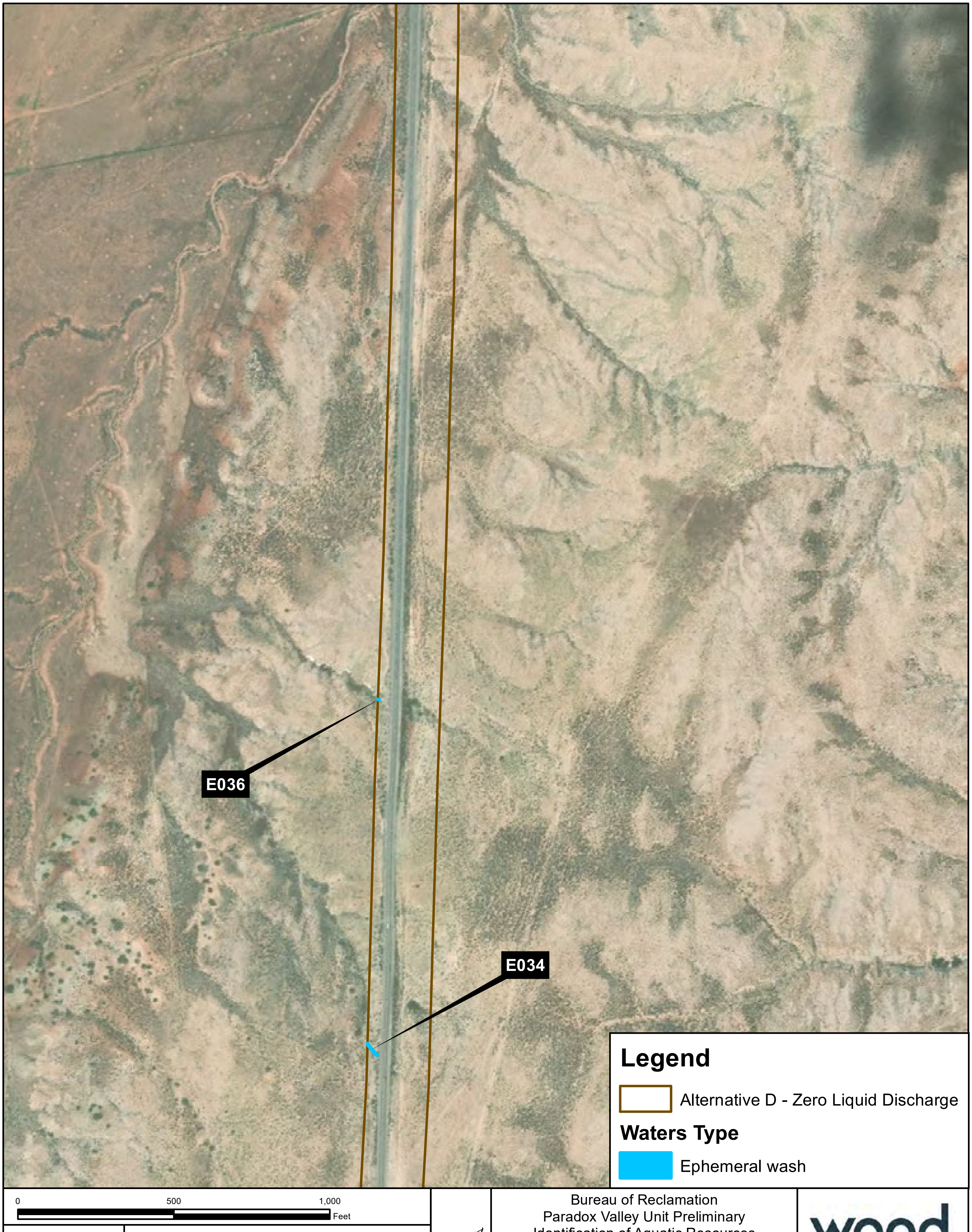
FIGURE 8-8




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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FIGURE 8-9


Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700



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**Alternative D Waters Map**
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FIGURE 8-10


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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wood.

**Alternative D Waters Map**
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FIGURE 8-11

## Legend

Alternative D - Zero Liquid Discharge

0 500 1,000 Feet

N

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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Paradox Valley Unit Preliminary
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Bedrock, CO

wood.

**Alternative D Waters Map**
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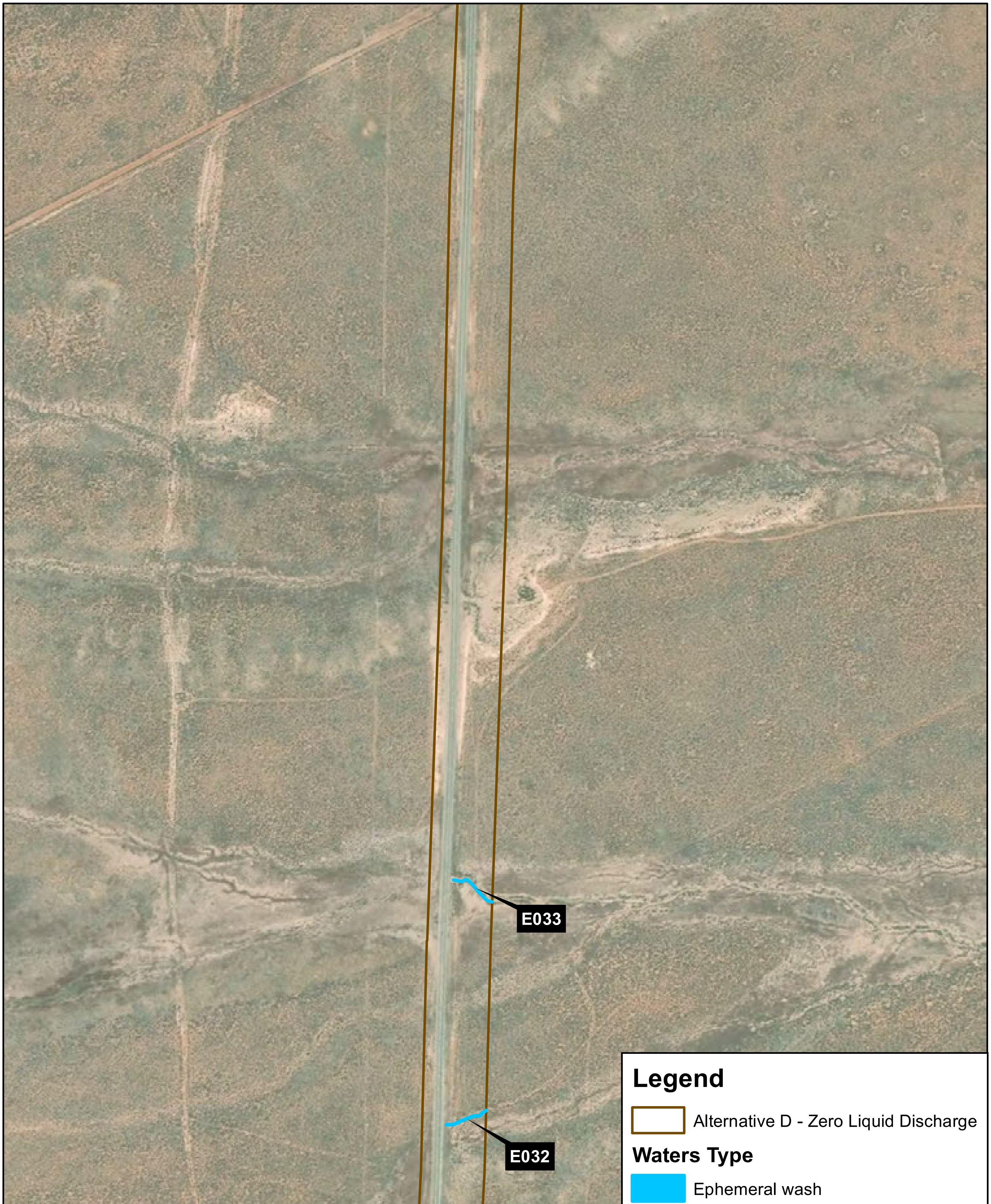
FIGURE 8-12




0 500 1,000 Feet

| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

**Alternative D Waters Map**
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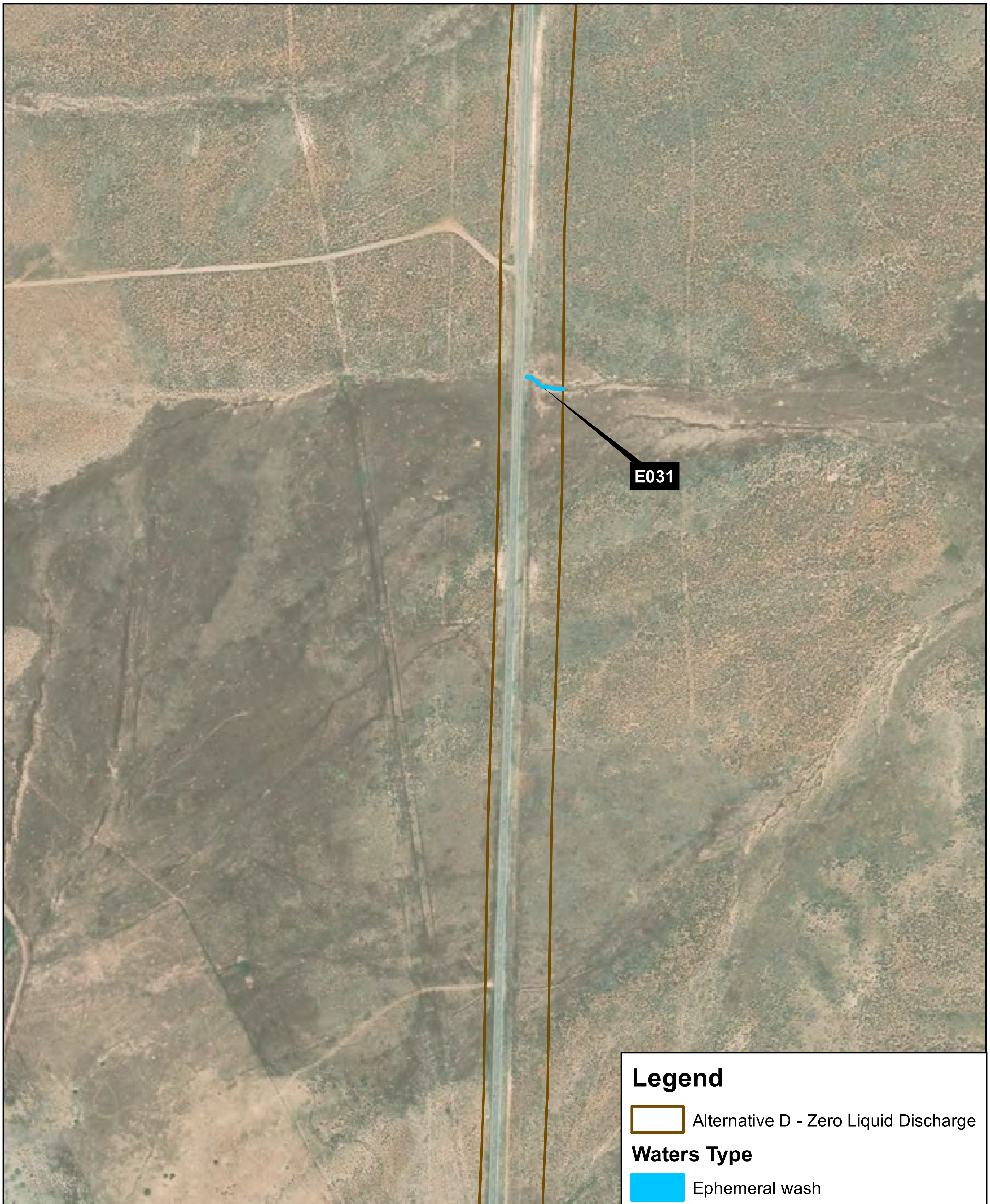
FIGURE 8-13




Job No.: GSA314C004
PM: DJ
Date: 7/3/2018
Scale: 1:4,700



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Bedrock, CO

**Alternative D Waters Map**
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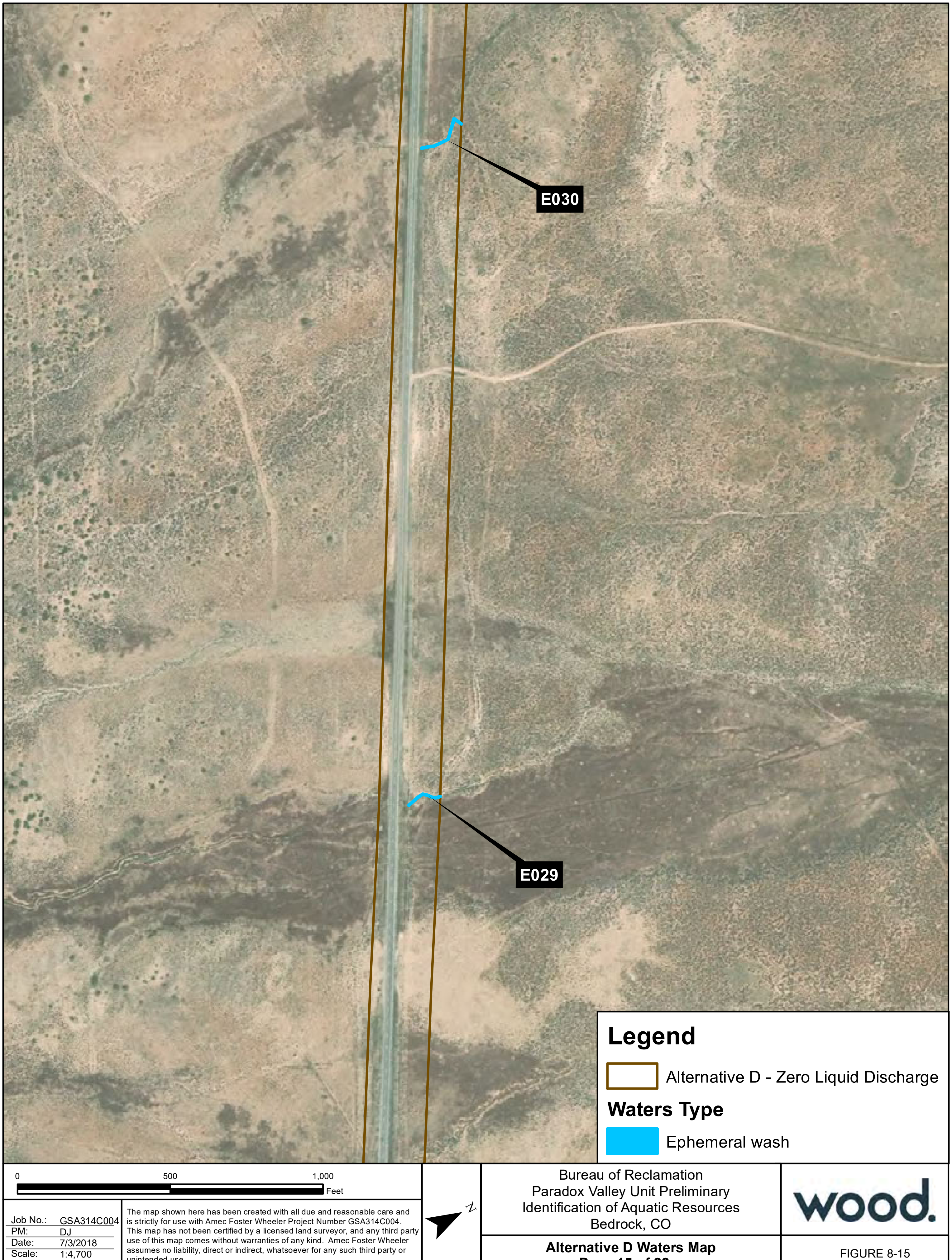
FIGURE 8-14




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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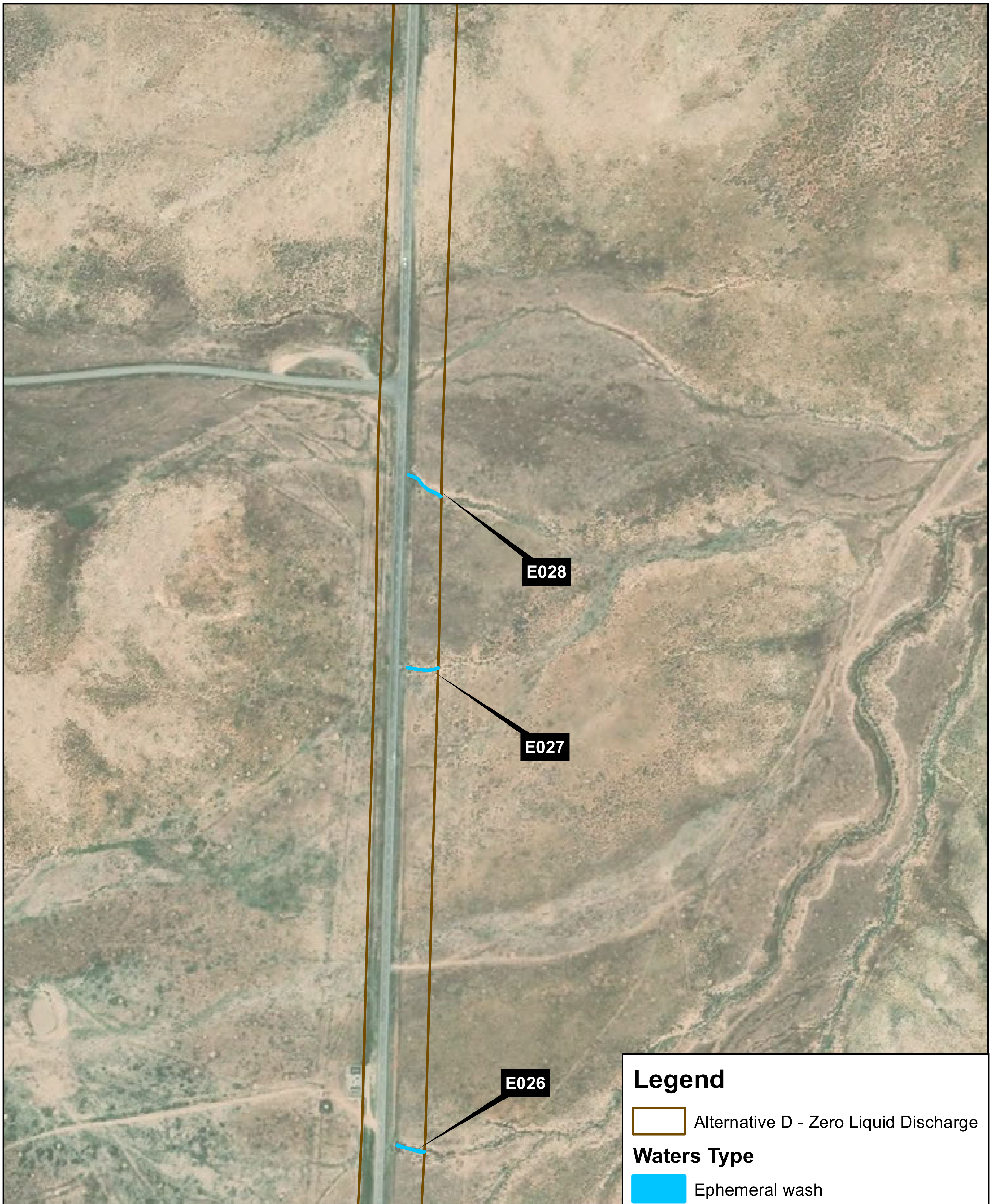
wood.

FIGURE 8-15




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |



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wood.

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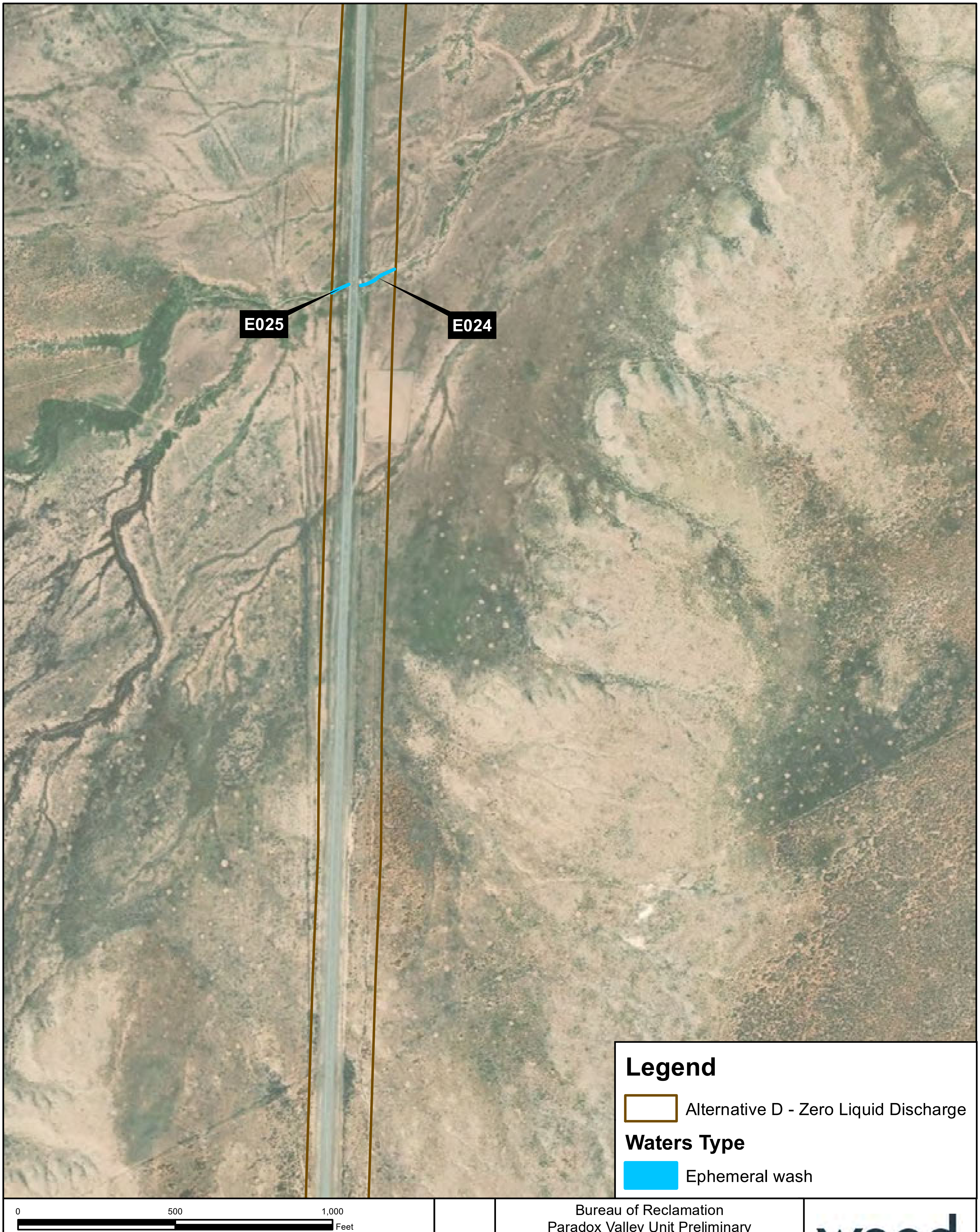
FIGURE 8-16




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,700 |

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FIGURE 8-17


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,720 |

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FIGURE 8-18


| | | | |
|---|---|---|---|
| 0 500 1,000 Feet | N | Bureau of Reclamation<br>Paradox Valley Unit Preliminary<br>Identification of Aquatic Resources<br>Bedrock, CO | wood. |
| Job No.: GSA314C004<br>PM: DJ<br>Date: 7/3/2018<br>Scale: 1:4,720 | The map shown here has been created with all due and reasonable care and is strictly for use with Amec Foster Wheeler Project Number GSA314C004. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Amec Foster Wheeler assumes no liability, direct or indirect, whatsoever for any such third party or unintended use. | **Alternative D Waters Map**<br>**Page 19 of 22** | FIGURE 8-19 |


| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,720 |



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wood.

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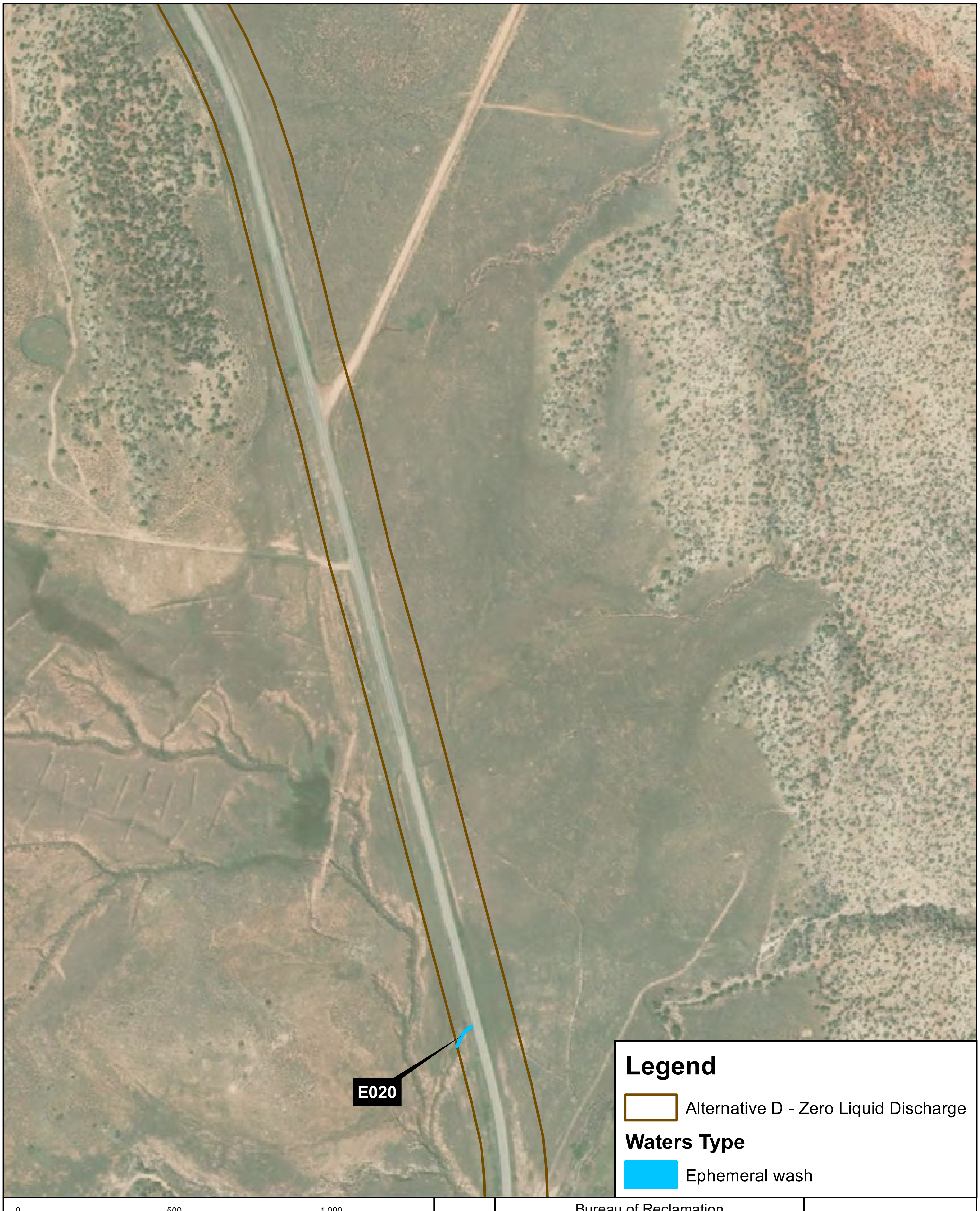
FIGURE 8-20




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,720 |

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wood.

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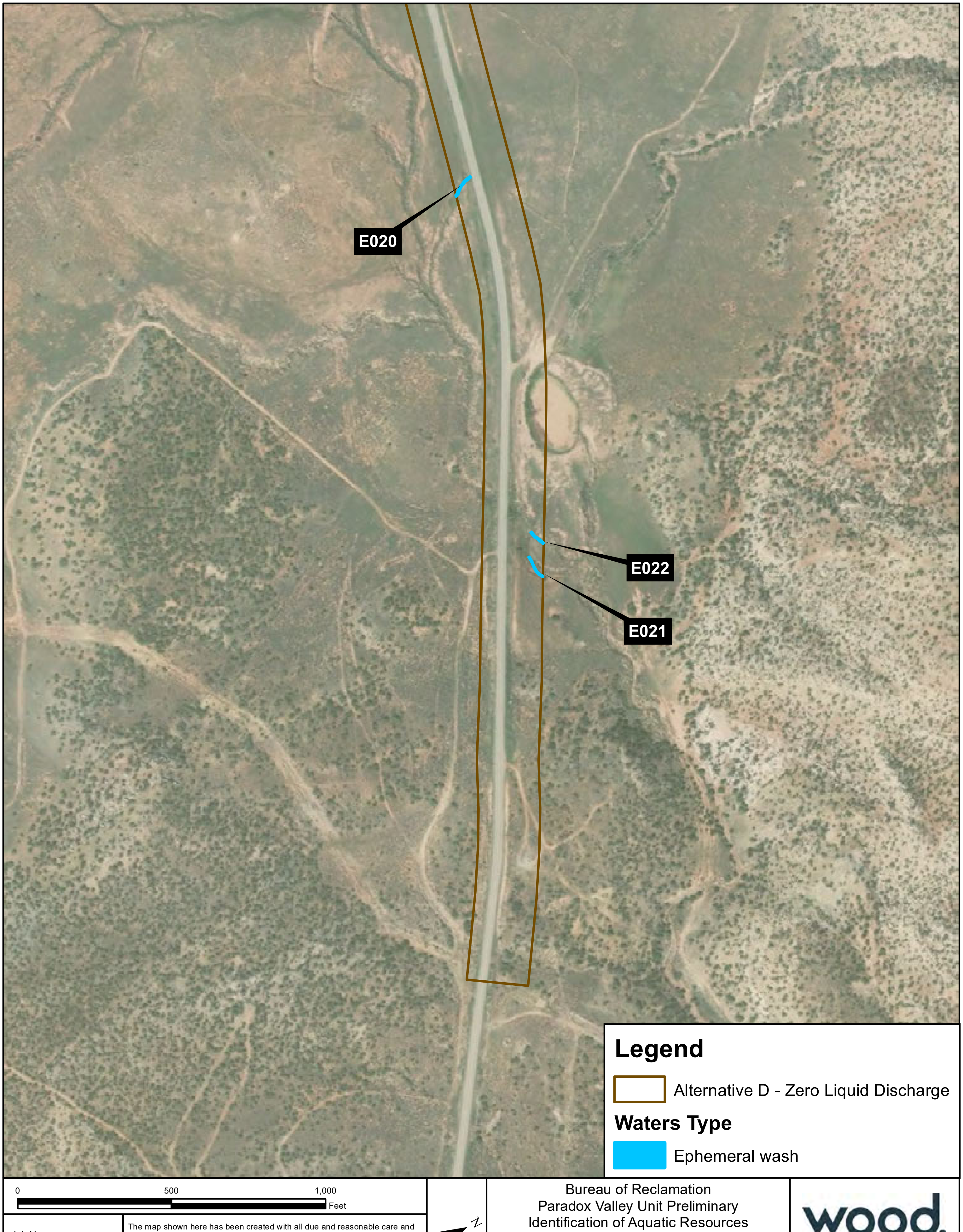
FIGURE 8-21




| | |
|---|---|
| Job No.: | GSA314C004 |
| PM: | DJ |
| Date: | 7/3/2018 |
| Scale: | 1:4,720 |

The map shown here has been created with all due and reasonable care and is strictly for use with Amec Foster Wheeler Project Number GSA314C004. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Amec Foster Wheeler assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

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wood.

FIGURE 8-22

# APPENDIX B: PHOTOGRAPHS

**Photo 1**. Swale developed from culvert in Alt D. No WUS characteristics were noted and not identified as a potential WUS.

**Photo 2**. Vegetated swale in Alt D with no WUS characteristics noted. Not identified as a potential WUS.

**Photo 3**. Swale in Alt C developed from runoff on top of high topographic feature. No WUS characteristics were noted and not identified as a potential WUS.

**Photo 4**. Ephemeral wash (E077) in Alt C with particle distribution and defined bed and bank. Included as a potential WUS.

**Photo 5**. Dry, detention area in Alt C with mudcracks and little to no vegetation and no water. Classified as an NHD feature but did not classify as WUS after field surveys.

**Photo 6**. Wide, vegetated swale in Alt C with no WUS characteristics documented. Did not delineate as a potential WUS feature.

**Photo 7**. Large drainage (E024) in Alt B2 and C with a box culvert present. Bed and bank and particle distribution noted in drainage. Delineated as a potential WUS.

**Photo 8**. Upland data point 1, along the Dolores River in Alt B1. Willows dominate a 5 – 10 foot area along the River. Hydrophytic vegetation present, but hydrology and hydric soils are not present.

**Photo 9**. Wetland data point 2 (W001), along the Dolores River in Alt B1. Phragmites and three-square dominate a 1 – 3 foot buffer of the River, 3 – 5 feet above the water table. Hydrophytic vegetation, hydrology, and hydric soils are all present.

**Photo 10**. Upland data point 2, along the Dolores River in Alt B1. Hydrophytic vegetation present, but hydrology and hydric soils are not present.

**Photo 11**. OWUS data point 1 within East Paradox Creek (E114) in Alt C.

**Photo 12**. OWUS data point 2 within unnamed drainage (E003) in Alt B2.

**Photo 13**. OWUS data point 3 within unnamed drainage (E060) in Alt D.

Photo 14. OWUS data point 4 of the Dolores River (P005) in Alt C.

# APPENDIX C: PLANT LIST

**Table 7. List of Observed Plant Species**

| Scientific Name | Common Name | National Wetland Plant Indicator | Colorado Noxious Weed: A,B,C |
|---|---|---|---|
| *Achnatherum hymenoides* | Indian ricegrass | UPL | |
| *Acroptilon repens* | Hardheads (Russian knapweed) | UPL | B |
| *Agropyron cristatum* | Crested wheatgrass | UPL* | |
| *Artemisia spiciformis* | Snowfield sagebrush | UPL* | |
| *Artemisia tridentata ssp. wyomingensis* | Sagebrush | UPL* | |
| *Astragalus sp.* | milkvetch | UNK | |
| *Atriplex canescens* | Four-wing saltbush | UPL* | |
| *Bassia prostrata* | Forage kochia | UPL* | |
| *Bouteloua gracilis* | Blue grama | UPL* | |
| *Bromus tectorum* | Cheatgrass | UPL* | |
| *Carex aquatilis* | Water sedge | OBL | |
| *Chrysothamnus viscidiflorus* | Rabbitbrush | UPL* | |
| *Distichlis spicata* | Saltgrass | FAC | |
| *Echinocereus triglochidiatus* | Kingcup cactus | UPL* | |
| *Ericameria nauseosa* | Rubber rabbitbrush | UPL* | |
| *Erodium cicutarium* | Redstem stork's bill | UPL* | B |
| *Forestiera pubescens* | Stretchberry | UPL* | |
| *Fraxinus anomala* | Singleleaf ash | UPL* | |
| *Halogeton glomeratus* | Saltlover | UPL* | C |
| *Hesperostipa comata* | Needle and thread grass | UPL* | |
| *Juniperus monosperma* | Oneseed juniper | UPL* | |
| *Melilotus officinalis* | Yellow sweet clover | FACU | |
| *Muhlenbergia sp.* | Muhly | UNK | |
| *Nasturtium officinale* | Watercress | OBL | |
| *Oenothera deltoides* | Birdcage evening primrose | UPL* | |
| *Opuntia phaeacantha* | Tulip prickly pear | UPL* | |
| *Philadelphus microphyllus* | Littleleaf mock-orange | UPL* | |
| *Phalarus arundinacea* | Reed canarygrass | FACW | |
| *Phleum pratense* | Timothy grass | FACU | |
| *Phragmites australis* | Common reed | FACW | |
| *Physaria acutifolia* | Double bladderpod | UPL* | |
| *Populus deltoides* | Eastern cottonwood | FAC | |
| *Salsola tragus* | Prickly Russian thistle | FACU | |
| *Salix exigua* | Coyote willow | FACW | |
| *Sarcobatus vermiculatus* | Greasewood | FACU | |
| *Schoenoplectus pungens* | Common threesquare | OBL | |
| *Sclerocactus parviflorus* | Smallflower fishhook cactus | UPL* | |

| Scientific Name | Common Name | National Wetland Plant Indicator | Colorado Noxious Weed: A,B,C |
|---|---|---|---|
| *Tamarix sp.* | Saltcedar | FAC | B |
| *Thlaspi arvense* | Field pennycress | UPL | |
| *Typha latifolia* | Broad-leaf cattail | OBL | |
| *Ulmus pumila* | Siberian elm | UPL | |
| *Xanthium strumarium* | Rough cockleburr | FAC | |

**Source:** (Lichvar et al. 2016; CDA 2018; USDA 2018)
**CO Noxious Weed definitions:** (CDA 2018)
**National Wetland Plant Rating definition and percent of occurrence in wetland:**
UPL*: Not assessed as a wetland plant by the NWPL therefore it is given an UPL rating
UNK: Species unknown, unable to determine NWPL Indicator
UPL: Upland, 1; FACU: Facultative Upland: 1-33; FAC: Facultative: 34-66;
FACW: Facultative Wetland: 67-99; OBL: Obligate: 99

# APPENDIX D: WETLAND DATA SHEETS

# WETLAND DETERMINATION DATA FORM - Arid West Region

**Project/Site:** PVU  **City/County:** Mesa  **Sampling Date:** 09-May-18

**Applicant/Owner:** BLM  **State:** Colorado  **Sampling Point:** Upland 1 - NOTFULLPT

**Investigator(s):** c.photos, m. Greulich  **Section, Township, Range:** S  T  R

**Landform (hillslope, terrace, etc.):** Floodplain  **Local relief (concave, convex, none):** flat  **Slope:** 0.0 % / 0.0 °

**Subregion (LRR):**  **Lat.:**  **Long.:**  **Datum:**

**Soil Map Unit Name:**  **NWI classification:**

**Are climatic/hydrologic conditions on the site typical for this time of year?** Yes ○ No ◉ **(If no, explain in Remarks.)**

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **significantly disturbed?** **Are "Normal Circumstances" present?** Yes ◉ No ○

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **naturally problematic?** **(If needed, explain any answers in Remarks.)**

## Summary of Findings - Attach site map showing sampling point locations, transects, important features, etc.

| | | |
|---|---|---|
| **Hydrophytic Vegetation Present?** | Yes ◉ No ○ | **Is the Sampled Area within a Wetland?** Yes ○ No ◉ |
| **Hydric Soil Present?** | Yes ○ No ◉ | |
| **Wetland Hydrology Present?** | Yes ○ No ◉ | |

**Remarks:** worst drought in 25. yrs, plot 8ft above the river, soil not moist, no hydric soil indicators so a complete datasheet was not entered.

## VEGETATION - Use scientific names of plants.

| | Absolute % Cover | Dominant Species? | Rel.Strat. Cover | Indicator Status |
|---|---|---|---|---|
| **Tree Stratum** (Plot size: 30) | | | | |
| 1. | 0 | ☐ | 0.0% | |
| 2. | 0 | ☐ | 0.0% | |
| 3. | 0 | ☐ | 0.0% | |
| 4. | 0 | ☐ | 0.0% | |
| | 0 | = Total Cover | | |
| **Sapling/Shrub Stratum** (Plot size: 15) | | | | |
| 1. Tamarix chinensis | 20 | ☑ | 20.0% | FAC |
| 2. Salix exigua | 80 | ☑ | 80.0% | FACW |
| 3. | 0 | ☐ | 0.0% | |
| 4. | 0 | ☐ | 0.0% | |
| 5. | 0 | ☐ | 0.0% | |
| | 100 | = Total Cover | | |
| **Herb Stratum** (Plot size: 5) | | | | |
| 1. Thlaspi arvense | 15 | ☑ | 75.0% | UPL |
| 2. Carex aquatilis | 2 | ☐ | 10.0% | OBL |
| 3. Phalaris angusta | 3 | ☐ | 15.0% | FACW |
| 4. | 0 | ☐ | 0.0% | |
| 5. | 0 | ☐ | 0.0% | |
| 6. | 0 | ☐ | 0.0% | |
| 7. | 0 | ☐ | 0.0% | |
| 8. | 0 | ☐ | 0.0% | |
| 9. | 0 | ☐ | 0.0% | |
| 10. | 0 | ☐ | 0.0% | |
| 11. | 0 | ☐ | 0.0% | |
| | 20 | = Total Cover | | |
| **Woody Vine Stratum** (Plot size: ) | | | | |
| 1. | 0 | ☐ | 0.0% | |
| 2. | 0 | ☐ | 0.0% | |
| | 0 | = Total Cover | | |

**% Bare Ground in Herb Stratum:** 80  **% Cover of Biotic Crust** 0

**Dominance Test worksheet:**

| | | |
|---|---|---|
| Number of Dominant Species That are OBL, FACW, or FAC: | 2 | (A) |
| Total Number of Dominant Species Across All Strata: | 3 | (B) |
| Percent of dominant Species That Are OBL, FACW, or FAC: | 66.7% | (A/B) |

**Prevalence Index worksheet:**

| Total % Cover of: | | Multiply by: | |
|---|---|---|---|
| OBL species | 2 | x 1 = | 2 |
| FACW species | 83 | x 2 = | 166 |
| FAC species | 20 | x 3 = | 60 |
| FACU species | 0 | x 4 = | 0 |
| UPL species | 15 | x 5 = | 75 |
| Column Totals: | 120 (A) | | 303 (B) |

Prevalence Index = B/A = 2.525

**Hydrophytic Vegetation Indicators:**

- ☑ **Dominance Test is > 50%**
- ☑ **Prevalence Index is ≤3.0** [1]
- ☐ **Morphological Adaptations** [1] **(Provide supporting data in Remarks or on a separate sheet)**
- ☐ **Problematic Hydrophytic Vegetation** [1] **(Explain)**

[1] **Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.**

**Hydrophytic Vegetation Present?** Yes ◉ No ○

**Remarks:**

field penny cress id ?, leaf litter and salix branches dominate ground

*Indicator suffix = National status or professional decision assigned because Regional status not defined by FWS.

## Soil

**Sampling Point:** Upland 1 - NOTFULLPT

**Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)**

| Depth (inches) | Matrix Color (moist) | Matrix % | Redox Features Color (moist) | Redox Features % | Type[1] | Loc² | Texture | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

[1] Type: C=Concentration. D=Depletion. RM=Reduced Matrix, CS=Covered or Coated Sand Grains ²Location: PL=Pore Lining. M=Matrix

**Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)**

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5) (LRR C)
- ☐ 1 cm Muck (A9) (LRR D)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Muck Mineral (S1)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Loamy Mucky Mineral (F1)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox depressions (F8)
- ☐ Vernal Pools (F9)

**Indicators for Problematic Hydric Soils:**[3]

- ☐ 1 cm Muck (A9) (LRR C)
- ☐ 2 cm Muck (A10) (LRR B)
- ☐ Reduced Vertic (F18)
- ☐ Red Parent Material (TF2)
- ☐ Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present.

**Restrictive Layer (if present):**

Type:

Depth (inches):

**Hydric Soil Present?** Yes ○ No ◉

Remarks:

## Hydrology

**Wetland Hydrology Indicators:**

Primary Indicators (minimum of one required; check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1) (Nonriverine)
- ☐ Sediment Deposits (B2) (Nonriverine)
- ☐ Drift deposits (B3) (Noneriverine)
- ☐ Surface Soil Cracks (B6)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Salt Crust (B11)
- ☐ Biotic Crust (B12)
- ☐ Aquatic Invertebrates (B13)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres along Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Plowed Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ☐ Water Marks (B1) (Riverine)
- ☐ Sediment Deposits (B2) (Riverine)
- ☐ Drift Deposits (B3) Riverine)
- ☐ Drainage Patterns (B10)
- ☐ Dry Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Shallow Aquitard (D3)
- ☐ FAC-neutral Test (D5)

**Field Observations:**

| | | | |
|---|---|---|---|
| Surface Water Present? | Yes ○ | No ◉ | Depth (inches): 0 |
| Water Table Present? | Yes ○ | No ◉ | Depth (inches): 0 |
| Saturation Present? (includes capillary fringe) | Yes ○ | No ◉ | Depth (inches): 0 |

**Wetland Hydrology Present?** Yes ○ No ◉

Describe Recorded Data (stream gauge, monitor well, aerial photos, previous inspections), if available:

Remarks:

# WETLAND DETERMINATION DATA FORM - Arid West Region

**Project/Site:** PVU **City/County:** Mesa **Sampling Date:** 09-May-18

**Applicant/Owner:** BLM **State:** Colorado **Sampling Point:** **Wetland 2**

**Investigator(s):** C.Photos, M. Greulich **Section, Township, Range:** S 30 T 47N R 18W

**Landform (hillslope, terrace, etc.):** Floodplain **Local relief (concave, convex, none):** flat **Slope:** 0.0 % / 0.0 °

**Subregion (LRR):** LRR D **Lat.:** 38.297229 **Long.:** -108.895822 **Datum:** NAD 83

**Soil Map Unit Name:** Water **NWI classification:** PSAA

**Are climatic/hydrologic conditions on the site typical for this time of year?** Yes ○ No ● **(If no, explain in Remarks.)**

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **significantly disturbed?** **Are "Normal Circumstances" present?** Yes ● No ○

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **naturally problematic?** **(If needed, explain any answers in Remarks.)**

## Summary of Findings - Attach site map showing sampling point locations, transects, important features, etc.

| | | | |
|---|---|---|---|
| **Hydrophytic Vegetation Present?** | Yes ● No ○ | **Is the Sampled Area within a Wetland?** | Yes ● No ○ |
| **Hydric Soil Present?** | Yes ● No ○ | | |
| **Wetland Hydrology Present?** | Yes ● No ○ | | |

**Remarks:** worst drought in 25. yrs, plot 8ft above the river. Soil map aligns with water mapping, adjacent to soil type Pojoaque-Chilton complex., 5 to 30 percent slope, extremely stony

## VEGETATION - Use scientific names of plants.

| | Absolute % Cover | Dominant Species? | Rel.Strat. Cover | Indicator Status |
|---|---|---|---|---|
| **Tree Stratum** (Plot size: 30) | | | | |
| 1. Populus deltoides | 10 | ☑ | 40.0% | FAC |
| 2. Ulmus pumila | 15 | ☑ | 60.0% | UPL |
| 3. | 0 | ☐ | 0.0% | |
| 4. | 0 | ☐ | 0.0% | |
| | 25 | = Total Cover | | |
| **Sapling/Shrub Stratum** (Plot size: 15) | | | | |
| 1. Ulmus pumila | 1 | ☑ | 100.0% | UPL |
| 2. | 0 | ☐ | 0.0% | |
| 3. | 0 | ☐ | 0.0% | |
| 4. | 0 | ☐ | 0.0% | |
| 5. | 0 | ☐ | 0.0% | |
| | 1 | = Total Cover | | |
| **Herb Stratum** (Plot size: 5ft) | | | | |
| 1. Distichlis spicata | 10 | ☐ | 11.1% | FAC |
| 2. Muhlenbergia filiformis | 30 | ☑ | 33.3% | FACW |
| 3. Phalaris arundinacea | 5 | ☐ | 5.6% | FACW |
| 4. Typha latifolia | 44 | ☑ | 48.9% | OBL |
| 5. Nasturtium officinale | 1 | ☐ | 1.1% | OBL |
| 6. | 0 | ☐ | 0.0% | |
| 7. | 0 | ☐ | 0.0% | |
| 8. | 0 | ☐ | 0.0% | |
| 9. | 0 | ☐ | 0.0% | |
| 10. | 0 | ☐ | 0.0% | |
| 11. | 0 | ☐ | 0.0% | |
| | 90 | = Total Cover | | |
| **Woody Vine Stratum** (Plot size: ) | | | | |
| 1. | 0 | ☐ | 0.0% | |
| 2. | 0 | ☐ | 0.0% | |
| | 0 | = Total Cover | | |

**% Bare Ground in Herb Stratum:** 10 **% Cover of Biotic Crust** 0

**Dominance Test worksheet:**

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of dominant Species That Are OBL, FACW, or FAC: 60.0% (A/B)

**Prevalence Index worksheet:**

| Total % Cover of: | | Multiply by: | |
|---|---|---|---|
| OBL species | 45 | x 1 = | 45 |
| FACW species | 35 | x 2 = | 70 |
| FAC species | 20 | x 3 = | 60 |
| FACU species | 0 | x 4 = | 0 |
| UPL species | 16 | x 5 = | 80 |
| Column Totals: | 116 (A) | | 255 (B) |

Prevalence Index = B/A = 2.198

**Hydrophytic Vegetation Indicators:**

- ☑ **Dominance Test is > 50%**
- ☑ **Prevalence Index is ≤3.0** [1]
- ☐ **Morphological Adaptations** [1] **(Provide supporting data in Remarks or on a separate sheet)**
- ☐ **Problematic Hydrophytic Vegetation** [1] **(Explain)**

[1] **Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.**

**Hydrophytic Vegetation Present?** Yes ● No ○

**Remarks:**

*Indicator suffix = National status or professional decision assigned because Regional status not defined by FWS.

## Soil

**Sampling Point:** Wetland 2

**Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)**

| Depth (inches) | Matrix Color (moist) | | Matrix % | Redox Features Color (moist) | | Redox % | Type[1] | Loc² | Texture | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-16 | 5YR | 4/2 | 90 | 5YR | 6/8 | 10 | C | PL | Very Fine Sand | saturated. Fibrous. |
| 16-20 | 5YR | 4/3 | 100 | | | | | | silty sand | |

[1] Type: C=Concentration. D=Depletion. RM=Reduced Matrix, CS=Covered or Coated Sand Grains ²Location: PL=Pore Lining. M=Matrix

**Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)**

- [ ] Histosol (A1)
- [ ] Histic Epipedon (A2)
- [ ] Black Histic (A3)
- [ ] Hydrogen Sulfide (A4)
- [ ] Stratified Layers (A5) (LRR C)
- [ ] 1 cm Muck (A9) (LRR D)
- [ ] Depleted Below Dark Surface (A11)
- [ ] Thick Dark Surface (A12)
- [ ] Sandy Muck Mineral (S1)
- [ ] Sandy Gleyed Matrix (S4)
- [x] Sandy Redox (S5)
- [ ] Stripped Matrix (S6)
- [ ] Loamy Mucky Mineral (F1)
- [ ] Loamy Gleyed Matrix (F2)
- [ ] Depleted Matrix (F3)
- [ ] Redox Dark Surface (F6)
- [ ] Depleted Dark Surface (F7)
- [ ] Redox depressions (F8)
- [ ] Vernal Pools (F9)

**Indicators for Problematic Hydric Soils:[3]**

- [ ] 1 cm Muck (A9) (LRR C)
- [ ] 2 cm Muck (A10) (LRR B)
- [ ] Reduced Vertic (F18)
- [ ] Red Parent Material (TF2)
- [ ] Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present.

**Restrictive Layer (if present):**

Type:

Depth (inches):

**Hydric Soil Present?** Yes (●) No ( )

Remarks:

## Hydrology

**Wetland Hydrology Indicators:**

Primary Indicators (minimum of one required; check all that apply)

- [ ] Surface Water (A1)
- [x] High Water Table (A2)
- [x] Saturation (A3)
- [ ] Water Marks (B1) (Nonriverine)
- [ ] Sediment Deposits (B2) (Nonriverine)
- [ ] Drift deposits (B3) (Noneriverine)
- [ ] Surface Soil Cracks (B6)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Salt Crust (B11)
- [ ] Biotic Crust (B12)
- [ ] Aquatic Invertebrates (B13)
- [ ] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres along Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Plowed Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- [ ] Water Marks (B1) (Riverine)
- [ ] Sediment Deposits (B2) (Riverine)
- [ ] Drift Deposits (B3) Riverine)
- [ ] Drainage Patterns (B10)
- [ ] Dry Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Shallow Aquitard (D3)
- [ ] FAC-neutral Test (D5)

**Field Observations:**

| | | | |
|---|---|---|---|
| Surface Water Present? | Yes ( ) | No (●) | Depth (inches): 0 |
| Water Table Present? | Yes (●) | No ( ) | Depth (inches): 0 |
| Saturation Present? (includes capillary fringe) | Yes (●) | No ( ) | Depth (inches): 0 |

**Wetland Hydrology Present?** Yes (●) No ( )

Describe Recorded Data (stream gauge, monitor well, aerial photos, previous inspections), if available:

test

Remarks:

5 feet from OHWM, saturated at surface, water table

Plot ID: Wetland 2 Photo Path: C:\WetForm\PVU\

Photo File: **Photo2.jpg** Orientation: -facing

Lat/Long or UTM : Long/Easting: **-108.895822** Lat/Northing: **38.297229**

Description:

Photo File: **Photo1.jpg** Orientation: -facing

Lat/Long or UTM: Long/Easting: Lat/Northing:

Description:

# WETLAND DETERMINATION DATA FORM - Arid West Region

**Project/Site:** PVU **City/County:** Mesa **Sampling Date:** 09-May-18

**Applicant/Owner:** BLM **State:** Colorado **Sampling Point:** **Upland 2**

**Investigator(s):** C.Photos, M. Greulich **Section, Township, Range:** S 30 T 47N R 18W

**Landform (hillslope, terrace, etc.):** Floodplain **Local relief (concave, convex, none):** convex **Slope:** 1.0 % / 0.6 °

**Subregion (LRR):** LRR D **Lat.:** 38.297276 **Long.:** -108.895898 **Datum:** NAD 83

**Soil Map Unit Name:** Water **NWI classification:** PSSA

**Are climatic/hydrologic conditions on the site typical for this time of year?** Yes ○ No ◉ **(If no, explain in Remarks.)**

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **significantly disturbed?** **Are "Normal Circumstances" present?** Yes ◉ No ○

**Are Vegetation** ☐ **, Soil** ☐ **, or Hydrology** ☐ **naturally problematic?** **(If needed, explain any answers in Remarks.)**

## Summary of Findings - Attach site map showing sampling point locations, transects, important features, etc.

| | | | | |
|---|---|---|---|---|
| **Hydrophytic Vegetation Present?** | Yes ◉ | No ○ | **Is the Sampled Area within a Wetland?** | Yes ○ No ◉ |
| **Hydric Soil Present?** | Yes ○ | No ◉ | | |
| **Wetland Hydrology Present?** | Yes ◉ | No ○ | | |

**Remarks:** Worst drought in 25 years. Soil map aligns with water mapping, adjacent to soil type Pojoaque-Chilton complex., 5 to 30 percent slope, extremely stony

## VEGETATION - Use scientific names of plants.

| | Absolute % Cover | Dominant Species? Rel.Strat. Cover | Indicator Status |
|---|---|---|---|
| **Tree Stratum** (Plot size: 30 ft) | | | |
| 1. | 0 | ☐ 0.0% | |
| 2. | 0 | ☐ 0.0% | |
| 3. | 0 | ☐ 0.0% | |
| 4. | 0 | ☐ 0.0% | |
| | 0 | = Total Cover | |
| **Sapling/Shrub Stratum** (Plot size: 15 ft) | | | |
| 1. Tamarix chinensis | 1 | ☐ 9.1% | FAC |
| 2. Salix exigua | 10 | ☑ 90.9% | FACW |
| 3. | 0 | ☐ 0.0% | |
| 4. | 0 | ☐ 0.0% | |
| 5. | 0 | ☐ 0.0% | |
| | 11 | = Total Cover | |
| **Herb Stratum** (Plot size: 5 ft) | | | |
| 1. Phragmites australis | 38 | ☑ 95.0% | FACW |
| 2. Schoenoplectus pungens | 2 | ☐ 5.0% | OBL |
| 3. | 0 | ☐ 0.0% | |
| 4. | 0 | ☐ 0.0% | |
| 5. | 0 | ☐ 0.0% | |
| 6. | 0 | ☐ 0.0% | |
| 7. | 0 | ☐ 0.0% | |
| 8. | 0 | ☐ 0.0% | |
| 9. | 0 | ☐ 0.0% | |
| 10. | 0 | ☐ 0.0% | |
| 11. | 0 | ☐ 0.0% | |
| | 40 | = Total Cover | |
| **Woody Vine Stratum** (Plot size: ) | | | |
| 1. | 0 | ☐ 0.0% | |
| 2. | 0 | ☐ 0.0% | |
| | 0 | = Total Cover | |

**% Bare Ground in Herb Stratum:** 60 **% Cover of Biotic Crust** 0

**Dominance Test worksheet:**

| | | |
|---|---|---|
| Number of Dominant Species That are OBL, FACW, or FAC: | 2 | (A) |
| Total Number of Dominant Species Across All Strata: | 2 | (B) |
| Percent of dominant Species That Are OBL, FACW, or FAC: | 100.0% | (A/B) |

**Prevalence Index worksheet:**

| Total % Cover of: | | Multiply by: | |
|---|---|---|---|
| OBL species | 2 | x 1 = | 2 |
| FACW species | 48 | x 2 = | 96 |
| FAC species | 1 | x 3 = | 3 |
| FACU species | 0 | x 4 = | 0 |
| UPL species | 0 | x 5 = | 0 |
| Column Totals: | 51 (A) | | 101 (B) |

Prevalence Index = B/A = 1.980

**Hydrophytic Vegetation Indicators:**

- ☑ **Dominance Test is > 50%**
- ☑ **Prevalence Index is ≤3.0** [1]
- ☐ **Morphological Adaptations** [1] **(Provide supporting data in Remarks or on a separate sheet)**
- ☐ **Problematic Hydrophytic Vegetation** [1] **(Explain)**

[1] **Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.**

**Hydrophytic Vegetation Present?** Yes ◉ No ○

**Remarks:**

*Indicator suffix = National status or professional decision assigned because Regional status not defined by FWS.

## Soil

**Sampling Point:** Upland 2

**Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)**

| Depth (inches) | Matrix Color (moist) | | Matrix % | Redox Features Color (moist) | | Redox % | Type[1] | Loc² | Texture | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-20 | 5YR | 4/3 | 100 | | | | | | Very Fine Sand | |

[1] Type: C=Concentration. D=Depletion. RM=Reduced Matrix, CS=Covered or Coated Sand Grains ²Location: PL=Pore Lining. M=Matrix

**Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)**

- [ ] Histosol (A1)
- [ ] Histic Epipedon (A2)
- [ ] Black Histic (A3)
- [ ] Hydrogen Sulfide (A4)
- [ ] Stratified Layers (A5) (LRR C)
- [ ] 1 cm Muck (A9) (LRR D)
- [ ] Depleted Below Dark Surface (A11)
- [ ] Thick Dark Surface (A12)
- [ ] Sandy Muck Mineral (S1)
- [ ] Sandy Gleyed Matrix (S4)
- [ ] Sandy Redox (S5)
- [ ] Stripped Matrix (S6)
- [ ] Loamy Mucky Mineral (F1)
- [ ] Loamy Gleyed Matrix (F2)
- [ ] Depleted Matrix (F3)
- [ ] Redox Dark Surface (F6)
- [ ] Depleted Dark Surface (F7)
- [ ] Redox depressions (F8)
- [ ] Vernal Pools (F9)

**Indicators for Problematic Hydric Soils:**[3]

- [ ] 1 cm Muck (A9) (LRR C)
- [ ] 2 cm Muck (A10) (LRR B)
- [ ] Reduced Vertic (F18)
- [ ] Red Parent Material (TF2)
- [ ] Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present.

**Restrictive Layer (if present):**

Type:

Depth (inches):

**Hydric Soil Present?** Yes ○ No ●

Remarks:

## Hydrology

**Wetland Hydrology Indicators:**

Primary Indicators (minimum of one required; check all that apply)

- [ ] Surface Water (A1)
- [x] High Water Table (A2)
- [x] Saturation (A3)
- [ ] Water Marks (B1) (Nonriverine)
- [ ] Sediment Deposits (B2) (Nonriverine)
- [ ] Drift deposits (B3) (Noneriverine)
- [ ] Surface Soil Cracks (B6)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Salt Crust (B11)
- [ ] Biotic Crust (B12)
- [ ] Aquatic Invertebrates (B13)
- [ ] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres along Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Plowed Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- [ ] Water Marks (B1) (Riverine)
- [ ] Sediment Deposits (B2) (Riverine)
- [ ] Drift Deposits (B3) Riverine)
- [ ] Drainage Patterns (B10)
- [ ] Dry Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Shallow Aquitard (D3)
- [x] FAC-neutral Test (D5)

**Field Observations:**

| | Yes | No | Depth (inches) |
|---|---|---|---|
| Surface Water Present? | ○ | ● | 0 |
| Water Table Present? | ● | ○ | 0 |
| Saturation Present? (includes capillary fringe) | ● | ○ | 11 |

**Wetland Hydrology Present?** Yes ● No ○

Describe Recorded Data (stream gauge, monitor well, aerial photos, previous inspections), if available:

Remarks:

Saturation at 11 inches, high water table at 11 inches

Plot ID: **Upland 2** Photo Path: C:\WetForm\PVU\

Photo File: **Photo2_up.jpg** Orientation: -facing

Lat/Long or UTM : Long/Easting: **-108.895898** Lat/Northing: **38.297276**

Description: Sandy Soil, no redox

Photo File: **Photo3_UP.jpg** Orientation: Southwest -facing

Lat/Long or UTM: Long/Easting: Lat/Northing:

Description: Area of deposition with wetland vegetation, lacking hydric soil. 2017 was a high flow year creating areas of deposition along the floodplain of the river.

# APPENDIX E: OHWM DATA SHEETS

# Arid West Ephemeral and Intermittent Streams OHWM Datasheet

**Project:** PVU  Sample Point: OWUS 1  **Date:** 5/8/18  **Time:** 9:17 a.m.
**Project Number:**  **Town:**  **State:**
**Stream:** Unnamed Ephemeral - East paradox Creek.  **Photo begin file#:**  **Photo end file#:**
**Investigator(s):**

Y ☐ / N ☑ Do normal circumstances exist on the site?

Y ☐ / N ☑ Is the site significantly disturbed?

**Location Details:** Near Bedrock

**Projection:**  **Datum:**
**Coordinates:**

**Potential anthropogenic influences on the channel system:**
Cattle crossing, looks like dirt road crossing @ one point
Area in drought - lowest precip in 25yrs

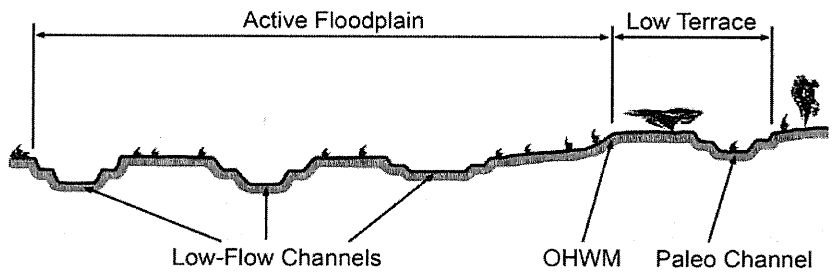
**Brief site description:** Ftype 460
-Channel has evidence of low flow channel, active floodplain and low-terrace. GPS pts OW7 (w/ pt @ L, OHWM, +) w/ images. walked centerline upstream + downstream

**Checklist of resources (if available):**

- ☑ Aerial photography
  Dates:
- ☑ Topographic maps
- ☐ Geologic maps
- ☐ Vegetation maps
- ☐ Soils maps
- ☐ Rainfall/precipitation maps
- ☐ Existing delineation(s) for site
- ☐ Global positioning system (GPS)
- ☐ Other studies

- ☐ Stream gage data
  Gage number:
  Period of record:
  - ☐ History of recent effective discharges
  - ☐ Results of flood frequency analysis
  - ☐ Most recent shift-adjusted rating
  - ☐ Gage heights for 2-, 5-, 10-, and 25-year events and the most recent event exceeding a 5-year event

Hydrogeomorphic Floodplain Units



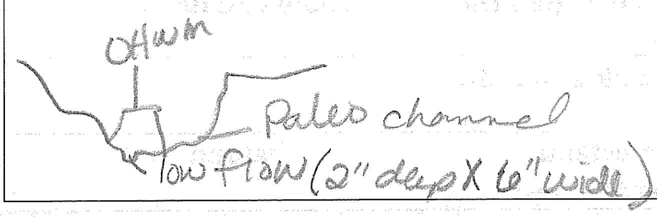

**Procedure for identifying and characterizing the floodplain units to assist in identifying the OHWM:**

1. Walk the channel and floodplain within the study area to get an impression of the geomorphology and vegetation present at the site.
2. Select a representative cross section across the channel. Draw the cross section and label the floodplain units.
3. Determine a point on the cross section that is characteristic of one of the hydrogeomorphic floodplain units.
   a) Record the floodplain unit and GPS position.
   b) Describe the sediment texture (using the Wentworth class size) and the vegetation characteristics of the floodplain unit.
   c) Identify any indicators present at the location.
4. Repeat for other points in different hydrogeomorphic floodplain units across the cross section.
5. Identify the OHWM and record the indicators. Record the OHWM position via:
   - ☐ Mapping on aerial photograph
   - ☐ Digitized on computer
   - ☑ GPS
   - ☐ Other:

Sample Point: OWUS 1

**Project ID:** PVU **Cross section ID:** 1 **Date:** 5/8/18 **Time:** 9:17

**Cross section drawing:**




## OHWM

**GPS point:** ~~Center line~~ OW10 (2)

**Indicators:**

- [x] Change in average sediment texture
- [x] Change in vegetation species
- [x] Change in vegetation cover
- [x] Break in bank slope
- [ ] Other: ____
- [ ] Other: ____

**Comments:**

Only 10% Cover
mostly barren
OHWM + L flow boundary on (L) Bank Same

**Floodplain unit:** [ ] Low-Flow Channel [x] Active Floodplain [ ] Low Terrace

**GPS point:** ~~Centerline~~ OW 1

**Characteristics of the floodplain unit:**

Average sediment texture: fine sand, smaller pebbles in channel

Total veg cover: 10 % Tree: — % Shrub: — % Herb: 10 %

Community successional stage:

- [ ] NA
- [ ] Early (herbaceous & seedlings)
- [ ] Mid (herbaceous, shrubs, saplings)
- [x] Late (herbaceous, shrubs, mature trees) Sage

**Indicators:**

- [x] Mudcracks
- [ ] Ripples
- [ ] Drift and/or debris
- [x] Presence of bed and bank
- [x] Benches
- [x] Soil development – change in particle size
- [x] Surface relief
- [ ] Other: ____
- [ ] Other: ____
- [ ] Other: ____

**Comments:**

Sample Point: OWUS 1

**Project ID:** PVU **Cross section ID:** 7 **Date:** 5/8 **Time:** 9:17

**Floodplain unit:** ☑ Low-Flow Channel ☐ Active Floodplain ☐ Low Terrace

**GPS point:** ______

**Characteristics of the floodplain unit:**

Average sediment texture: Silt with pebbles

Total veg cover: 2 % Tree: — % Shrub: — % Herb: 2 %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☑ Mid (herbaceous, shrubs, saplings)
- ☐ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☑ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☐ Presence of bed and bank
- ☐ Benches
- ☑ Soil development
- ☑ Surface relief
- ☐ Other: ______
- ☐ Other: ______
- ☐ Other: ______

**Comments:**

Depth ~2" X 6" wide

---

**Floodplain unit:** ☐ Low-Flow Channel ☐ Active Floodplain ☑ Low Terrace

**GPS point:** OW 1+

**Characteristics of the floodplain unit:**

Average sediment texture: Silt

Total veg cover: 10 % Tree: ____ % Shrub: 9 % Herb: 1 %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☐ Mid (herbaceous, shrubs, saplings)
- ☐ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☐ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☐ Presence of bed and bank
- ☐ Benches
- ☐ Soil development
- ☐ Surface relief
- ☐ Other: ______
- ☐ Other: ______
- ☐ Other: ______

**Comments:**

Point taken @ outer boundary of R low terrace

Artemisia Cover

# Arid West Ephemeral and Intermittent Streams OHWM Datasheet

**Project:** PVU
**Project Number:** Sample Point: OWUS 2
**Stream:** Unnamed ephemeral
**Investigator(s):** C. Photos, M. Greulich

**Date:** 5/8
**Town:** Bedrock
**Photo begin file#:**

**Time:** 1151
**State:** CO
**Photo end file#:**

Y ☐ / N ☑ Do normal circumstances exist on the site?
Drought year
Y ☐ / N ☑ Is the site significantly disturbed?

**Location Details:**

**Projection:**
**Datum:**
**Coordinates:**

**Potential anthropogenic influences on the channel system:**
Mill (old)/mining in area.

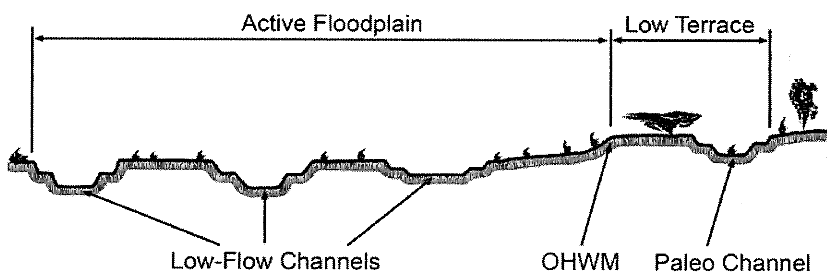
**Brief site description:**
F Type 460
Farthest SW plot of B2, more juniper in Upland area than other alternates Some pinion,

**Checklist of resources (if available):**

☑ Aerial photography
Dates:
☑ Topographic maps
☐ Geologic maps
☐ Vegetation maps
☐ Soils maps
☐ Rainfall/precipitation maps
☐ Existing delineation(s) for site
☐ Global positioning system (GPS)
☐ Other studies

☐ Stream gage data
Gage number:
Period of record:
☐ History of recent effective discharges
☐ Results of flood frequency analysis
☐ Most recent shift-adjusted rating
☐ Gage heights for 2-, 5-, 10-, and 25-year events and the most recent event exceeding a 5-year event

Hydrogeomorphic Floodplain Units




**Procedure for identifying and characterizing the floodplain units to assist in identifying the OHWM:**

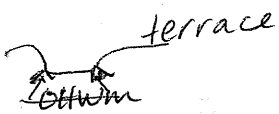
1. Walk the channel and floodplain within the study area to get an impression of the geomorphology and vegetation present at the site.
2. Select a representative cross section across the channel. Draw the cross section and label the floodplain units.
3. Determine a point on the cross section that is characteristic of one of the hydrogeomorphic floodplain units.
   a) Record the floodplain unit and GPS position.
   b) Describe the sediment texture (using the Wentworth class size) and the vegetation characteristics of the floodplain unit.
   c) Identify any indicators present at the location.
4. Repeat for other points in different hydrogeomorphic floodplain units across the cross section.
5. Identify the OHWM and record the indicators. Record the OHWM position via:

☐ Mapping on aerial photograph
☐ Digitized on computer
☑ GPS
☐ Other:

Sample Point: OWUS 2

**Project ID:** **Cross section ID:** OW2 **Date:** 8/8/18 **Time:** 1:52

**Cross section drawing:**




## OHWM

**GPS point:** OW2

**Indicators:**

- [x] Change in average sediment texture
- [ ] Change in vegetation species
- [x] Change in vegetation cover
- [x] Break in bank slope
- [ ] Other: ____________
- [ ] Other: ____________

**Comments:**

Area unvegetated in channel bottom.

**Floodplain unit:** [x] Low-Flow Channel [ ] Active Floodplain [ ] Low Terrace

**GPS point:** OW2L

**Characteristics of the floodplain unit:**

Average sediment texture: Silt

Total veg cover: 0 % Tree: — % Shrub: — % Herb: — %

Community successional stage:

- [x] NA
- [ ] Early (herbaceous & seedlings)
- [ ] Mid (herbaceous, shrubs, saplings)
- [ ] Late (herbaceous, shrubs, mature trees)

**Indicators:**

- [x] Mudcracks
- [ ] Ripples
- [ ] Drift and/or debris
- [x] Presence of bed and bank
- [ ] Benches
- [ ] Soil development
- [ ] Surface relief
- [ ] Other: ____________
- [ ] Other: ____________
- [ ] Other: ____________

**Comments:**

Unvegetated

Sample Point: OWUS 2

**Project ID:** **Cross section ID:** OW2 **Date:** 5/8/18 **Time:** 1:52

**Floodplain unit:** ☐ Low-Flow Channel ☑ Active Floodplain ☐ Low Terrace

**GPS point:** OW2 - OHWM (2 pts @ each boundary

**Characteristics of the floodplain unit:**

Average sediment texture: Silty Sand

Total veg cover: 5 % Tree: ___ % Shrub: 5 % Herb: – %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☐ Mid (herbaceous, shrubs, saplings)
- ☐ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☐ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☑ Presence of bed and bank
- ☐ Benches
- ☐ Soil development
- ☐ Surface relief
- ☐ Other: ________
- ☐ Other: ________
- ☐ Other: ________

**Comments:**

Rubber rabbit brush, Art. triden

---

**Floodplain unit:** ☐ Low-Flow Channel ☐ Active Floodplain ☑ Low Terrace

**GPS point:** ________

**Characteristics of the floodplain unit:**

Average sediment texture: Silty Sand w/ cobble

Total veg cover: 8 % Tree: 6 % Shrub: 2 % Herb: – %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☐ Mid (herbaceous, shrubs, saplings)
- ☑ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☐ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☑ Presence of bed and bank - relic
- ☐ Benches
- ☐ Soil development
- ☐ Surface relief
- ☐ Other: ________
- ☐ Other: ________
- ☐ Other: ________

**Comments:**

Low terrace also where road erosion joins channel

Juniper mono

Area in drought

# Arid West Ephemeral and Intermittent Streams OHWM Datasheet

| | | |
|---|---|---|
| **Project:** PVU<br>**Project Number:** Sample Point: OWUS 3<br>**Stream:**<br>**Investigator(s):** C. Photos, M. Greenlee | **Date:** 5/10<br>**Town:** Bedrock<br>**Photo begin file#:** | **Time:** 8am<br>**State:** CO<br>**Photo end file#:** |
| Y ☐ / N ☑ Do normal circumstances exist on the site?<br><br>Y ☐ / N ☑ Is the site significantly disturbed? | **Location Details:**<br><br>**Projection:** **Datum:**<br>**Coordinates:** | |

**Potential anthropogenic influences on the channel system:**

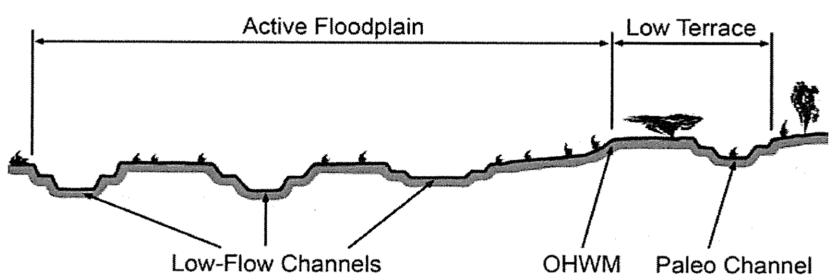
**Brief site description:**
In drought, Cattle utilize area - wide ephemeral stream
OW3, sandy-Cobble 10ft wide channel, likely connects to Dolores
No water now

**Checklist of resources (if available):**

- ☐ Aerial photography
  Dates:
- ☑ Topographic maps
- ☐ Geologic maps
- ☐ Vegetation maps
- ☐ Soils maps
- ☐ Rainfall/precipitation maps
- ☐ Existing delineation(s) for site
- ☐ Global positioning system (GPS)
- ☐ Other studies

- ☐ Stream gage data
  Gage number:
  Period of record:
  - ☐ History of recent effective discharges
  - ☐ Results of flood frequency analysis
  - ☐ Most recent shift-adjusted rating
  - ☐ Gage heights for 2-, 5-, 10-, and 25-year events and the most recent event exceeding a 5-year event

Hydrogeomorphic Floodplain Units



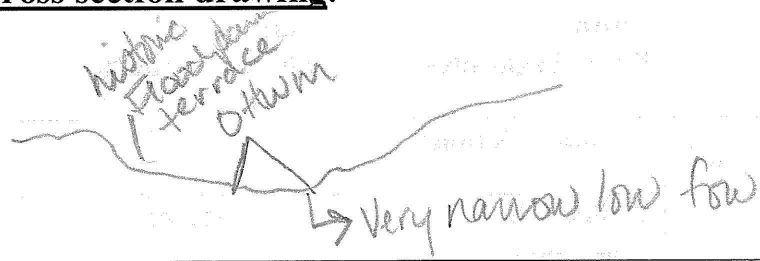

**Procedure for identifying and characterizing the floodplain units to assist in identifying the OHWM:**

1. Walk the channel and floodplain within the study area to get an impression of the geomorphology and vegetation present at the site.
2. Select a representative cross section across the channel. Draw the cross section and label the floodplain units.
3. Determine a point on the cross section that is characteristic of one of the hydrogeomorphic floodplain units.
   a) Record the floodplain unit and GPS position.
   b) Describe the sediment texture (using the Wentworth class size) and the vegetation characteristics of the floodplain unit.
   c) Identify any indicators present at the location.
4. Repeat for other points in different hydrogeomorphic floodplain units across the cross section.
5. Identify the OHWM and record the indicators. Record the OHWM position via:
   - ☐ Mapping on aerial photograph
   - ☑ Digitized on computer
   - ☑ GPS
   - ☐ Other:

Sample Point: OWUS 3

**Project ID:** PVU **Cross section ID:** OW3 **Date:** 5/10/18 **Time:** 8am

**Cross section drawing:**




## OHWM

**GPS point:** OW3

**Indicators:**

- [x] Change in average sediment texture
- [x] Change in vegetation species
- [ ] Change in vegetation cover
- [x] Break in bank slope
- [ ] Other: ______
- [ ] Other: ______

**Comments:**

Channel barren

**Floodplain unit:** [x] Low-Flow Channel [ ] Active Floodplain [ ] Low Terrace

**GPS point:** OW3L

**Characteristics of the floodplain unit:**

Average sediment texture: Sandy - Cobble

Total veg cover: 5 % Tree: 2 % Shrub: 5 % Herb: — %

Community successional stage:

- [ ] NA
- [ ] Early (herbaceous & seedlings)
- [ ] Mid (herbaceous, shrubs, saplings)
- [x] Late (herbaceous, shrubs, mature trees)

**Indicators:**

- [ ] Mudcracks
- [ ] Ripples
- [x] Drift and/or debris (Minimal)
- [x] Presence of bed and bank
- [ ] Benches
- [ ] Soil development
- [ ] Surface relief
- [ ] Other: ______
- [ ] Other: ______
- [ ] Other: ______

**Comments:**

Artemisia trid, Ericameria in terrace

Sample Point: OWUS 3

**Project ID:** **Cross section ID:** OW3 **Date:** 5/10 **Time:** 8

**Floodplain unit:** ☐ Low-Flow Channel ☑ Active Floodplain ☐ Low Terrace

**GPS point:** OW3C/oldtown

**Characteristics of the floodplain unit:**

Average sediment texture: Sandy-cobble

Total veg cover: 0 % Tree: 0 % Shrub: — % Herb: — %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☐ Mid (herbaceous, shrubs, saplings)
- ☑ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☐ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☑ Presence of bed and bank
- ☑ Benches
- ☐ Soil development
- ☐ Surface relief
- ☐ Other: ____
- ☐ Other: ____
- ☐ Other: ____

**Comments:**

Veg only outside channel, normal circumstances even considering drought

**Floodplain unit:** ☐ Low-Flow Channel ☐ Active Floodplain ☑ Low Terrace

**GPS point:** ____

**Characteristics of the floodplain unit:**

Average sediment texture: Silty Sand

Total veg cover: 30 % Tree: ____ % Shrub: 28 % Herb: 2 %

Community successional stage:

- ☐ NA
- ☐ Early (herbaceous & seedlings)
- ☐ Mid (herbaceous, shrubs, saplings)
- ☑ Late (herbaceous, shrubs, mature trees)

**Indicators:**

- ☐ Mudcracks
- ☐ Ripples
- ☐ Drift and/or debris
- ☐ Presence of bed and bank
- ☐ Benches
- ☑ Soil development
- ☐ Surface relief
- ☐ Other: ____
- ☐ Other: ____
- ☐ Other: ____

**Comments:**

Artemisia tri, Ericameria, Cheatgrass (dead), needle + thread grass, Juniper on higher slopes

# OHWM Delineation Cover Sheet

**Project:** PVU Sample Point: OWUS 4 **Date:** 05/09/2018

**Location:** Bedrock, CO **Investigator(s):** Corinna Photos, Melissa Greulich

**Project Description:**

Delineation of Dolores River OHWM. Reviewing wetlands and Other Waters of the US for the Bureau of Reclamation PVU Project alternatives.

**Describe the river or stream's condition (disturbances, in-stream structures, etc.):**

The Dolores River is a perennial channel. Within the Survey Area, the Dolores River is incised approximately 5-8 feet. Within the Survey Area, the channel is approximately 25-35 feet wide. Gauge data for the Dolores River at Bedrock, CO shows that the river consistently fluctuates between 100 cubic feet per second (cfs) in January to an average peak of 1,000 cfs (2014 - 2017). Provisional gauge data for 2018 shows the river level to run approximately 60 cfs in January and 6 cfs in June.

**Off-site Information**

**Remotely sensed image(s) acquired?** ■ **Yes** ☐ **No** [If yes, attach image(s) to datasheet(s) and indicate approx. locations of transects, OHWM, and any other features of interest on the image(s); describe below] Description:

NAIP imagery avail

**Hydrologic/hydraulic information acquired?** ■ **Yes** ☐ **No** [If yes, attach information to datasheet(s) and describe below.] Description:

Reviewed USGS Gauge data for the Dolores River in Bedrock, CO (USGS 09169500)

**List and describe any other supporting information received/acquired:**

Reviewed US Drought Map, WETs Tables

Instructions: Complete one cover sheet and one or more datasheets for each project site. Each datasheet should capture the dominant characteristics of the OHWM along some length of a given stream. Complete enough datasheets to adequately document up- and/or downstream variability in OHWM indicators, stream conditions, etc. Transect locations can be marked on a recent aerial image or their GPS coordinates noted on the datasheet.

**Transect (cross-section) drawing:** (choose a location that is representative of the dominant stream characteristics over some distance; label the OHWM and other features of interest along the transect; include an estimate of transect length)

**Break in Slope at OHWM:** ■ Sharp (> 60□) | ☐ Moderate (30–60□) | ☐ Gentle (< 30□) | ☐ None

Notes/Description:

**Sediment Texture:** Estimate percentages to describe the general sediment texture above and below the OHWM

| | Clay/Silt <0.05mm | Sand 0.05 – 2mm | Gravel 2mm – 1cm | Cobbles 1 – 10cm | Boulders >10cm | Developed Soil Horizons (Y/N) |
|---|---|---|---|---|---|---|
| Above OHWM | 30 | 40 | 20 | 10 | <1 | N |
| Below OHWM | | | | | | |

Notes/Description:

**Vegetation:** Estimate absolute percent cover to describe general vegetation characteristics above and below the OHWM

| | Tree (%) | Shrub (%) | Herb (%) | Bare (%) |
|---|---|---|---|---|
| Above OHWM | 25 | 20 | 90 | 10 |
| Below OHWM | 0 | 0 | 0 | 0 |

Notes/Description:

**Other Evidence:** List/describe any additional field evidence and/or lines of reasoning used to support your delineation

Sharp break in slope at OHWM, 6-8 feet on average. Stream bank is primarily composed of sand and easily eroded.

National Water Information System: Web Interface

USGS Water Resources

Data Category: Current Conditions
Geographic Area: Colorado
GO

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- Full News

Click to hide state-specific text

# USGS 09169500 DOLORES RIVER AT BEDROCK, CO

# PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Current/Historical Observations GO

Click to hidestation-specific text

Station operated by the U.S. Geological Survey in cooperation with Bureau of Reclamation.

Current shift adjusted rating table.
What is a shift adjusted stage-discharge rating table?

Boating safety tips

This station managed by the Durango Field Office.

**Available Parameters** **Available Period**

| | Available Parameters | Available Period |
|---|---|---|
| ☐ | All 4 Available Parameters for this site | |
| ☐ | 00010 Temperature, water | 2007-12-13 2018-06-19 |
| ☑ | 00060 Discharge | 1991-08-11 2018-06-19 |
| ☐ | 00065 Gage height | 2018-02-19 2018-06-19 |
| ☐ | 00095 Specific cond at 25C | 2007-12-13 2018-06-19 |

**Output format**

- ◉ Graph
- ○ Graph w/ stats
- ○ Graph w/o stats
- ○ Graph w/ (up to 3) parms
- ○ Table
- ○ Tab-separated

**Days** (1630)

-- or --

**Begin date**

2014-01-01

**End date**

2018-06-19

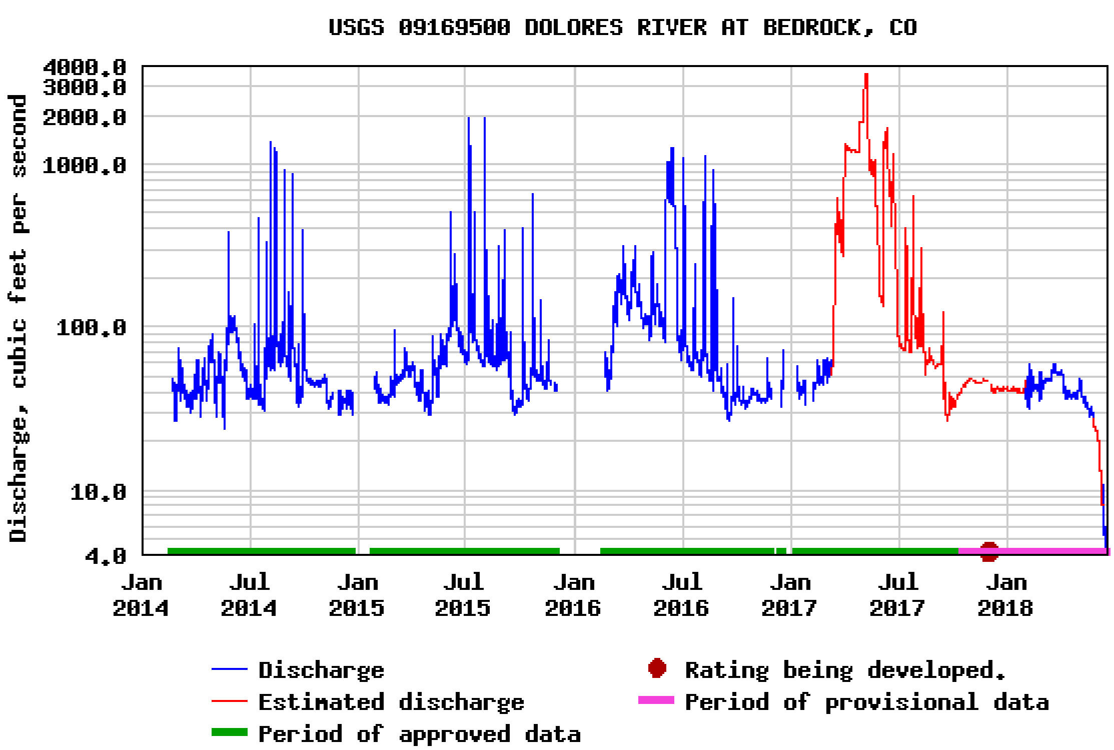
GO

**Summary of all available data for this site**

**Instantaneous-data availability statement**

**Discharge, cubic feet per second**

Most recent instantaneous value: 4.93 06-19-2018 10:45 MDT



Add up to 2 more sites and replot for "Discharge, cubic feet per second"

?
Add site numbers
Note

Enter up to 2 site numbers separated by a comma. A site number consists of 8 to 15 digits

GO

Create presentation-quality / stand-alone graph. Subscribe to
?
WaterAlert

Share this graph |

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Questions about sites/data?
Feedback on this web site
Automated retrievals
Help
Data Tips
Explanation of terms
Subscribe for system changes
News



**Title: USGS Current Conditions for Colorado**
**URL: https://nwis.waterdata.usgs.gov/co/nwis/uv?**

Page Contact Information: Colorado Water Data Support Team
Page Last Modified: 2018-06-19 13:39:00 EDT
27.33 22.25 nadww01

USGS Home
Contact USGS
Search USGS

National Water Information System: Web Interface

USGS Water Resources

Data Category: Current Conditions

Geographic Area: Colorado

GO

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- Full News

Click to hide state-specific text

# USGS 09169500 DOLORES RIVER AT BEDROCK, CO

# PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Current/Historical Observations GO

Click to hidestation-specific text

Station operated by the U.S. Geological Survey in cooperation with Bureau of Reclamation.

Current shift adjusted rating table.
What is a shift adjusted stage-discharge rating table?

Boating safety tips

This station managed by the Durango Field Office.

**Available Parameters** **Available Period**

| | **Available Parameters** | **Available Period** |
|---|---|---|
| ☐ | All 4 Available Parameters for this site | |
| ☐ | 00010 Temperature, water | 2007-12-13 2018-06-19 |
| ☑ | 00060 Discharge | 1991-08-11 2018-06-19 |
| ☐ | 00065 Gage height | 2018-02-19 2018-06-19 |
| ☐ | 00095 Specific cond at 25C | 2007-12-13 2018-06-19 |

**Output format**

- ◉ Graph
- ○ Graph w/ stats
- ○ Graph w/o stats
- ○ Graph w/ (up to 3) parms
- ○ Table
- ○ Tab-separated

**Days** (169)

-- or --

**Begin date**

2018-01-01

**End date**

2018-06-19

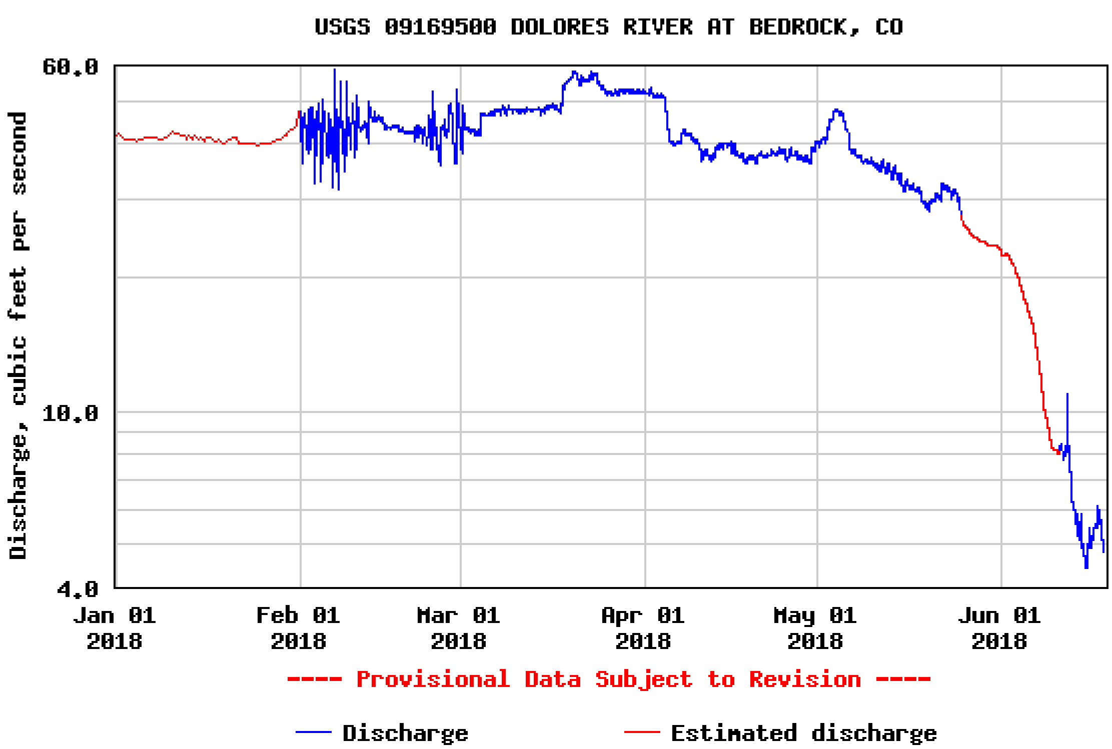
GO

[Summary of all available data for this site]

[Instantaneous-data availability statement]

**Discharge, cubic feet per second**

Most recent instantaneous value: 4.93 06-19-2018 10:45 MDT




Add up to 2 more sites and replot for "Discharge, cubic feet per second"

?
Add site numbers
Note

Enter up to 2 site numbers separated by a comma. A site number consists of 8 to 15 digits

GO

Create presentation-quality / stand-alone graph. Subscribe to
?
WaterAlert

Share this graph |

---

Questions about sites/data?
Feedback on this web site
Automated retrievals
Help
Data Tips
Explanation of terms
Subscribe for system changes
News



**Title: USGS Current Conditions for Colorado**
**URL: https://nwis.waterdata.usgs.gov/co/nwis/uv?**

Page Contact Information: Colorado Water Data Support Team
Page Last Modified: 2018-06-19 13:42:04 EDT
9.03 3.15 nadww01

# APPENDIX F: AQUATIC RESOURCES SPREADSHEET

| Waters_Name | State | Cowardin_Code | HGM_Code | Meas_Type | Amount | Units | Waters_Type | Latitude | Longitude | Local_Waterway | Project area | Delineation or Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E043 | COLORADO | R6 | RIVERINE | Area | 0.02484041331 | ACRE | NRPW | 38.28318180690 | -108.90059092600 | | AltB1 | Visual |
| E044 | COLORADO | R6 | RIVERINE | Area | 0.01865552522 | ACRE | NRPW | 38.28389570060 | -108.89726760500 | | AltB1 | Visual |
| E045 | COLORADO | R6 | RIVERINE | Area | 0.00619289055 | ACRE | NRPW | 38.28480447120 | -108.89574603100 | | AltB1 | Visual |
| E046 | COLORADO | R6 | RIVERINE | Area | 0.00966572640 | ACRE | NRPW | 38.28362182440 | -108.89495337300 | | AltB1 | Visual |
| E047 | COLORADO | R6 | RIVERINE | Area | 0.01566946576 | ACRE | NRPW | 38.29572081290 | -108.89655128400 | | AltB1 | Visual |
| P001 | COLORADO | R2UB | RIVERINE | Area | 2.94286290268 | ACRE | TNW | 38.29675527660 | -108.89654247400 | Dolores River | AltB1 | Visual |
| P002 | COLORADO | R2UB | RIVERINE | Area | 0.15452212585 | ACRE | TNW | 38.30020756170 | -108.89466317600 | Dolores River | AltB1 | Visual |
| P003 | COLORADO | R2UB | RIVERINE | Area | 0.42280478357 | ACRE | TNW | 38.30107252020 | -108.89428792300 | Dolores River | AltB1 | Visual |
| P006 | COLORADO | R2UB | RIVERINE | Area | 0.32180382526 | ACRE | TNW | 38.29007388670 | -108.89772911100 | Dolores River | AltB1 | Visual |
| P007 | COLORADO | R2UB | RIVERINE | Area | 0.15118617383 | ACRE | TNW | 38.28967106260 | -108.89789534200 | Dolores River | AltB1 | Visual |
| P008 | COLORADO | R2UB | RIVERINE | Area | 0.66828310064 | ACRE | TNW | 38.28904725530 | -108.89633459100 | Dolores River | AltB1 | Visual |
| P009 | COLORADO | R2UB | RIVERINE | Area | 0.61396502927 | ACRE | TNW | 38.28836249070 | -108.89487359200 | Dolores River | AltB1 | Visual |
| P010 | COLORADO | R2UB | RIVERINE | Area | 0.11482286148 | ACRE | TNW | 38.28795734780 | -108.89411256400 | Dolores River | AltB1 | Visual |
| P011 | COLORADO | R2UB | RIVERINE | Area | 0.27096418666 | ACRE | TNW | 38.28785906300 | -108.89505555200 | Dolores River | AltB1 | Visual |
| P012 | COLORADO | R2UB | RIVERINE | Area | 3.04040979343 | ACRE | TNW | 38.28424077650 | -108.90400236900 | Dolores River | AltB1 | Visual |
| P013 | COLORADO | R2UB | RIVERINE | Area | 0.06668072616 | ACRE | TNW | 38.28348887620 | -108.90697718300 | Dolores River | AltB1 | Visual |
| P014 | COLORADO | R2UB | RIVERINE | Area | 1.87628107452 | ACRE | TNW | 38.28525391630 | -108.89627286900 | Dolores River | AltB1 | Visual |
| W001 | COLORADO | PEM | RIVERINE | Area | 0.35407863515 | ACRE | RPWWD | 38.29677101750 | -108.89653170400 | Dolores River | AltB1 | Delineation and visual |
| W002 | COLORADO | PEM | RIVERINE | Area | 0.09159172977 | ACRE | RPWWD | 38.30020657110 | -108.89466367500 | Dolores River | AltB1 | Visual |
| W003 | COLORADO | PEM | RIVERINE | Area | 0.05223441501 | ACRE | RPWWD | 38.30106127870 | -108.89430161000 | Dolores River | AltB1 | Visual |
| W006 | COLORADO | PEM | RIVERINE | Area | 0.07717292912 | ACRE | RPWWD | 38.29007482980 | -108.89772863200 | Dolores River | AltB1 | Visual |
| W007 | COLORADO | PEM | RIVERINE | Area | 0.06018175651 | ACRE | RPWWD | 38.28967206720 | -108.89789816200 | Dolores River | AltB1 | Visual |
| W008 | COLORADO | PEM | RIVERINE | Area | 0.07852432067 | ACRE | RPWWD | 38.28905628540 | -108.89635587800 | Dolores River | AltB1 | Visual |
| W009 | COLORADO | PEM | RIVERINE | Area | 0.11784320944 | ACRE | RPWWD | 38.28837627360 | -108.89490040500 | Dolores River | AltB1 | Visual |
| W010 | COLORADO | PEM | RIVERINE | Area | 0.01528069615 | ACRE | RPWWD | 38.28795703620 | -108.89413492600 | Dolores River | AltB1 | Visual |
| W011 | COLORADO | PEM | RIVERINE | Area | 0.10837177213 | ACRE | RPWWD | 38.28785890560 | -108.89505600800 | Dolores River | AltB1 | Visual |
| W012 | COLORADO | PEM | RIVERINE | Area | 0.30244599983 | ACRE | RPWWD | 38.28424266710 | -108.90399030600 | Dolores River | AltB1 | Visual |
| W013 | COLORADO | PEM | RIVERINE | Area | 0.02659476282 | ACRE | RPWWD | 38.28348692230 | -108.90697632000 | Dolores River | AltB1 | Visual |
| W014 | COLORADO | PEM | RIVERINE | Area | 0.18804672181 | ACRE | RPWWD | 38.28525268340 | -108.89627881200 | Dolores River | AltB1 | Visual |
| E112 | COLORADO | R6 | RIVERINE | Area | 0.00777900000 | ACRE | NRPW | 38.26693000000 | -108.90233700000 | | AltB2 | Visual |

| Waters_Name | State | Cowardin_Code | HGM_Code | Meas_Type | Amount | Units | Waters_Type | Latitude | Longitude | Project area | Delineation or Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E001 | COLORADO | R6 | RIVERINE | Area | 0.03433976996 | ACRE | NRPW | 38.20051037 | -108.77822197 | Alt B2 | Visual |
| E002 | COLORADO | R6 | RIVERINE | Area | 0.09284162254 | ACRE | NRPW | 38.19875352 | -108.77406800 | Alt B2 | Delineation and Visual |
| E003 | COLORADO | R6 | RIVERINE | Area | 0.10220841531 | ACRE | NRPW | 38.19949614 | -108.77123098 | Alt B2 | Delineation and Visual |
| E004 | COLORADO | R6 | RIVERINE | Area | 0.00053755247 | ACRE | NRPW | 38.19881510 | -108.76942754 | Alt B2 | Visual |
| E005 | COLORADO | R6 | RIVERINE | Area | 0.00195772864 | ACRE | NRPW | 38.19099346 | -108.74614773 | Alt B2 | Visual |
| E006 | COLORADO | R6 | RIVERINE | Area | 0.00361219483 | ACRE | NRPW | 38.18830434 | -108.71778023 | Alt B2 | Visual |
| E007 | COLORADO | R6 | RIVERINE | Area | 0.00381774662 | ACRE | NRPW | 38.18926939 | -108.71717468 | Alt B2 | Visual |
| E008 | COLORADO | R6 | RIVERINE | Area | 0.00380439842 | ACRE | NRPW | 38.18827788 | -108.71263782 | Alt B2 | Visual |
| E009 | COLORADO | R6 | RIVERINE | Area | 0.01229241133 | ACRE | NRPW | 38.18862045 | -108.71245230 | Alt B2 | Visual |
| E010 | COLORADO | R6 | RIVERINE | Area | 0.00351115521 | ACRE | NRPW | 38.18966355 | -108.70945160 | Alt B2 | Visual |
| E011 | COLORADO | R6 | RIVERINE | Area | 0.00282322995 | ACRE | NRPW | 38.19732643 | -108.69967163 | Alt B2 | Visual |
| E012 | COLORADO | R6 | RIVERINE | Area | 0.00486712565 | ACRE | NRPW | 38.20146530 | -108.69698229 | Alt B2 | Visual |
| E013 | COLORADO | R6 | RIVERINE | Area | 0.00614956272 | ACRE | NRPW | 38.20922078 | -108.69035193 | Alt B2 | Visual |
| E014 | COLORADO | R6 | RIVERINE | Area | 0.00264668307 | ACRE | NRPW | 38.20888293 | -108.69024894 | Alt B2 | Visual |
| E015 | COLORADO | R6 | RIVERINE | Area | 0.00278980039 | ACRE | NRPW | 38.21082166 | -108.68913206 | Alt B2 | Visual |
| E016 | COLORADO | R6 | RIVERINE | Area | 0.00199976820 | ACRE | NRPW | 38.21166546 | -108.68713842 | Alt B2 | Visual |
| E017 | COLORADO | R6 | RIVERINE | Area | 0.00787922174 | ACRE | NRPW | 38.21525399 | -108.69072624 | Alt B2 | Visual |
| E018 | COLORADO | R6 | RIVERINE | Area | 0.00663015380 | ACRE | NRPW | 38.21844412 | -108.68749897 | Alt B2 | Visual |
| E019 | COLORADO | R6 | RIVERINE | Area | 0.00259027368 | ACRE | NRPW | 38.21826853 | -108.68714264 | Alt B2 | Visual |
| E023 | COLORADO | R6 | RIVERINE | Area | 0.00077424218 | ACRE | NRPW | 38.23160559 | -108.69360247 | Alt B2 | Visual |
| E024 | COLORADO | R6 | RIVERINE | Area | 0.00107758273 | ACRE | NRPW | 38.23936002 | -108.71245848 | Alt B2 | Visual |
| E025 | COLORADO | R6 | RIVERINE | Area | 0.00310328094 | ACRE | NRPW | 38.23903152 | -108.71255462 | Alt B2 | Visual |
| E026 | COLORADO | R6 | RIVERINE | Area | 0.00027643473 | ACRE | NRPW | 38.24077297 | -108.71549921 | Alt B2 | Visual |
| E027 | COLORADO | R6 | RIVERINE | Area | 0.00023028541 | ACRE | NRPW | 38.24279401 | -108.72005852 | Alt B2 | Visual |
| E028 | COLORADO | R6 | RIVERINE | Area | 0.00053639822 | ACRE | NRPW | 38.24359190 | -108.72189487 | Alt B2 | Visual |
| E029 | COLORADO | R6 | RIVERINE | Area | 0.00022157475 | ACRE | NRPW | 38.24718772 | -108.72976689 | Alt B2 | Visual |
| E030 | COLORADO | R6 | RIVERINE | Area | 0.00086916597 | ACRE | NRPW | 38.25010128210 | -108.73628978500 | Alt B2 | Visual |
| E031 | COLORADO | R6 | RIVERINE | Area | 0.00125057952 | ACRE | NRPW | 38.25412631540 | -108.74517701600 | Alt B2 | Visual |
| E032 | COLORADO | R6 | RIVERINE | Area | 0.00098148922 | ACRE | NRPW | 38.25605976610 | -108.74949692600 | Alt B2 | Visual |
| E033 | COLORADO | R6 | RIVERINE | Area | 0.00087914654 | ACRE | NRPW | 38.25709193080 | -108.75181651800 | Alt B2 | Visual |
| E034 | COLORADO | R6 | RIVERINE | Area | 0.01926612648 | ACRE | NRPW | 38.27653116120 | -108.79585460400 | Alt B2 | Visual |
| E035 | COLORADO | R6 | RIVERINE | Area | 0.00395310272 | ACRE | NRPW | 38.27683072440 | -108.79667113400 | Alt B2 | Visual |
| E036 | COLORADO | R6 | RIVERINE | Area | 0.00245232133 | ACRE | NRPW | 38.27783349330 | -108.79884302300 | Alt B2 | Visual |
| E037 | COLORADO | R6 | RIVERINE | Area | 0.00109816116 | ACRE | NRPW | 38.28165466060 | -108.80641674700 | Alt B2 | Visual |
| E038 | COLORADO | R6 | RIVERINE | Area | 0.00922406564 | ACRE | NRPW | 38.28132415330 | -108.80657208100 | Alt B2 | Visual |
| E048 | COLORADO | R6 | RIVERINE | Area | 0.00037475975 | ACRE | NRPW | 38.31118762360 | -108.85928630400 | Alt B2 | Visual |
| E049 | COLORADO | R6 | RIVERINE | Area | 0.01399133380 | ACRE | NRPW | 38.31392464740 | -108.85906474400 | Alt B2 | Visual |
| E050 | COLORADO | R6 | RIVERINE | Area | 0.04064544448 | ACRE | NRPW | 38.31703409890 | -108.85789658800 | Alt B2 | Visual |
| L001 | COLORADO | L1UB | LACUSTRINI | Area | 0.02787241652 | ACRE | ISOLATE | 38.19121842470 | -108.74572736700 | Alt B2 | Visual |

| Waters_Name | State | Cowardin_Code | HGM_Code | Meas_Type | Amount | Units | Waters_Type | Latitude | Longitude | Local_Waterway | Project area | Delineation or Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E034 | COLORADO | R6 | RIVERINE | Area | 0.01924574780 | ACRE | NRPW | 38.27653105530 | -108.79585390000 | | Alt C | Visual |
| E035 | COLORADO | R6 | RIVERINE | Area | 0.00393461867 | ACRE | NRPW | 38.27683114940 | -108.79667073600 | | Alt C | Visual |
| E036 | COLORADO | R6 | RIVERINE | Area | 0.00244197378 | ACRE | NRPW | 38.27783375630 | -108.79884238300 | | Alt C | Visual |
| E037 | COLORADO | R6 | RIVERINE | Area | 0.00113784080 | ACRE | NRPW | 38.28165545050 | -108.80641669600 | | Alt C | Visual |
| E038 | COLORADO | R6 | RIVERINE | Area | 0.00918751795 | ACRE | NRPW | 38.28132475710 | -108.80657158600 | | Alt C | Visual |
| E039 | COLORADO | R6 | RIVERINE | Area | 0.00263262250 | ACRE | NRPW | 38.31054976240 | -108.86892222200 | | Alt C | Visual |
| E040 | COLORADO | R6 | RIVERINE | Area | 0.00251051590 | ACRE | NRPW | 38.31057831630 | -108.86981812600 | | Alt C | Visual |
| E041 | COLORADO | R6 | RIVERINE | Area | 0.00396155256 | ACRE | NRPW | 38.31041426020 | -108.87745061700 | | Alt C | Visual |
| E042 | COLORADO | R6 | RIVERINE | Area | 0.00383430123 | ACRE | NRPW | 38.31020682660 | -108.88414945500 | | Alt C | Visual |
| E048 | COLORADO | R6 | RIVERINE | Area | 0.00026173612 | ACRE | NRPW | 38.31119274390 | -108.85929190300 | | Alt C | Visual |
| E049 | COLORADO | R6 | RIVERINE | Area | 0.01440319992 | ACRE | NRPW | 38.31392683500 | -108.85907023700 | | Alt C | Visual |
| E050 | COLORADO | R6 | RIVERINE | Area | 0.04039517733 | ACRE | NRPW | 38.31704483580 | -108.85790183200 | | Alt C | Visual |
| E061 | COLORADO | R6 | RIVERINE | Area | 0.07839166914 | ACRE | NRPW | 38.27908067940 | -108.77542026300 | | Alt C | Visual |
| E062 | COLORADO | R6 | RIVERINE | Area | 0.01329591312 | ACRE | NRPW | 38.27866891400 | -108.77460421100 | | Alt C | Visual |
| E063 | COLORADO | R6 | RIVERINE | Area | 0.02120627053 | ACRE | NRPW | 38.27863988930 | -108.77580329400 | | Alt C | Visual |
| E064 | COLORADO | R6 | RIVERINE | Area | 0.00519812652 | ACRE | NRPW | 38.27901941310 | -108.77248571400 | | Alt C | Visual |
| E065 | COLORADO | R6 | RIVERINE | Area | 0.00735549624 | ACRE | NRPW | 38.27861161430 | -108.77185245600 | | Alt C | Visual |
| E066 | COLORADO | R6 | RIVERINE | Area | 0.07422220796 | ACRE | NRPW | 38.27676258150 | -108.77193491000 | | Alt C | Visual |
| E067 | COLORADO | R6 | RIVERINE | Area | 0.01045779689 | ACRE | NRPW | 38.27588249860 | -108.77263114100 | | Alt C | Visual |
| E068 | COLORADO | R6 | RIVERINE | Area | 0.04329174056 | ACRE | NRPW | 38.27604969780 | -108.77133754100 | | Alt C | Visual |
| E069 | COLORADO | R6 | RIVERINE | Area | 0.03376341789 | ACRE | NRPW | 38.27704862390 | -108.76888427300 | | Alt C | Visual |
| E070 | COLORADO | R6 | RIVERINE | Area | 0.04056766740 | ACRE | NRPW | 38.27967319540 | -108.76756653600 | | Alt C | Visual |
| E071 | COLORADO | R6 | RIVERINE | Area | 0.01437927367 | ACRE | NRPW | 38.27991566890 | -108.76586077100 | | Alt C | Visual |
| E072 | COLORADO | R6 | RIVERINE | Area | 0.00700042511 | ACRE | NRPW | 38.28027507470 | -108.76535490300 | | Alt C | Visual |
| E073 | COLORADO | R6 | RIVERINE | Area | 0.02232018179 | ACRE | NRPW | 38.27983163960 | -108.76390226600 | | Alt C | Visual |
| E074 | COLORADO | R6 | RIVERINE | Area | 0.02622448864 | ACRE | NRPW | 38.27957964930 | -108.76241016100 | | Alt C | Visual |
| E075 | COLORADO | R6 | RIVERINE | Area | 0.13165745515 | ACRE | NRPW | 38.27913736070 | -108.76081309300 | | Alt C | Visual |
| E076 | COLORADO | R6 | RIVERINE | Area | 0.05716733615 | ACRE | NRPW | 38.27679911160 | -108.76314985300 | | Alt C | Visual |
| E077 | COLORADO | R6 | RIVERINE | Area | 0.00362647830 | ACRE | NRPW | 38.27637037910 | -108.76166536000 | | Alt C | Visual |
| E078 | COLORADO | R6 | RIVERINE | Area | 0.00445285118 | ACRE | NRPW | 38.27578846240 | -108.76103781200 | | Alt C | Visual |
| E079 | COLORADO | R6 | RIVERINE | Area | 0.00880671756 | ACRE | NRPW | 38.27513562170 | -108.76057765300 | | Alt C | Visual |
| E080 | COLORADO | R6 | RIVERINE | Area | 0.06697772678 | ACRE | NRPW | 38.27602789600 | -108.75743582000 | | Alt C | Visual |
| E081 | COLORADO | R6 | RIVERINE | Area | 0.10494997754 | ACRE | NRPW | 38.27737606170 | -108.75808524400 | | Alt C | Visual |
| E082 | COLORADO | R6 | RIVERINE | Area | 0.03823427893 | ACRE | NRPW | 38.27389691310 | -108.75851971200 | | Alt C | Visual |
| E083 | COLORADO | R6 | RIVERINE | Area | 0.01617270270 | ACRE | NRPW | 38.27385912130 | -108.75900610900 | | Alt C | Visual |
| E084 | COLORADO | R6 | RIVERINE | Area | 0.16430247784 | ACRE | NRPW | 38.26850942240 | -108.75500905400 | | Alt C | Visual |
| E085 | COLORADO | R6 | RIVERINE | Area | 0.05552030872 | ACRE | NRPW | 38.26852758660 | -108.75067897100 | | Alt C | Visual |
| E086 | COLORADO | R6 | RIVERINE | Area | 0.14303487576 | ACRE | NRPW | 38.26787964000 | -108.74955687400 | | Alt C | Visual |
| E087 | COLORADO | R6 | RIVERINE | Area | 0.04252072135 | ACRE | NRPW | 38.26617130440 | -108.75093052700 | | Alt C | Visual |
| E088 | COLORADO | R6 | RIVERINE | Area | 0.00617339989 | ACRE | NRPW | 38.26389550200 | -108.75124275500 | | Alt C | Visual |
| E089 | COLORADO | R6 | RIVERINE | Area | 0.01404470995 | ACRE | NRPW | 38.28061811630 | -108.78255408200 | | Alt C | Visual |
| E090 | COLORADO | R6 | RIVERINE | Area | 0.01196789092 | ACRE | NRPW | 38.28082947810 | -108.78003560300 | | Alt C | Visual |
| E091 | COLORADO | R6 | RIVERINE | Area | 0.00824920481 | ACRE | NRPW | 38.28001403340 | -108.77982843300 | | Alt C | Visual |
| E092 | COLORADO | R6 | RIVERINE | Area | 0.00939100221 | ACRE | NRPW | 38.27949685270 | -108.77980226600 | | Alt C | Visual |
| E093 | COLORADO | R6 | RIVERINE | Area | 0.01335093308 | ACRE | NRPW | 38.28077001390 | -108.77756155500 | | Alt C | Visual |
| E094 | COLORADO | R6 | RIVERINE | Area | 0.03610698813 | ACRE | NRPW | 38.28053511400 | -108.77622814700 | | Alt C | Visual |
| E095 | COLORADO | R6 | RIVERINE | Area | 0.01003328812 | ACRE | NRPW | 38.28004688190 | -108.77401342900 | | Alt C | Visual |
| E096 | COLORADO | R6 | RIVERINE | Area | 0.02940398638 | ACRE | NRPW | 38.27932905710 | -108.77067331300 | | Alt C | Visual |
| E097 | COLORADO | R6 | RIVERINE | Area | 0.02639109695 | ACRE | NRPW | 38.27879188260 | -108.77054400200 | | Alt C | Visual |
| E098 | COLORADO | R6 | RIVERINE | Area | 0.00665051999 | ACRE | NRPW | 38.27892384840 | -108.77007534100 | | Alt C | Visual |
| E099 | COLORADO | R6 | RIVERINE | Area | 0.04874134114 | ACRE | NRPW | 38.27605637400 | -108.76784284600 | | Alt C | Visual |
| E100 | COLORADO | R6 | RIVERINE | Area | 0.00877336601 | ACRE | NRPW | 38.27209416730 | -108.75639296100 | | Alt C | Visual |
| E101 | COLORADO | R6 | RIVERINE | Area | 0.01177533282 | ACRE | NRPW | 38.26279495910 | -108.76061684200 | | Alt C | Visual |

| Waters_Name | State | Cowardin_Code | HGM_Code | Meas_Type | Amount | Units | Waters_Type | Latitude | Longitude | Local_Waterway | Project area | Delineation or Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E102 | COLORADO | R6 | RIVERINE | Area | 0.00181463050 | ACRE | NRPW | 38.26376668600 | -108.76020512700 | | Alt C | Visual |
| E103 | COLORADO | R6 | RIVERINE | Area | 0.00269170916 | ACRE | NRPW | 38.27458214390 | -108.78159505400 | | Alt C | Visual |
| E104 | COLORADO | R6 | RIVERINE | Area | 0.00838681303 | ACRE | NRPW | 38.27973640700 | -108.77781503600 | | Alt C | Visual |
| E105 | COLORADO | R6 | RIVERINE | Area | 0.00350551205 | ACRE | NRPW | 38.28013715760 | -108.77938066200 | | Alt C | Visual |
| E106 | COLORADO | R6 | RIVERINE | Area | 0.00713751473 | ACRE | NRPW | 38.27985626400 | -108.77358038600 | | Alt C | Visual |
| E107 | COLORADO | R6 | RIVERINE | Area | 0.06215858765 | ACRE | NRPW | 38.27174370060 | -108.75920875500 | | Alt C | Visual |
| E108 | COLORADO | R6 | RIVERINE | Area | 0.05746480712 | ACRE | NRPW | 38.27189374900 | -108.74496539200 | | Alt C | Visual |
| E109 | COLORADO | R6 | RIVERINE | Area | 0.16102888486 | ACRE | NRPW | 38.27096600500 | -108.74326142900 | | Alt C | Visual |
| E110 | COLORADO | R6 | RIVERINE | Area | 0.03584936884 | ACRE | NRPW | 38.27050322240 | -108.74461040300 | | Alt C | Visual |
| E111 | COLORADO | R6 | RIVERINE | Area | 0.01997146265 | ACRE | NRPW | 38.26593618390 | -108.74980695300 | | Alt C | Visual |
| E113 | COLORADO | R6 | RIVERINE | Area | 0.16278173418 | ACRE | NRPW | 38.26746437200 | -108.75210645800 | East Paradox Creek | Alt C | Delineation and Visual |
| E114 | COLORADO | R6 | RIVERINE | Area | 1.56646218522 | ACRE | NRPW | 38.27708103890 | -108.76641953200 | East Paradox Creek | Alt C | Delineation and Visual |
| E115 | COLORADO | R6 | RIVERINE | Area | 0.04140750408 | ACRE | NRPW | 38.28107038670 | -108.78267407100 | East Paradox Creek | Alt C | Delineation and Visual |
| P004 | COLORADO | R2UB | RIVERINE | Area | 0.33624276335 | ACRE | TNW | 38.30283827770 | -108.89314736100 | Dolores River | Alt C | Visual |
| P005 | COLORADO | R2UB | RIVERINE | Area | 0.13329964311 | ACRE | TNW | 38.30875227950 | -108.88814318400 | Dolores River | Alt C | Visual |
| P015 | COLORADO | R2UB | RIVERINE | Area | 0.15983557537 | ACRE | TNW | 38.31005118220 | -108.88593258900 | Dolores River | Alt C | Visual |
| W004 | COLORADO | PEM | RIVERINE | Area | 0.04688816668 | ACRE | RPWWD | 38.30295347420 | -108.89311003900 | Dolores River | Alt C | Visual |
| W005 | COLORADO | PEM | RIVERINE | Area | 0.02377458255 | ACRE | RPWWD | 38.30868769720 | -108.88822563200 | Dolores River | Alt C | Visual |
| W015 | COLORADO | PEM | RIVERINE | Area | 0.03203682532 | ACRE | RPWWD | 38.31004884940 | -108.88592708400 | Dolores River | Alt C | Visual |

| Waters_Name | State | Cowardin_Code | HGM_Code | Meas_Type | Amount | Units | Waters_Type | Latitude | Longitude | Project area | Delineation or Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E020 | COLORADO | R6 | RIVERINE | Area | 0.00364589291 | ACRE | NRPW | 38.22430 | -108.65763 | Alt D | Visual |
| E021 | COLORADO | R6 | RIVERINE | Area | 0.00180167512 | ACRE | NRPW | 38.22327 | -108.65343 | Alt D | Visual |
| E022 | COLORADO | R6 | RIVERINE | Area | 0.00124021576 | ACRE | NRPW | 38.22341 | -108.65372 | Alt D | Visual |
| E023 | COLORADO | R6 | RIVERINE | Area | 0.00240386475 | ACRE | NRPW | 38.23169 | -108.69355 | Alt D | Visual |
| E024 | COLORADO | R6 | RIVERINE | Area | 0.00280121998 | ACRE | NRPW | 38.23946 | -108.71246 | Alt D | Visual |
| E025 | COLORADO | R6 | RIVERINE | Area | 0.00142082951 | ACRE | NRPW | 38.23913 | -108.71255 | Alt D | Visual |
| E026 | COLORADO | R6 | RIVERINE | Area | 0.00408603284 | ACRE | NRPW | 38.24086 | -108.71540 | Alt D | Visual |
| E027 | COLORADO | R6 | RIVERINE | Area | 0.00226999744 | ACRE | NRPW | 38.24289 | -108.71997 | Alt D | Visual |
| E028 | COLORADO | R6 | RIVERINE | Area | 0.00290824179 | ACRE | NRPW | 38.24365 | -108.72174 | Alt D | Visual |
| E029 | COLORADO | R6 | RIVERINE | Area | 0.00273326427 | ACRE | NRPW | 38.24732 | -108.72976 | Alt D | Visual |
| E030 | COLORADO | R6 | RIVERINE | Area | 0.00442498547 | ACRE | NRPW | 38.25029 | -108.73632 | Alt D | Visual |
| E031 | COLORADO | R6 | RIVERINE | Area | 0.00296618224 | ACRE | NRPW | 38.25419 | -108.74508 | Alt D | Visual |
| E032 | COLORADO | R6 | RIVERINE | Area | 0.00312595756 | ACRE | NRPW | 38.25618 | -108.74947 | Alt D | Visual |
| E033 | COLORADO | R6 | RIVERINE | Area | 0.00348452630 | ACRE | NRPW | 38.25717 | -108.75167 | Alt D | Visual |
| E034 | COLORADO | R6 | RIVERINE | Area | 0.00216036737 | ACRE | NRPW | 38.27638 | -108.79527 | Alt D | Visual |
| E036 | COLORADO | R6 | RIVERINE | Area | 0.00012284273 | ACRE | NRPW | 38.27788 | -108.79869 | Alt D | Visual |
| E037 | COLORADO | R6 | RIVERINE | Area | 0.00802484978 | ACRE | NRPW | 38.28179 | -108.80642 | Alt D | Visual |
| E038 | COLORADO | R6 | RIVERINE | Area | 0.00359533894 | ACRE | NRPW | 38.28142 | -108.80651 | Alt D | Visual |
| E048 | COLORADO | R6 | RIVERINE | Area | 0.00269754326 | ACRE | NRPW | 38.31107722 | -108.85918075 | Alt D | Visual |
| E049 | COLORADO | R6 | RIVERINE | Area | 0.00650002998 | ACRE | NRPW | 38.31389 | -108.85896 | Alt D | Visual |
| E050 | COLORADO | R6 | RIVERINE | Area | 0.04444691285 | ACRE | NRPW | 38.31679 | -108.85779 | Alt D | Visual |
| E051 | COLORADO | R6 | RIVERINE | Area | 0.00142049337 | ACRE | NRPW | 38.31799 | -108.85584 | Alt D | Visual |
| E052 | COLORADO | R6 | RIVERINE | Area | 0.00267004633 | ACRE | NRPW | 38.31769 | -108.85571 | Alt D | Visual |
| E053 | COLORADO | R6 | RIVERINE | Area | 0.00529306882 | ACRE | NRPW | 38.31870 | -108.85370 | Alt D | Visual |
| E054 | COLORADO | R6 | RIVERINE | Area | 0.00269011707 | ACRE | NRPW | 38.31477 | -108.84985 | Alt D | Visual |
| E055 | COLORADO | R6 | RIVERINE | Area | 0.00424827585 | ACRE | NRPW | 38.31450 | -108.85041 | Alt D | Visual |
| E056 | COLORADO | R6 | RIVERINE | Area | 0.01594051879 | ACRE | NRPW | 38.31448 | -108.85098 | Alt D | Visual |
| E057 | COLORADO | R6 | RIVERINE | Area | 0.00562088567 | ACRE | NRPW | 38.31476 | -108.84844 | Alt D | Visual |
| E058 | COLORADO | R6 | RIVERINE | Area | 0.02076794313 | ACRE | NRPW | 38.31618 | -108.84548 | Alt D | Visual |
| E059 | COLORADO | R6 | RIVERINE | Area | 0.01772225425 | ACRE | NRPW | 38.31582 | -108.84470 | Alt D | Visual |
| E060 | COLORADO | R6 | RIVERINE | Area | 0.18512449469 | ACRE | NRPW | 38.32029853690 | -108.84389869500 | Alt D | Delineation and visual |

# Appendix H

## Hydrologic Modeling Report and Memoranda

-FINAL-
# Paradox Valley Unit Environmental Impact Statement Modeling

*January, 2019*
*Elliot Alexander*

## Overview

The Bureau of Reclamation (Reclamation) conducted hydrologic modeling runs using Reclamation's long-term planning model, Colorado River Simulation System (CRSS). The results from simulating each Paradox Valley Unit Environmental Impact Statement (EIS) alternative across a range of future hydrologic and salinity conditions have been documented in this report.

A key assumption, which is different from the typical CRSS modeling, is that certain Colorado River System conditions were kept at 2017 values throughout the simulation to conduct a steady state run with the CRSS model. This model assumption adopts a rigorous definition of reasonably foreseeable future actions. In this context, a reasonably foreseeable future action is one which has state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant impact (FONSI) or record of decision (ROD). The Colorado River System conditions that were kept constant at 2017 values include: all future Water Quality Improvement Projects salt mass removal requests, all future Upper and Lower Colorado River Basin demands, and time varying Colorado River operational elements were also kept constant at 2017 values. The model runs presented in this report analyze different salt mass removal rate alternatives at the Paradox Valley Unit site and their effect on salt concentration at the Colorado River Basin numeric criteria points, below Hoover and Parker dams and above Imperial Dam.

The organization of this report contains four separate sections that describe the modeling conducted for the Paradox Valley Unit EIS. The first section provides an overview of the model inputs that were required for the steady state CRSS runs. The next section provides details on the general methodology and modeling assumptions specific to this study and model runs. The following section presents the modeling results of the different Paradox Valley Unit EIS alternatives. A discussion section concludes this report.

## Model Inputs

The model inputs that were required for the steady state CRSS model runs are described in the preceding subsections.

### *2017 Salinity Control Scenarios*

Under each EIS alternative, all future Water Quality Improvement Projects (WQIPs) salt mass removal requests were kept at 2017 monthly values for the entire simulation period

(2017 – 2060). Table 1 provides a list of each of the WQIP sites that were input and kept at 2017 monthly values during the CRSS steady state modeling.

Table 1. List of name and location of all WQIP sites included in the CRSS.

| List of Water Quality Improvement Projects (WQIPs) | |
|---|---|
| **Name** | **Location** |
| Big Sandy | WY |
| West Black's Fork | WY |
| Manila/Henry's Fork | UT/WY |
| Uintah Basin | UT |
| Price/San Rafael River | UT |
| Dirty Devil River | UT |
| Tropic Ditch-Paria | UT |
| Green River | UT |
| Meeker Dome | CO |
| Grand Valley | CO |
| Paradox Valley Unit | CO |
| McElmo Creek/Mancos River | CO |
| Lower Gunnison | CO |
| Silt | CO |
| Moapa Valley | NV |
| San Juan/Navajo | NM |
| BLM Rangeland | [ basin-wide] |
| USDA Tier 2 | [ basin-wide] |

For this analysis, the primary difference between the EIS alternatives is the annual salt mass removal rate at the Paradox Valley Unit. The annual salt mass removal rates at the Paradox Valley Unity for the four EIS alternatives include:

1. Current Salt Control removing 95,000 tons of salt per year
2. Alternative A removing 0 tons of salt per year
3. Alternative B removing 114,000 tons of salt per year
4. and Alternative C/D removing 171,000 tons of salt per year

Alternatives C & D are represented as a single alternative since both alternatives have identical Paradox Valley salt mass removal rates and are indistinguishable for CRSS steady state modeling purposes. Refer to Table 2 for additional descriptions of each of the four EIS alternatives considered in this analysis.

Table 2. List of each EIS alternative's description and 2017 salt mass removal at the Paradox Valley Unit.

| EIS Alternative | Description | Paradox Valley Unit Salt Mass Removal Request [tons/yr] |
|---|---|---|
| Current Salt Control | Salt control at existing injection well | 95,000 |
| A | No salt control at Paradox Valley Unit [No Action] | 0 |
| B | Installation of a new injection well | 114,000 |
| C/D | Evaporation ponds [C] or ZLD technology [D] | 171,000 |

The 2017 salt mass removal request at the Paradox Valley Unit for each of the EIS alternatives needed to be disaggregated into monthly values before these requests could be read into the CRSS model. Each of the EIS alternative's 2017 salt mass removal requests were uniformly divided into twelve monthly values. These 2017 monthly salt mass removal values were then repeated for each proceeding year (2018 – 2060) of the CRSS steady state model simulation. Table 3 provides the 2017 monthly salt mass removal values for each of the EIS alternatives considered in this analysis.

Table 3. List of monthly salt mass removal values for each of the four EIS alternatives.

| Paradox Valley EIS Alternatives | | | | |
|---|---|---|---|---|
| Monthly Salt Mass Removal Request [tons/month] | | | | |
| Date | Current Salt Control | A | B | C/D |
| 17-Jan | 7,917 | 0 | 9,500 | 14,250 |
| 17-Feb | 7,917 | 0 | 9,500 | 14,250 |
| 17-Mar | 7,917 | 0 | 9,500 | 14,250 |
| 17-Apr | 7,917 | 0 | 9,500 | 14,250 |
| 17-May | 7,917 | 0 | 9,500 | 14,250 |
| 17-Jun | 7,917 | 0 | 9,500 | 14,250 |
| 17-Jul | 7,917 | 0 | 9,500 | 14,250 |
| 17-Aug | 7,917 | 0 | 9,500 | 14,250 |
| 17-Sep | 7,917 | 0 | 9,500 | 14,250 |
| 17-Oct | 7,917 | 0 | 9,500 | 14,250 |
| 17-Nov | 7,917 | 0 | 9,500 | 14,250 |
| 17-Dec | 7,917 | 0 | 9,500 | 14,250 |

### *2017 Demand Scenario*

Similar to the salinity control WQIPs requests, all future Upper and Lower Colorado River Basin water demands were kept at 2017 monthly values for the entire simulation period (2017 – 2060). The Upper Basin demands were based on the 2017 demand projections included in the 2007 Upper Colorado River Commission (UCRC) demand schedule. These data were included in an Excel file that was read into the CRSS model before the start of each simulation. The Lower Basin States' demands are at their full allocation in 2017; therefore all Lower Basin demand remained constant at full allocation throughout the simulation period. If reservoir conditions warranted, Lower Basin states could receive surplus waters during the simulation.

### *Initial Reservoir Conditions*

The CRSS steady state model was initialized with observed 2016 end-of-calendar-year (EOCY) reservoir pool elevations, which are shown in Table 4. The CRSS steady state model was also initialized with observed 2016 EOCY reservoir salt concentration, as shown in Table 5.

Table 4. Initial Reservoir Conditions -- 2016 Observed End-of-Calendar-Year Pool Elevations.

| Reservoir | Elevation [ft AMSL] |
|---|---|
| Fontenelle | 6,486.33 |
| Flaming Gorge | 6,024.19 |
| Starvation | 5,734.92 |
| Taylor Park | 9,309.56 |
| Blue Mesa | 7,491.43 |
| Morrow Point | 7,150.44 |
| Crystal | 6,751.45 |
| Navajo | 6,055.92 |
| Powell | 3,600.49 |
| Mead | 1,080.82 |
| Mohave | 641.31 |
| Havasu | 447.64 |

Table 5. Initial Reservoir Conditions – projection[1] of 2016 End-of-Calendar-Year Salt Concentration.

| Reservoir | Salt Concentration [mg/l] |
|---|---|
| Fontenelle | 298.1 |
| Flaming Gorge | 372.2 |
| Starvation | 400.0 |
| Navajo | 167.0 |
| Powell | 432.7 |
| Mead | 618.0 |
| Mohave | 618.0 |
| Havasu | 643.4 |

[1] 2015 U.S. Geological Survey SLOAD data was used for the projection of the 2016 initial reservoir salt concentrations. Contact James Prairie (jprairie@usbr.gov) for further inquiries regarding the SLOAD dataset.

### *Inflow Hydrology Scenario*

The future hydrology used as input to the model consisted of samples taken from the historical record of natural flow in the river system over the 107-year period from 1906 through 2012 from 29 individual inflow points (or nodes) on the Colorado River System. Natural flow is the observed flow adjusted by removing the effects of diversions and the operation of reservoirs upstream of the flow gage. This natural flow record[2] was developed by Reclamation and is used extensively in their hydrologic modeling and studies. The existing historical record of natural flows was used to create 107 different future hydrologic sequences using a resampling technique known as the Index Sequential Method (ISM[3]). The ISM provides the basis for quantification of the uncertainty and an assessment of the risk with respect to future inflows. This inflow dataset and methodology was used as the primary inflow scenario in the 2007 Shortage EIS and one of four inflow scenarios used in the 2012 Basin Study.

### *Inflow Salt Concentration Scenario*

The future inflow salt concentration used as input to the model was generated at 20 nodes in the Colorado River watershed using Reclamation's nonparametric natural salt model. The natural salt model includes annual (Upper Basin) and monthly (Lower Basin) regressions built with 1971-2012 natural flow and salt mass data. The natural salt model provides salt mass based on flows. Salt concentrations are computed from flow and salt mass. The methods used in the basin-wide salinity modeling framework is described in a paper[4] published by Prairie and Rajagopalan in 2007.

## Methodology

Hydrologic modeling of the Colorado River system was conducted using Reclamation's long-term planning model, CRSS. Under a conventional CRSS simulation, the hydrologic modeling provides projections of potential future Colorado River system conditions (e.g., reservoir elevations, reservoir releases, river flows).  For this study, CRSS is setup to use a steady state mode where 2017 system conditions are simulated across an ensemble of naturalized streamflow and salinity. Once it was verified that the hydrologic and salinity conditions reached a steady state condition, a comparative analysis of salinity concentration at the numeric criteria points for each EIS alternative was conducted.

This report provides an overview of the hydrologic modeling and the framework within which the many simulations were undertaken. Further details regarding CRSS and its

[2] Colorado River Basin Natural Flow and Salt Data, available at: http://www.usbr.gov/lc/region/g4000/NaturalFlow/

[3] Index Sequential Method:  Ouarda, T., Labadie, J.W., and Fontane, D.G. (1997), Index sequential hydrologic modeling for hydropower capacity estimation, *J. of the American Water Resources Association*, 33(6) 1337-1349; and Kendall, D.B. and Dracup, J.A. (1991), A comparison of index-sequential and AR(1) generated hydrologic sequences, *J. of Hydrology*, 122, 335-352.

[4] Basin-wide salinity generation framework:  Prairie, J. R. and Rajagopalan, B. (2007), A basin wide stochastic salinity model, *J. of Hydrology*, 344, 43-54.

standard assumptions are available in the modeling appendix of the 2007 Interim Guidelines EIS[5].

### Period of Analysis

CRSS steady state modeling extends from 2017 through 2060, a 44 year period.

### Model Description

Colorado River system conditions for each EIS alternative were simulated using CRSS. The modeling framework for CRSS is commercial software called Riverware[6]; a generalized river basin modeling package developed by the University of Colorado through a cooperative arrangement originally with Reclamation and the Tennessee Valley Authority. CRSS was first developed by Reclamation in the early 1970s and was implemented in Riverware in 1996.

CRSS simulates the operation of the major reservoirs on the Colorado River on a monthly time-step and provides information regarding the state of the system in terms of output variables including the amount of water in storage, reservoir elevations, releases from the dams, the amount of water flowing at various points throughout the system, and the diversions to and return flows from the water users throughout the system. The simulation uses a mass balance (or water budget) approach to account for water entering the system, water leaving the system (e.g., from consumptive use of water, trans-basin diversions, evaporation), and water moving through the system (i.e., either stored in reservoirs or flowing in river reaches).

The input data for the model, as described in the Model Input section, includes monthly future natural streamflow and salt concentration, repeating 2017 WQIPs salt mass removal request, initial reservoir conditions on December 31, 2016, and the repeating 2017 diversion and depletion schedules for entities in the Basin States and for Mexico over the 44 year period of analysis.

The rules of operation of the Colorado River mainstream reservoirs are also provided as input to the model. These sets of operating rules describe how water is released and delivered under various hydrologic conditions.

### General model assumptions:

- CRSS model built off the 2017 Triennial Review model (CRSS.V2.4.2017.Jan2017)
- CRSS model initialized with December 2016 EOCY reservoir conditions and salinity conditions based on values used for the 2017 Triennial Review modeling
- Steady state CRSS simulation based on repeating 2017 data
    - 44-year simulation period

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[5] Final EIS – Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake MeadAppendix A – CRSS Model Documentation, available at: http://www.usbr.gov/lc/region/programs/strategies/FEIS/AppA.pdf

[6] Riverware: A generalized tool for complex reservoir system modeling, Edith A. Zagona, Terrance J. Fulp, Richard Shane, Timothy Magee, and H. Morgan Goranflo, Published in the Journal of the American Water Resources Association, August 2001.

- Index sequential method used for the Direct Natural Flow & Salt Concentration period of record (1906 - 2012): 107 simulations
- Applied 2007 Interim Guidelines as implemented in 2017 through simulation period

### *Modifications to CRSS*

A couple modifications were made to the official version of CRSS to hold time varying Colorado River operational elements constant at 2017 values. The first modification was made to ensure the Lake Powell Equalization Line remained at the 2017 value, 3,652 feet throughout the simulation period. This change was made in the CRSS model by setting each annual value in the Equalizing Line *Series Slot* within the EqualizationData *Data Object* to be a repeat of the 2017 value. This Equalizing Line *Series Slot* is referenced in Lake Powell's operating rules, which determines the precise tier Lake Powell is operating in, and simulates releases consistent with the determined tier. This modification ensures that the 2017 Equalization Line pool elevation is used to distinguish between Lake Powell's Equalization and Upper Elevation Balancing operational tiers regardless of the simulation timestep.

In addition, Intentionally Created Surplus (ICS) was disabled in the official version of the CRSS model. This modification restricts water banking at Lake Mead for Mexico and Lower Basin States, which includes Arizona, Nevada, and California. ICS was disabled to suppress time varying water banking deposits and withdrawals which would make it challenging for Lake Mead to reach a steady state hydrologic condition by the end of the simulation period.

## Results

Each alternative (A, B, C/D and Current Salt Control) was simulated 107 times using the Direct Natural Flow & Salt Concentration record, resulting in four CRSS steady model runs. Since EIS alternatives C and D share the same annual salt mass removal rate, results for both alternatives are presented as a single alternative. The following results from each EIS alternative CRSS model runs were evaluated:

- Powell pool elevation on Dec 31$^{st}$ (average, 10$^{th}$, 90$^{th}$ percentiles over time)
- Mead pool elevation on Dec 31$^{st}$ (average, 10$^{th}$, 90$^{th}$ percentiles over time)
- Annual average of Paradox Valley Unit Salt Mass Removal over time
- Colorado River below Hoover Dam flow weighted average annual concentration
- Colorado River below Parker Dam flow weighted average annual concentration
- Colorado River at Imperial Dam flow weighted average annual concentration
- Table of 2051-2060 flow weighted average salt concentration at each numeric criteria point for each alternative considered
- Table of change in 2051-2060 flow weighted average salt concentration between Current Salt Control and each alternative at each numeric criteria point
- Table of estimated 2017 average annual economic damages at each numeric criteria point for each alternative considered
- Table of change in 2017 average annual economic damages between Current Salt Control and each alternative at each numeric criteria point

## Post-processing and Interpretation Procedures

CRSS generates data on a monthly time-step for over 300 points (or nodes) on the Colorado River system. Furthermore, using the ISM on the natural flow and salt concentration record, the model generated 107 possible outcomes for each node for each month of the model simulation. These data were aggregated to reduce the volume of data and to facilitate comparison of the alternatives.

For aggregation of data, simple techniques were employed. For example, Lake Powell pool elevations were evaluated on an annual basis (i.e., end of December) to show long-term pool elevation trends as opposed to short-term fluctuations. Standard statistical techniques were used to analyze the 107 possible outcomes for a fixed time or particular temporal span. Statistics that were generated included the $10^{th}$ and $90^{th}$ percentiles and the annual average. Percentiles were determined by simply ranking the outcomes at each time-step (from highest to lowest) and determining the value at the specified percentile. For example, 107 pool elevation values were generated for December 2017, one for each natural flow inflow trace. These 107 values were ranked and then the $10^{th}$ and $90^{th}$ percentile values were taken along with the annual average to statistically represent the distribution of pool elevations generated for December 2017. This process was then repeated for December 2018, December 2019, and so on. It is important to note that the $10^{th}$ percentile values determined for December 2017, December 2018, and December 2019, do not necessarily come from the same inflow hydrology trace and do not represent a timeseries of elevations. Rather, the values are a statistical representation of the distribution of data at each annual period in the model simulation. This statistical method is used to view the results of all hydrologic and salinity sequences in a compact manner yet maintains the variability at high, average, and low hydrologic and salinity conditions in the Colorado River system.

## Paradox Valley Unit EIS Modeling Results

Figure 1 shows the difference in the end of December Lake Powell pool elevation between each EIS alternatives ensembles average, $10^{th}$ and $90^{th}$ percentiles. Throughout the entire modeling period there was no difference in Lake Powell pool elevations between each EIS alternative at any statistical level. In general, Lake Powell pool elevations reach a quasi-steady state condition by year 2025 with the ensemble average pool elevation varying approximately 5 feet during the 2025-2060 range.

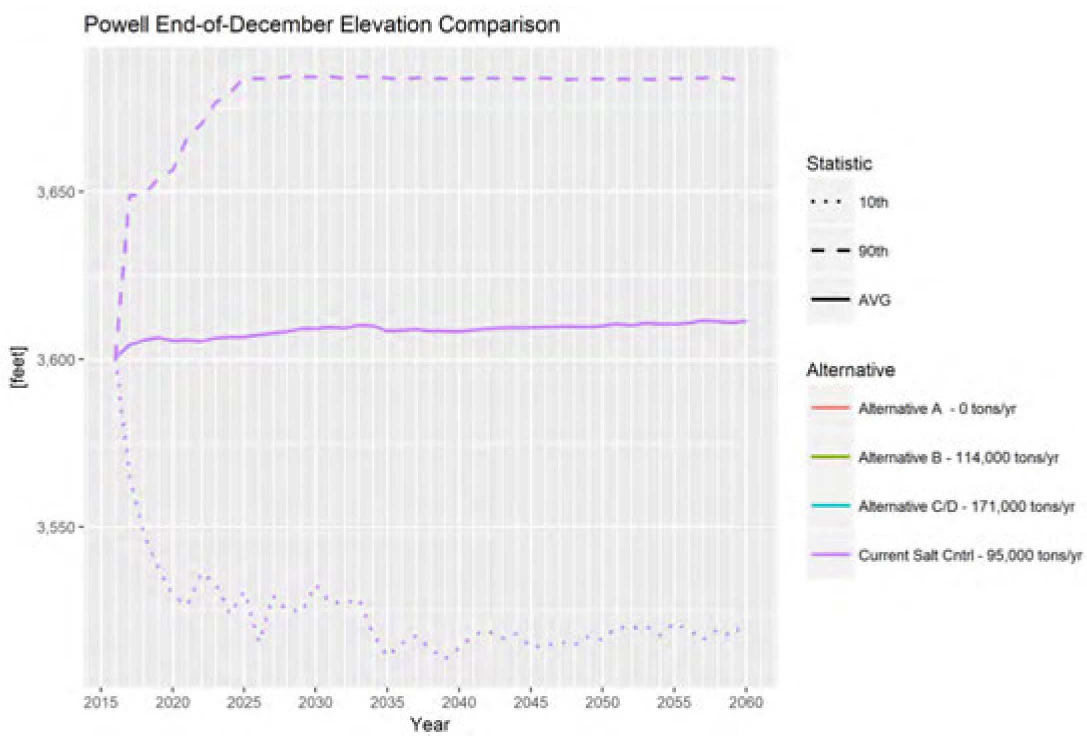


Figure 1. Plot of Lake Powell Pool Elevation, December for each EIS alternative. The line color distinguishes the EIS alternatives and the line type indicates ensemble based descriptive statistic.

Figure 2 shows the difference in the end of December Lake Mead pool elevation between each EIS alternatives ensemble average, 10th and 90th percentiles. Throughout the entire modeling period there was no difference in Lake Mead pool elevations between each EIS alternative at any statistical level. As observed in the 10th, 90th, and average pool elevation statistics, the Lake Mead pool elevations took until 2051 to reach a quasi-steady state condition. This 2051 onward steady state condition for Lake Mead pool elevation was further confirmed in an additional Lake Mead pool elevation initial condition sensitivity analysis where 2 additional CRSS steady state model runs were conducted. The additional steady state runs were conducted with 50 ft higher and 50 ft lower initial Lake Mead pool elevations. The additional perturbed initial condition steady state runs reached a comparable steady state condition starting on 2051. Therefore, the period from 2051 to 2060 is termed the steady state period for the remainder of this report.

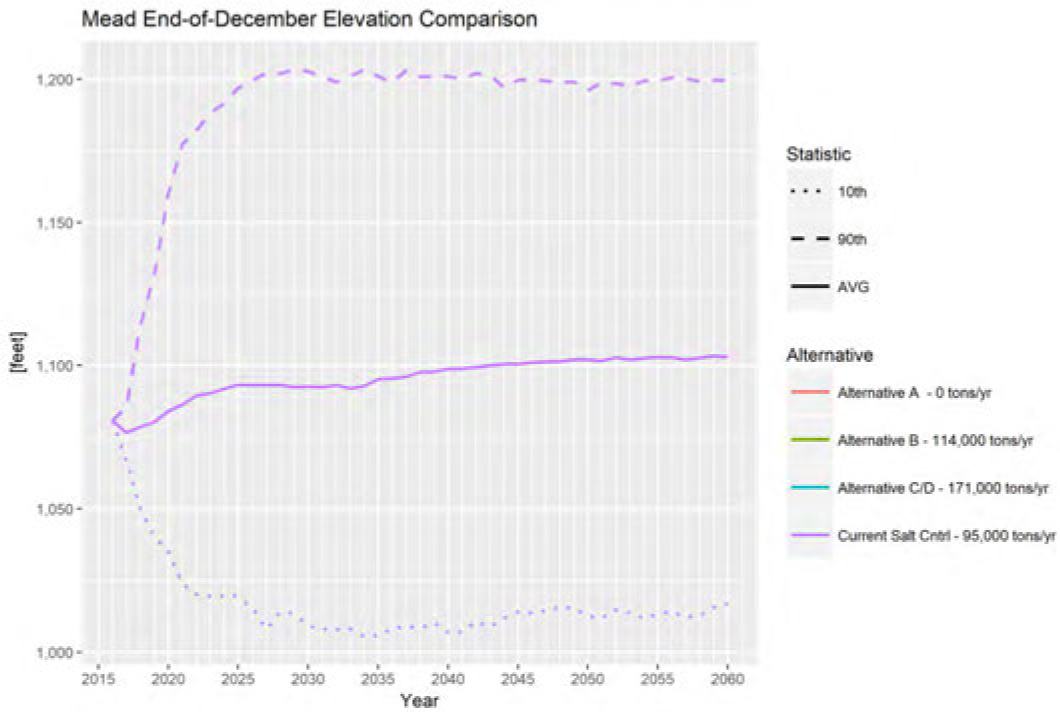


Figure 2. Plot of Lake Mead Pool Elevation, December for each EIS alternative The line color distinguishes the EIS alternatives and the line type indicates ensemble based descriptive statistic.

Figure 3 displays the difference in the average annual salt mass removal between each EIS alternative at the Paradox Valley Unit WQIP site. In general, each of the modeled EIS alternative's salt mass removal rates at the Paradox Valley Unit remains constant at the alternative's specified rates throughout the modeling period. A slight annual salt mass removal variability can be observed in EIS alternatives with higher salt mass removal rates (B and C/D). This variability can be attributed to the salt routing method utilized in CRSS. This salt routing method allows a reach to store salt during low flow conditions and release the stored salt once the reach has sufficient water to carry salt downstream ensuring salinity concentrations outside the historical range for a specific gaging site are not exceeded.

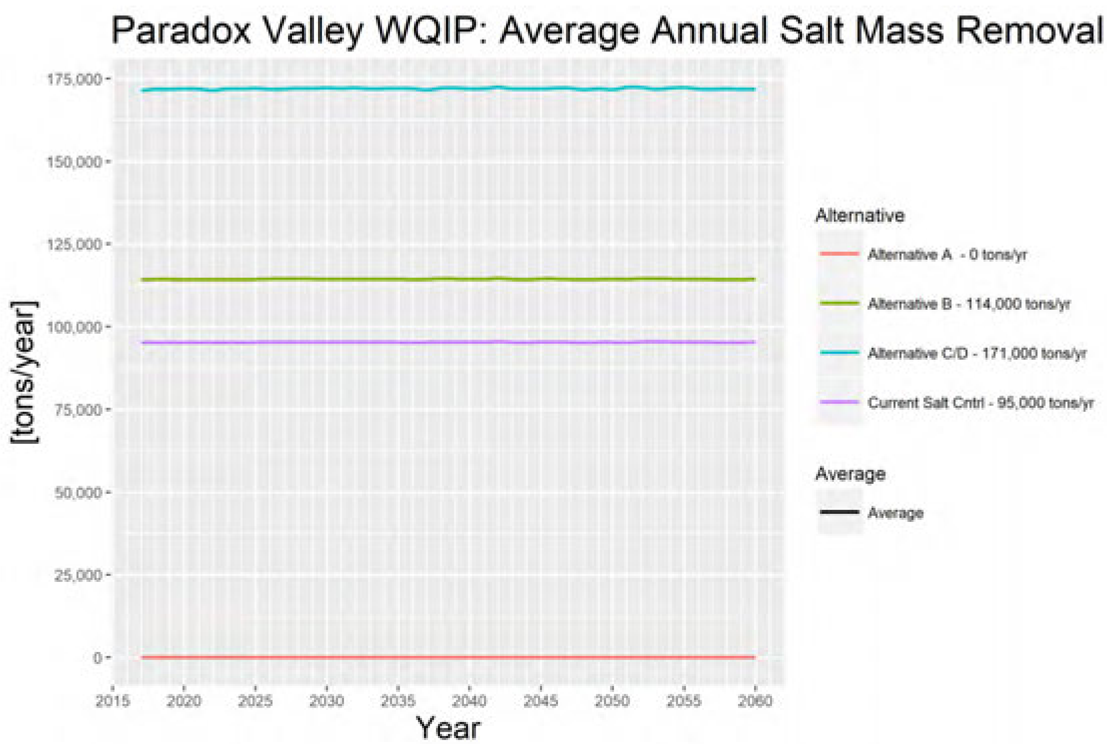


Figure 3. Plot of average annual salt mass removal at the Paradox Valley Water Quality Improvement Project (WQIP) site for each EIS alternative. The line color distinguishes the EIS alternatives.

Figure 4 shows the difference in the flow weighted average annual salt concentration between each EIS alternative below Hoover Dam. It is apparent that the EIS alternatives with the lower salt mass removal rates at the Paradox Valley Unit site (A and current salt control) have the highest salinity concentration below Hoover Dam throughout the modeling period. Conversely, the EIS alternatives with the higher salt mass removal rates at the Paradox Valley Unit site (C/D and B) have the lowest salinity concentration below Hoover Dam throughout the modeling period. Note that all the EIS alternative's flow weighted average salinity concentrations below Hoover Dam are all well below the 723 mg/L numeric criteria salinity concentration at this location on the Colorado River.

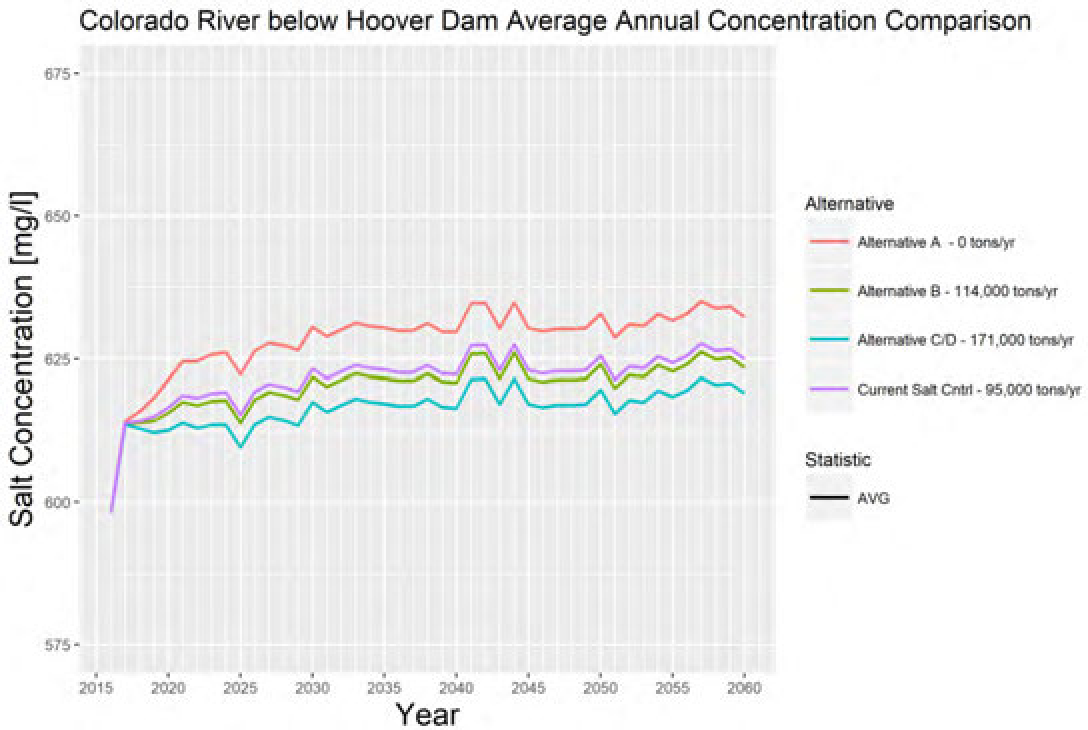


Figure 4. Plot of flow weighted average annual salt concentration of the Colorado River below Hoover Dam for each EIS alternative. The line color distinguishes the EIS alternatives and line type indicates ensemble based descriptive statistic. The numeric criteria for the Colorado River below Hoover Dam is 723 mg/l.

Figure 5 shows the difference in the flow weighted average annual salt concentration between each EIS alternative below Parker Dam. It is also apparent that the EIS alternatives with the lower salt mass removal rates at the Paradox Valley Unit site (A and current salt control) have the highest salinity concentration below Parker Dam throughout the modeling period. Conversely, the EIS alternatives with the higher salt mass removal rates at the Paradox Valley Unit site (C/D and B) have the lowest salinity concentration below Parker Dam throughout the modeling period. Note that all the EIS alternative's flow weighted average salinity concentrations below Parker Dam are all well below the 747 mg/L numeric criteria salinity concentration at this location on the Colorado River.

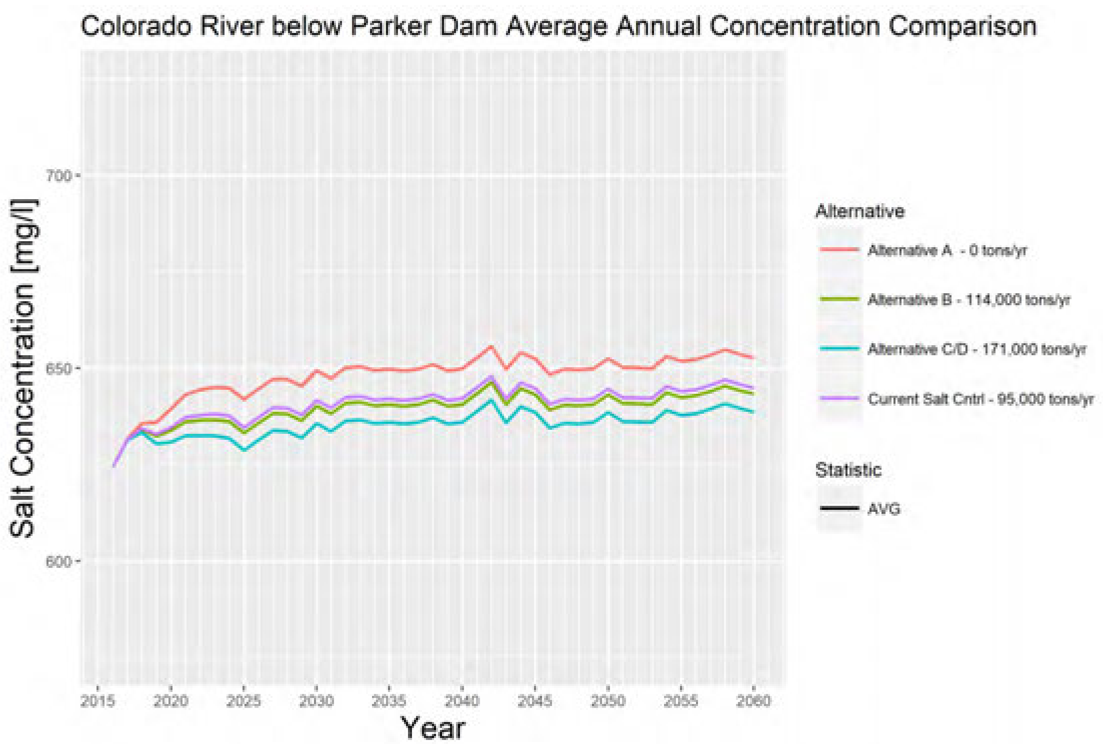

Figure 5. Plot of flow weighted average annual salt concentration of the Colorado River below Parker Dam for each EIS alternative. The line color distinguishes the EIS alternatives and line type indicates ensemble based descriptive statistic. The numeric criteria for the Colorado River below Parker Dam is 747 mg/l.

The difference in the flow weighted average annual salt concentration between each EIS alternative at Imperial Dam is shown in Figure 6. It is again apparent that the EIS alternatives with the lower salt mass removal rates at the Paradox Valley Unit site (A and Current Salt Control) have the highest salinity concentration at Imperial Dam throughout the modeling period. Conversely, the EIS alternatives with the higher salt mass removal rates at the Paradox Valley Unit site (C/D and B) have the lowest salinity concentration at Imperial Dam throughout the modeling period. Note that all the EIS alternative's flow weighted average salinity concentrations at Imperial Dam are all well below the 879 mg/L numeric criteria level at this location on the Colorado River. The salt concentration ordering between each EIS alternatives are consistent at each numeric criteria point for the entire modeling period.

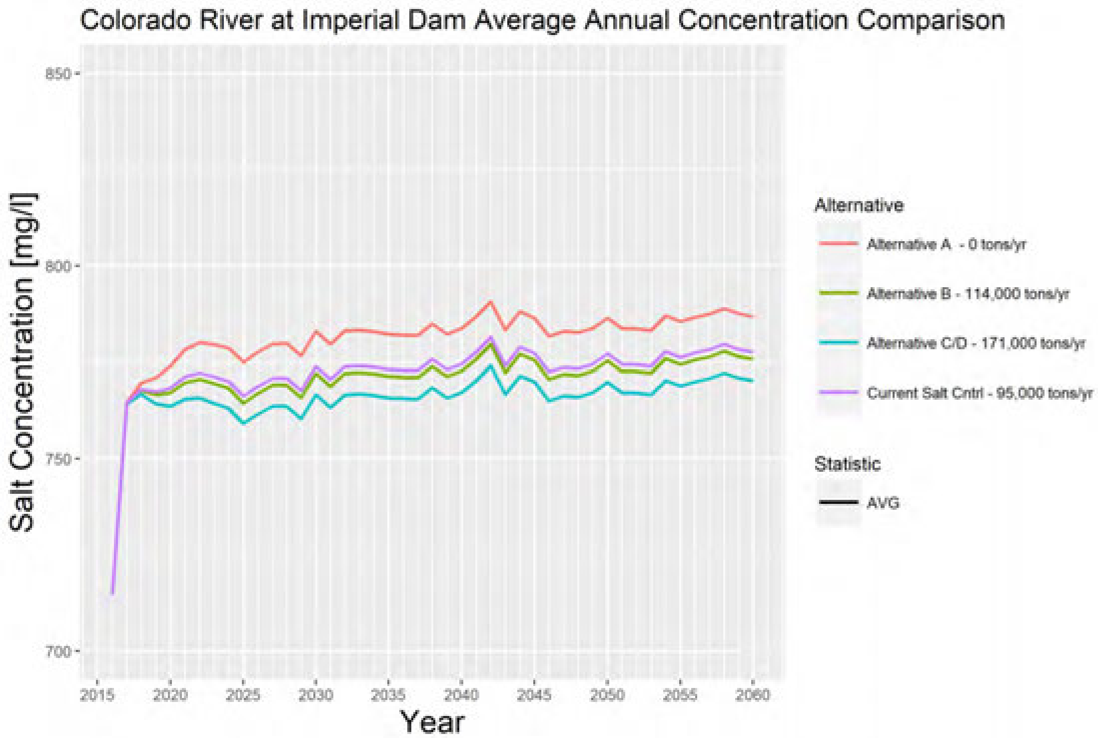


Figure 6. Plot of flow weighted average annual salt concentration of the Colorado River at Imperial Dam for each EIS alternatives. The line color distinguishes the EIS alternatives and line type indicates ensemble based descriptive statistic. The numeric criteria for the Colorado River at Imperial Dam is 879 mg/l.

Table 6 displays the summary of flow weighted average salt concentration for the period of 2051 to 2060 for each EIS alternative at the numeric criteria points. This period was chosen since both the hydrologic and salinity conditions are in a steady state condition. The ordering of alternatives from highest to lowest average salt concentration remain consistent at each numeric criteria point. The EIS alternatives listed from highest to lowest average salt concertation are: Alternative A, Current Salt Control, Alternative C/D, and Alternative B. This ordering of the EIS alternatives aligns with line orderings of the EIS alternatives in Figures 4 through 6.

Table 6. Table of flow weighted average salt concentration (2051 – 2060) for each EIS alternative at each numeric criteria point.

| Numeric Criteria Point | Alternative A | Alternative B | Alternative C/D | Current |
|---|---|---|---|---|
| **Below Hoover Salt Conc. [mg/l]** | 632.3 | 623.5 | 619.0 | 624.9 |
| **Below Parker Salt Conc. [mg/l]** | 652.1 | 642.9 | 638.2 | 644.4 |
| **At Imperial Salt Conc. [mg/l]** | 786.1 | 775.0 | 769.4 | 776.8 |

Table 7 displays the change in flow weighted average salt concentration in the steady state period compared to Current Salt Control for each EIS alternative at the numeric criteria points. The positive concentration values in Table 7 indicate an increase in concentration at a numeric criteria location compared to the Current Salt Control alternative and the negative concentrations indicate a decrease in concentration. The purpose of this table is to get a sense of the relative increase or decrease in salinity concentration at the numeric criteria points from the alternative salt mass removal rates at the Paradox Valley Unit site.

Alternative C/D has the greatest decrease in annual salt concentration at the numeric criteria points, -7.4 mg/L at Imperial Dam when compared to Current Salt Control at the Paradox Valley Unit, since it has the highest annual salt mass removal rate of 171,000 tons per year versus 95,000 tons per year removed under Current Salt Control. In general, Tables 6 & 7 showcase that the varying Paradox Valley Unit salt mass removal rates of the different EIS alternatives have a direct impact on the flow weighted average annual salt concentration at each of the numeric criteria points.

Table 7. Change in flow weighted average salt concentration (2051 – 2060) compared to Current Salt Control for each EIS alternatives at each numeric criteria point.

| Numeric Criteria Point | Alternative A | Alternative B | Alternative C/D | Current |
|---|---|---|---|---|
| **Below Hoover Salt Conc. [mg/l]** | 7.4 | -1.5 | -5.9 | 0.0 |
| **Below Parker Salt Conc. [mg/l]** | 7.7 | -1.5 | -6.2 | 0.0 |
| **At Imperial Salt Conc. [mg/l]** | 9.2 | -1.9 | -7.4 | 0.0 |

Table 8 displays the summary of economic damages for each EIS alternative estimated by the Salinity Economic Impact Model (SEIM). The SEIM was initialized with each EIS alternative's flow weighted average salt concentration for the steady state period (2051 – 2060) at each numeric criteria point and then run to estimate the 2017 average annual economic damages at each numeric criteria point in 2014 dollars. The version of SEIM employed in this study (SEIM dated 06/29/17) is also the same SEIM version used during the 2017 Triennial Review. It is important to note the SEIM does not calculate an absolute value of the economic impacts due to salinity. The SEIM estimates salinity impacts from the baseline condition of 500 mg/L and then calculates the change in economic impacts when salinity concentration increases or decreases in the Colorado River mainstem waters diverted within the Lower Colorado River Basin. For additional information regarding the SEIM refer to Appendix F[7] of the 2017 Triennial Review report. The EIS alternatives listed from highest to lowest average annual economic damages are: Alternative A, Current Salt Control, Alternative B, and Alternative C/D.

[7] 2017 Review, Water Quality Standard for Salinity Colorado River System, available at: https://www.coloradoriversalinity.org

Table 8. Table of 2017 average annual economic damages for each EIS alternative at each numeric criteria point and as a Lower Colorado River Basin total.

| Numeric Criteria Point | Alternative A | Alternative B | Alternative C/D | Current |
|---|---|---|---|---|
| Below Hoover Damages [$ millions] | $56.832 | $53.045 | $51.106 | $53.647 |
| Below Parker Damages [$ millions] | $201.148 | $188.030 | $181.514 | $190.173 |
| At Imperial Damage [$ millions] | $260.757 | $249.924 | $244.459 | $251.681 |
| Total Damages [$ millions] | $518.737 | $490.999 | $477.079 | $495.501 |

Table 9 displays the increase and decrease in 2017 average annual economic damages compared to the Current Salt Control for each EIS alternative at each numeric criteria point and as a Lower Colorado River Basin total. The positive economic damage values indicate an increase in damages and the negative economic damage values indicate a decrease in damages. In addition to the highest annual salt concentration decrease, Alternatives C/D has the highest decrease in average annual economic damages at each numeric criteria point and the Lower Colorado River Basin total as compared with the Current Salt Control alternative. In summary, Tables 8 & 9 demonstrate that the varying Paradox Valley Unit salt mass removal rates of the different EIS alternatives also have a direct impact on the 2017 average annual economic damages at each of the numeric criteria points.

Table 9. Change in 2017 average annual economic damages as compared to the Current Salt Control at each numeric criteria point and as a Lower Colorado River Basin total.

| Numeric Criteria Point | Alternative A | Alternative B | Alternative C/D | Current |
|---|---|---|---|---|
| Below Hoover Damages [$ millions] | $3.185 | -$0.602 | -$2.541 | $0.000 |
| Below Parker Damages [$ millions] | $10.975 | -$2.143 | -$8.659 | $0.000 |
| At Imperial Damages [$ millions] | $9.076 | -$1.757 | -$7.222 | $0.000 |
| Total Damages [$ millions] | $23.236 | -$4.502 | -$18.422 | $0.000 |

# Discussion

Unique to this analysis is the model assumption that no new projects or depletions will occur in the Upper Basin. This model assumption adopts a rigorous definition of what reasonably foreseeable future actions are in the Upper Basin and is consistent with DOI NEPA Implementing Regulations. Under this approach, a reasonably foreseeable future action is one which has state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant impact (FONSI) or record of decision (ROD). These are the criteria of certainty that a future action would occur at a particular time and place. This is a conservative approach to modeling the alternatives and takes the strictest approach to defining what is included and excluded for the cumulative impact analysis required by the Council on Environmental Quality's regulations at 40 CFR 1508.7.[8]

It is important to note that the modeling results presented in this report do not represent what the actual reservoir pool elevations, salinity concentrations, or economic damages will be in any given year. Colorado River System conditions were maintained at 2017 values to conduct the steady state simulations using the CRSS model. Therefore, the modeling results should be interpreted based on the relative differences of economic damages, hydrologic and salinity conditions between each of the EIS alternatives rather than viewing the results as projections of plausible system conditions.

The model results presented in this report are sensitive to the inflow hydrology scenario assumption. This analysis simulated the effects of each EIS alternative's Paradox Valley Unit salt mass removal rate 107 times with the DNF ensemble maintaining 2017 Colorado River System conditions throughout the CRSS steady state run. Using the DNF ensemble to represent a range of future hydrologic and salinity conditions for a 44-year simulation horizon provided a thorough analysis to determine the effects of each EIS alternative on the salt concentrations at each numeric criteria point.

## Attachments List

Three supplementary attachments are included with this report. The attachments include:

1. Attachment A – Model Input -- DIT_CRSS_UCRC2007shortageEIS2010_FINALv2.13.xlsx
2. Attachment B – Model Input -- WQIPs Salt Mass Removal Requests.xlsx
3. Attachment C – Model Output -- Summary Tables for Salt Conc. and Economic Damages at Numeric Criteria Points.xlsx

The first two attachments (A & B) provide model input data for the 2017 water demand scenario and the 2017 salinity control scenarios that were used for the CRSS simulations. The last attachment (C) provides the flow weighted average annual concentration model output data and summary tables for each EIS alternative simulated. Each supplementary attachment provides a ReadMe tab to describe the contents of the workbook, the model input or output for each EIS alternative are presented in a separate tab, and additional tables are provided to aid the interpretation of the model input or output tabs.

[8] Cumulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

**Attachments are available from Reclamation upon Request**

# Memorandum: Evaluating the Impact of Paradox Valley Environmental Impact Statement (EIS) Alternatives on Water Bypassed Pursuant to IBWC Minute No. 242

**To:** Hong Nguyen-DeCorse, U.S. Bureau of Reclamation, Yuma Area Office
**From:** Steve Setzer, Hydros Consulting Inc.
**Subject:** Evaluation of Paradox Valley EIS Alternatives
**Date:** January 30, 2019

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Hydros Consulting Inc. (Hydros) was tasked by the Yuma Area Office (YAO) of the U.S. Bureau of Reclamation to evaluate the potential impact of the Paradox Valley Environmental Impact Statement (EIS) alternatives on Water Bypassed Pursuant to International Boundary and Water Commission (IBWC) Minute No. 242. The RiverWare Salinity Projection Model (the model), which is currently used by the YAO staff for projecting the cumulative annual salinity differential at the Northerly International Boundary with the Republic of Mexico (NIB), was used for this analysis. The model assists the YAO Water Operations staff in determining the amount of pumped groundwater (from groundwater drainage wells) that can be directed to the Colorado River while remaining compliant with IBWC Minute No. 242 salinity requirements. Pumped groundwater that cannot be directed to the Colorado River is directed to the Main Outlet Drain Extension (MODE) and is accounted for as Water Bypassed Pursuant to IBWC Minute No. 242 (bypass flows or bypass water).

IBWC Minute No 242 states that the cumulative annual salinity differential between waters arriving at Imperial Dam and waters arriving at the NIB cannot exceed 145 ppm (mg/l). Therefore, as the average salt concentration of water arriving at Imperial Dam varies, the amount of groundwater that can be directed to the Colorado River while remaining below the 145 ppm differential also varies. Pumped groundwater that cannot be directed to the river is directed to the MODE and becomes bypass water.

## *Model Assumptions*

To determine the potential impact of the Paradox Valley EIS Alternatives on bypass flows, the model was simulated over a 15-year period from 2003 through 2017 given historical conditions and the estimated change in average salt concentration at Imperial Dam determined by the Colorado River Simulation System (CRSS) modeling study (Draft

Report Paradox Valley Unit Environment Impact Statement Modeling dated November 2018) for each EIS alternative.

The following assumptions were maintained for each simulation:

1) The volume of water arriving at Imperial Dam was unchanged from the historical volume.
2) The monthly historical salt concentration associated with water arriving at Imperial Dam was adjusted by the average change in salt concentration at Imperial Dam estimated by the CRSS model for each alternative.
3) The salt concentration associated with Pilot Knob Power Plant, Yuma Main Canal Wasteway, Flow below Imperial Dam, Tijuana, and Intentionally Created Mexican Allocation (ICMA) for a given month in each scenario is equal to the salt concentration of water arriving at Imperial Dam for that month and that scenario.
4) All other data EXCEPT the volume of pumped groundwater directed to the river is unchanged from the historical values.
5) The cumulative annual salinity differential that occurred historically was assumed to be the same for each year in the simulation, for each EIS alternative. In other words, the assumption is that all other operations would have remained the same except for the amount of groundwater sent to the river and the same cumulative annual salinity differential would be achieved for each year as occurred historically.

## *"Historical Alt" Scenario*

The baseline model simulation against which the EIS alternatives were compared is a modified version of the historical condition. Because of the assumption that the salt concentration at Pilot Knob Power Plant, Yuma Main Canal Wasteway, Below Imperial Dam, Tijuana, and ICMA is the same as that of water arriving at Imperial Dam, and due to the fact that the historical salt concentrations at these locations are slightly different than the historical salt concentration at Imperial Dam, a modified version of the historical condition was created where the historical salt concentration at Imperial Dam was used for Pilot Knob Power Plant, Yuma Main Canal Wasteway, below Imperial Dam, Tijuana, and ICMA.

The modified historical simulation resulted in slightly different cumulative annual salinity differentials compared to historical. In order to achieve the historical cumulative annual salinity differential values, the historical volume of groundwater directed to the river was adjusted slightly. The result is a modified simulation, called "Historical Alt" in the tables below, with the following characteristics:

1) The salt concentration at Imperial Dam, Pilot Knob Power Plant, Yuma Main Canal Wasteway, below Imperial Dam, Tijuana, and ICMA are equal to the historical salt concentration at Imperial Dam.
2) The cumulative annual salinity differential is the same for each year as historical.
3) The historical amount of groundwater directed to the river was adjusted slightly to account for the change described in item 1) above and in order to achieve the same cumulative annual salinity differential in each year as historical.
4) All other values are the same as historical.

The alternatives below were then compared to this "Historical Alt" as the baseline scenario used to compute the difference in groundwater directed to the river (and therefore the difference in bypass flows) for each scenario.

## *Scenario Development*

A scenario was developed with the model for each EIS alternative. For each scenario, the following steps were performed:

1) The historical salt concentration at Imperial Dam was adjusted by the average change at Imperial Dam determined by CRSS for the given alternative.
2) The salt concentration at Pilot Knob, Yuma Main Canal Wasteway, Below Imperial Dam, Tijuana, and ICMA were set equal to the adjusted value at Imperial Dam.
3) All other values EXCEPT for the volume of groundwater directed to the Colorado River remain the same as historical
4) For each year, the volume of groundwater directed to the river was adjusted from the historical value in order to achieve the same cumulative annual salinity differential as occurred for that year, historically.

## *Results*

Table 1 summarizes the model results for each Paradox Valley EIS alternative compared with the modified historical condition. The concentration at Imperial Dam shown in the table for each scenario was computed as the annual, flow-weighted average value further averaged over the 15-year simulation period. The Groundwater to River values are the annual volumes of pumped groundwater added to the river averaged over the 15-year simulation period. The "Difference from Historical" values are computed as the difference between the 15-year average value from the alternative simulation and the modified historical simulation (Historical Alt). The "Additional Water Released from Lake Mead" row shows that, as less groundwater is directed to the river (i.e. more groundwater is sent to the bypass channel), that same volume of water would theoretically need to come from Lake Mead to make up the difference at the NIB. The "Additional Water Saved in Lake Mead" row shows that, as more groundwater is directed to the river (i.e. less groundwater is sent to the bypass channel), that same volume of water would theoretically not need to be released from Lake Mead in order to achieve the same volume at the NIB as observed historically.

**Table 1: Comparison of Paradox Valley EIS Alternatives with Modified Historical Condition**

| | Historical Alt | Alternative A | Alternative B | Alternative C/D |
|---|---|---|---|---|
| At Imperial Dam Salt Conc. (mg/l) | 704.1 | 713.3 | 702.2 | 696.7 |
| Difference from Historical (mg/l) | | 9.2 | -1.9 | -7.4 |
| | | | | |
| Groundwater to River (acre-ft/yr) | 80,233 | 84,323 | 79,795 | 77,306 |
| Difference from Historical (acre-ft/yr) | | 4,090 | -438 | -2,927 |
| Max Annual Difference from Historical (acre-ft/yr) | | 5,473 | -1,073 | -6,475 |
| Min Annual Difference from Historical (acre-ft/yr) | | 2,011 | 982 | -2,083 |
| | | | | |
| Additional Water Released from Lake Mead (acre-ft/yr) | | | 438 | 2,927 |
| Additional Water Saved in Lake Mead (acre-ft/yr) | | 4,090 | | |

Note the results above are presented as annual volumes of pumped groundwater directed to the Colorado River in order to achieve the same cumulative annual salinity differential that was observed historically. The difference between the historical average and the simulated average annual volume of groundwater directed to the river is analogous to the annual average difference in the bypass flows. In other words, for every additional acre-foot of groundwater directed to the river under a given alternative, one less acre-foot of bypass flows would have occurred and vice versa.

## *Caveats*

Following are several caveats associated with the evaluation described above.

- The model simulations performed to evaluate the EIS alternatives are not unique solutions. When modifying the volume of groundwater required to match the historical cumulative annual salinity differential, it was necessary to select one or more months within that year to modify. Additionally, it was necessary to select whether the change in groundwater to the river should apply to the Drainage Pump Outlet Channel (DPOC) value or the Yuma Mesa Conduit value (these are two different sources of pumped groundwater entering the river). In general, the modeler attempted to spread the change out over several months using both the DPOCs and the Yuma Mesa Conduit, while avoiding months where one of the sources happened to have a higher than usual salt concentration associated with it. However, different combinations could result in different volumes to achieve the same salinity differential (due to the different salt concentrations observed each month and in the DPOCs vs. the Yuma Mesa Conduit).
- The simulations assume that nothing changes other than the salt concentration at Imperial Dam and the volume of groundwater directed to the river. It is possible

that, if the salt concentration arriving at Imperial Dam changes, the salt concentration of drains flows would also change. Additionally, as the volume of groundwater added to the river changes, the salinity associated with that groundwater could change (for example, as different pumps were used as the source). These nuances were not considered in this evaluation.

- This evaluation assumes that the river operators can be efficient enough to make adjustments of this magnitude.
- It is just as reasonable to assume there would be no change in bypass water due to the change in salt concentration at Imperial Dam. Rather, the cumulative annual salinity differential would have been different than what occurred historically.
- There is uncertainty associated with these scenarios and assumptions. However, no uncertainty estimates were given from the CRSS modeling study (Draft Report Paradox Valley Unit Environmental Impact Statement Modeling dated November 2018).

## Memorandum: General Description of Yuma Area Office Salinity Operations with Respect to IBWC Minute No. 242 Requirements and Comment on Impact of Paradox Valley EIS Alternatives on Operations and Lake Mead Storage

**To:** Hong Nguyen-DeCorse, U.S. Bureau of Reclamation, Yuma Area Office
**From:** Steve Setzer, Hydros Consulting Inc.
**Subject:** Commentary on Operations and Paradox Valley EIS Alternatives
**Date:** January 30, 2019

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This memorandum acts as a supplement to the memorandum from Hydros titled "Evaluating the Impact of Paradox Valley Environmental Impact Statement (EIS) Alternatives on Water Bypassed Pursuant to IBWC Minute No. 242." Within that memorandum, Hydros evaluated the Paradox Valley EIS Alternatives to determine the impact, if any, on the Yuma Area Office salinity operations related to Minute No. 242 and the potential impacts to Water Bypassed Pursuant to International Boundary and Water Commission (IBWC) Minute No. 242 (bypass flows or bypass water) and ultimately releases from Lake Mead.

This memorandum provides supplementary information regarding the following:

1) The current operations performed by the Yuma Area Office in order to meet the salinity differential as defined by IBWC Minute No. 242.
2) Perspective on relative the magnitude of potential impact reported in the Hydros memorandum entitled "Evaluating the Impact of Paradox Valley Environmental Impact Statement (EIS) Alternatives on Water Bypassed Pursuant to IBWC Minute No. 242."

### *Current Operations to Meet Salinity Differential*

The Water Operations staff at the Yuma Area Office use a RiverWare model (informally called the RiverWare Salinity Projection Model) to assist operators in remaining compliant with the IBWC Minute No. 242 salinity differential. IBWC Minute No 242 states that the cumulative annual average salinity differential between waters arriving at Imperial Dam and waters arriving at the Northerly International Boundary with the Republic of Mexico (NIB) cannot be more than 115 ppm ± 30 ppm U.S. count (121 ppm ± 30 ppm Mexican count). There are several sources of water, both controlled and uncontrolled, between

Imperial Dam and the NIB that contribute to this salinity differential (i.e. increase the concentration of water arriving at the NIB compared to water arriving at Imperial).

Uncontrolled sources between Imperial Dam and the NIB include the Gila River, several drains and wasteways, and unmeasured groundwater gains, all of which serve to increase the salinity differential (i.e. the salt concentration associated with these sources is higher than the water arriving at Imperial Dam).

The major controlled sources between Imperial Dam and the NIB are Pilot Knob Power Plant and Wasteway (PKPP), the Yuma Main Canal Wasteway, and pumped ground water from the Drainage Pump Outlet Channels (DPOCs), and the Yuma Mesa Conduit. Deliveries to the NIB through the PKPP and the Yuma Main Canal Wasteway do not affect the salinity differential as this water has the same (or very similar) concentration as water arriving at Imperial Dam. Pumped ground water deliver to the river from the DPOCs and the Yuma Mesa Conduit add to the salinity differential as this water has a concentration approximately in the range of 1400 – 1700 ppm depending on which pumping wells are being directed to these structures.

A major objective of operating the system is to blend as much groundwater as possible from the DPOCs and the Yuma Mesa Conduit with the Colorado River water from PKPP and Yuma Main Canal Wasteway (as well as the other uncontrolled sources) while remaining below the 145 ppm cumulative annual salinity differential. In order to ensure compliance, a factor of safety must be considered and a buffer is usually incorporated by attempting to achieve a target salinity differential in the range of 135 – 140 ppm. Two primary reasons for utilizing a buffer or factor of safety are:

1) The official "actual" data is not available real-time; rather, there is a lag of one to one-and-a-half months. Therefore, when planning operations towards the end of the year, the operator does not know the current status of the salinity differential – only the status based on the official data available 1 to 1.5 months ago.
2) There is uncertainty in the projected data, most notably the salt concentration of water arriving at Imperial Dam and the unmeasured flow and salt concentration.

Groundwater added to the river through the DPOCs and/or the Yuma Mesa Conduit can be used to meet the order at the NIB (1.36 million acre-feet annually) *in lieu* of Colorado River water released from Lake Mead. Therefore, generally speaking, each acre-foot of groundwater directed to the river could represent a 1 acre-foot "savings" at Lake Mead (real-world accounting is a bit more complicated due to the possibility of flows to Mexico in excess of treaty requirements and other various factors). Groundwater that is not added to the river is directed to the Main Outlet Drain Extension (MODE) and is accounted for as Water Bypassed Pursuant to IBWC Minute No. 242 (bypass flows or bypass water). Bypass water cannot be used to meet the treaty delivery requirement to Mexico at the NIB.

The RiverWare Salinity Projection Model (the model) is a tool used by the YAO Water Operations staff to determine the amount of groundwater that can be added to the river for the remainder of the calendar year while remaining below a target differential of about 135-140 ppm. The model projects the volume and salt concentration of uncontrolled sources to the river based on average historical data. The volume of Colorado River water projected to be delivered to the NIB is based on the forecasted orders at the NIB and the estimated volume of sources below Imperial Dam that could be used to meet the order at the NIB. The salt concentration of water arriving at Imperial Dam is forecast using a regression equation that correlates the monthly volume arriving at Imperial Dam with the monthly salt concentration (this relationship is usually accurate within +/- 3% of the observed monthly salt concentration). Given the data projected by the model, the operator can vary the volume and salt concentration of pumped groundwater added to the river through the DPOCs and Yuma Mesa Conduit and observe the resulting salinity differential. The model automatically adjusts the volume and salt concentration of water arriving at Imperial Dam to account for changes in pumped groundwater directed to the river. Various features exist in the model to allow the operator to perform sensitivity analyses and develop a range forecasted salinity differentials and the corresponding operations.

## *Magnitude of the Impact of Paradox Valley EIS Alternative on Lake Mead*

Hydros evaluated the Paradox Valley EIS Alternatives to determine the impact, if any, on the Yuma Area Office salinity operations related to Minute No. 242 and the potential impacts to Water Bypassed Pursuant to IBWC Minute No. 242 (bypass flows or bypass water) and ultimately releases from Lake Mead. This analysis is summarized in the memorandum titled "Evaluating the Impact of Paradox Valley Environmental Impact Statement (EIS) Alternatives on Water Bypassed Pursuant to IBWC Minute No. 242." Table 1 in that memorandum shows potential impacts on releases from Lake Mead in the range of 400 – 4,000 acre/feet per year averaged over the 15-year period used for the evaluation (2003 – 2017).

It is our opinion that these impacts are not significant considering the annual volume of water released from Lake Mead, the annual volume delivered to the NIB, and the accuracy of Yuma Area Office operations and model projections with respect to forecasting the year-end salinity differential. To put this in perspective, 4,000 acre-feet is about equivalent to the following:

- 0.3% of the annual delivery to the NIB
- 0.05% of the annual release from Lake Mead

- Seven hours of flow arriving at Imperial Dam (assuming a flow rate of 7,000 cfs at Imperial Dam)
- A few days of evaporation from Lake Mead

Furthermore, it may not be possible for Yuma Area Office Water Operations staff to forecast the year-end salinity differential to an accurate enough degree in order to adjust the annual volume of groundwater directed to the river (or bypassed) within a level of accuracy of a few thousand acre-feet. The RiverWare Salinity Projection Model, or rather the accuracy of the forecasted data regarding uncontrolled sources below Imperial Dam, unmeasured flows, and the salt concentration of water arriving at Imperial Dam, is simply not accurate enough to forecast the salinity differential to the degree of accuracy needed to determine the annual volume of groundwater that could be directed to the river within a few thousand acre-feet.

Over the past 10 years, the minimum, maximum, and average historical, cumulative annual salinity differentials are 123 ppm, 143 ppm, and 133 ppm, respectively. Modeling has shown that approximately 1,000 to 1,500 acre-feet of additional groundwater added to the river from either the DPOC's or the Yuma Mesa Conduit increases the cumulative annual salinity differential by about 1 ppm. Therefore, using this approximation, and given the minimum, maximum, and annual cumulative annual salinity differentials over the past 15 years (excluding 2005), the amount of additional groundwater that theoretically could have been added to the river to bring the salinity differential to 145 ppm can be estimated as shown in the table below. This does not imply that the operator should have or could have operated this way for reasons explained above; rather, it gives perspective on the variation in groundwater directed to the river or bypassed due to operational uncertainty. This can be compared with the impact estimated by the Paradox Valley EIS analysis.

**Table 1: Minimum, Maximum, and Average Historical Salinity Differential 2008 – 2017**

| Differential | Historical Cumulative Annual Salinity Differential (ppm) | Difference from 145 ppm Limit (ppm) | Additional Groundwater to Reach 145 ppm Limit* (acre-feet) |
|---|---|---|---|
| Minimum Differential | 127 ppm | 18 ppm | 18,000 – 27,000 |
| Maximum Differential | 143 ppm | 2 ppm | 2,000 – 3,000 |
| Average Differential | 135 ppm | 10 ppm | 10,000 – 15,000 |

*Note that this is a theoretical estimate based on an approximation of 1,000 to 1,500 acre-feet of groundwater added to the river increasing the cumulative annual salinity differential by 1 ppm.

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# Appendix I

## Biological Evaluation Report

RECLAMATION
Managing Water in the West

# Paradox Valley Unit of the Colorado River Basin Salinity Control Program

# Biological Evaluation Report

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Western Colorado Area Office
Grand Junction, Colorado

August 2019
Updated March 2020

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ATTACHMENTS

Attachment A – Photo Log

Attachment B – CPW Species Activity Area Definitions

Attachment C – Maps

Attachment D – BLM Sensitive Species List

Attachment E – FWS IPaC Report

Attachment F – eBird Bird Observation Species List

Attachment G – Avian Knowledge Network Species Report

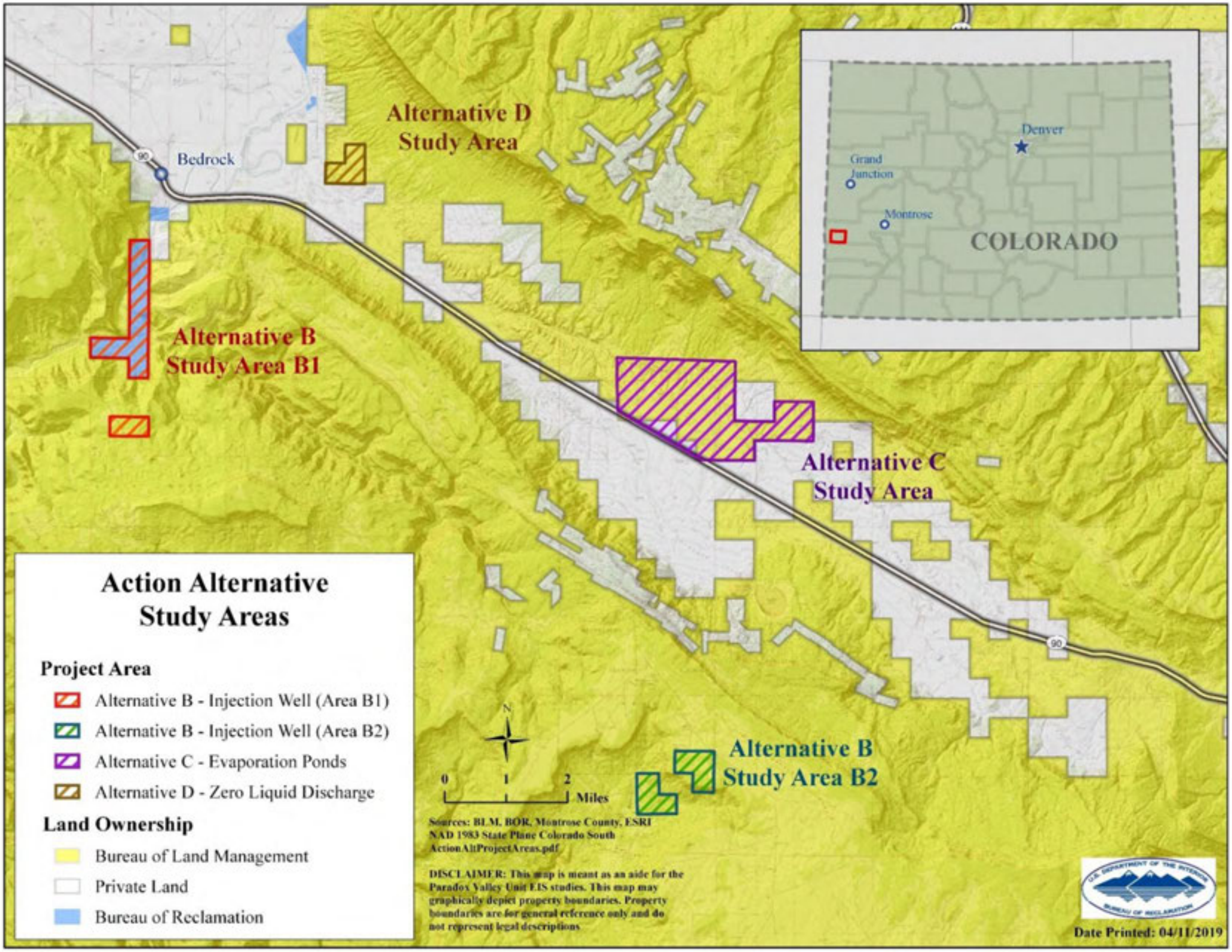
# Introduction

The United States Department of the Interior, Bureau of Reclamation (Reclamation), is in the process of preparing an Environmental Impact Statement (EIS) to analyze the impacts of continuing to construct, operate, and maintain the Paradox Valley Unit (PVU) facilities to control saline groundwater in the Paradox Valley, which is in western Montrose County, Colorado (**Figure 1**). The need for the proposed action is to control salinity in the Colorado River contributed by upstream water from the Dolores River. The PVU has injected naturally-occurring brine from the Paradox Valley since 1996, but the injection well may be nearing the end of its useful life. As the injection pressure increases and brine disposal rates are further reduced, a new brine control and disposal facility is needed to continue to enhance and protect the quality of water available in the Colorado River for use in the United States and the Republic of Mexico, and to enable the United States to comply with its obligations under the Agreement with Mexico of August 30, 1973. The Paradox Valley was specifically identified as an important area to locate salinity control facilities because it overlies a salt anticline, which is a major contributor of salinity in the Colorado River Basin. The naturally occurring salt is picked up by groundwater flowing toward the Dolores River from the nearby La Sal Mountains. The brine groundwater discharges into the Dolores River in the Paradox Valley, and eventually into the Colorado River.

The EIS assesses the potential environmental impacts of four alternatives under consideration: No Action Alternative (Alternative A) and three Action Alternatives (Alternatives B [Area B1 & Area B2], C, and D). Each alternative is briefly summarized below (**Figure 1**).

- Alternative A, No Action, represents no salinity control in the Paradox Valley. The existing deep injection well would not be replaced once the current well is no longer operational.
- Alternative B (Injection Well) involves drilling a second injection well for brine disposal. Two sites (Areas B1 and B2) are analyzed as potential locations for a new injection well: One primarily on Reclamation land near the existing injection well (Area B1; and one on Bureau of Land Management (BLM)-administered land on Monogram Mesa (Area B2).
- Alternative C (Evaporation Ponds) involves the construction of a series of evaporation ponds to evaporate the water from the brine and disposing the salt in an on-site landfill.
- Alternative D (Zero Liquid Discharge [ZLD]) creates a centralized treatment plant consisting of a series of thermally-driven crystallizers that evaporate water from the brine. The salt would be disposed in an on-site landfill.

*Figure 1: Location map and EIS study areas.*



This evaluation was prepared to serve as supporting documentation for the biological components of the PVU EIS and determine what information and species (both plants and animals) should be carried forward for analysis. The list of fish and wildlife species analyzed in the EIS is not intended to be exhaustive. In many cases, species may be present but not specifically identified because these species are abundant and widespread (e.g. rodents, coyotes, house finches, etc.). Focal species and groups based on their economic value, regulatory status, high public interest, or other qualities are evaluated. Species protected under the Federal Endangered Species Act (ESA), sensitive species identified by Federal land management agencies, and species managed as game species by the Colorado Parks and Wildlife (CPW) constitute the several categories of species used as focal species. Furthermore, fish and wildlife focal species may be placed in groups (e.g. reptiles) or sub-groups (e.g. birds - waterfowl), with representative species identified, since effects to species within a particular group or sub-group would be similar.

To complete the evaluation, a list of threatened, endangered, proposed, and candidate species was acquired from the U.S. Fish and Wildlife Service (FWS) through the Information for Planning and Consultation (IPaC) online environmental conservation system, staff from FWS, BLM, and CPW were consulted, literature, documents, and Geographic Information Systems (GIS) data resources reviewed, and field visits were conducted. Site-specific surveys were not performed. In March of 2020, the information in this evaluation was reviewed and updated, as appropriate. The IPaC list from FWS was updated in Attachment E. CPW updated GIS data in October of 2019. Information about peregrine falcons was edited in Table 3 and in Attachment C Map 10, to capture changes in CPW GIS data, since the GIS updates resulted in changes in the way this species was described in the EIS.

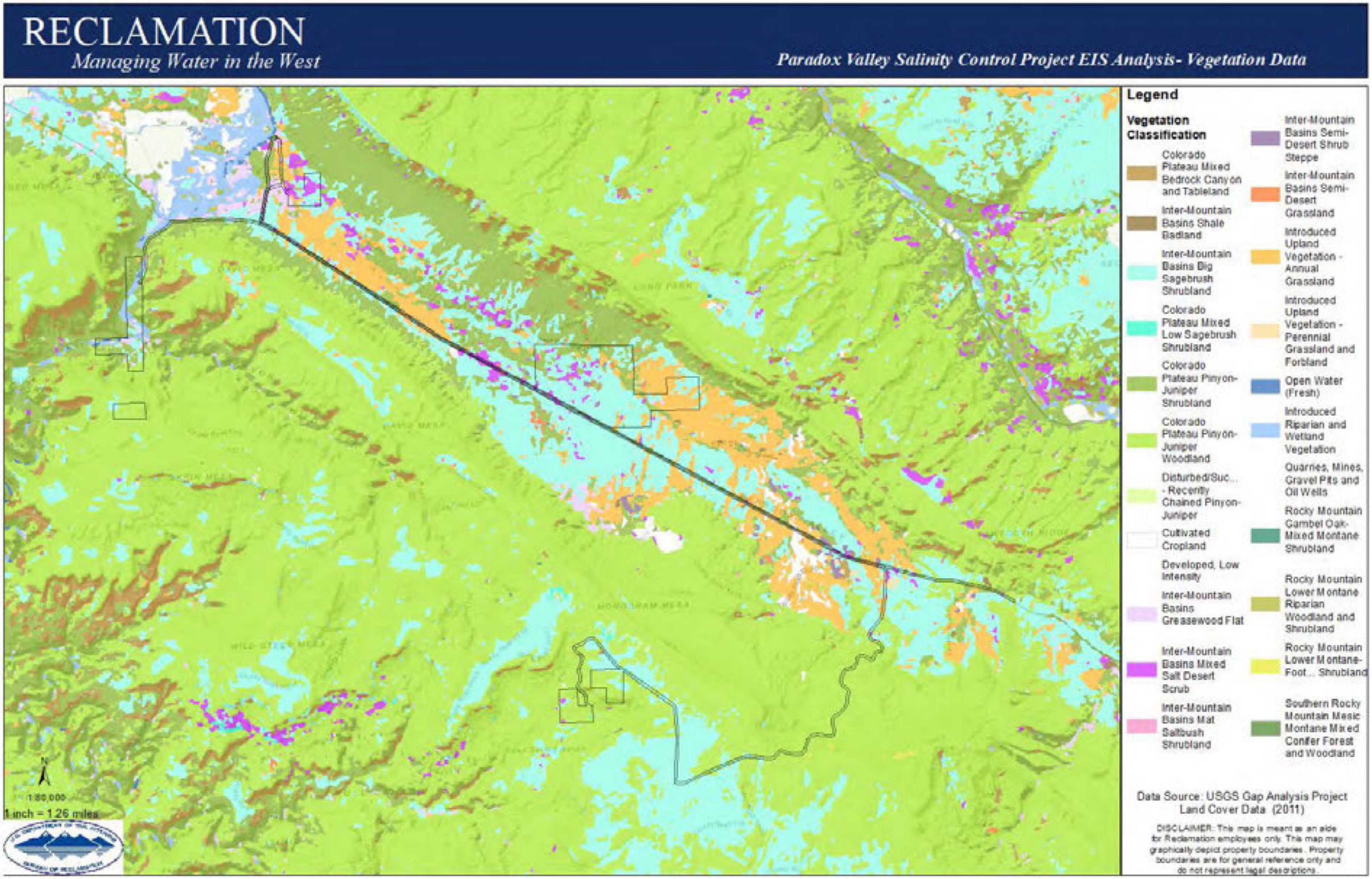
# Landscape Setting

The general project geographic setting is the Paradox Valley and adjacent areas within southwest Colorado. The area lies in the Colorado Plateau physiographic province and has an arid continental climate. The Colorado Plateaus ecoregion is characterized by a rugged tableland of mesas, plateaus, mountains, and canyons, often with abrupt changes in local relief (Chapman et al. 2006). Over the last ten years, temperatures for Paradox, Colorado have ranged from -15°F to 106°F for the lows and highs and annual precipitation ranged from 6 to 17.6 inches (ACIS, 2018). Elevations range from 4,950 to 6,994 feet. Land ownership in the area consists of lands managed by the BLM, privately-owned lands, and Reclamation land. Land use is primarily livestock grazing and recreation on BLM managed lands and residential and cultivated crops on private lands. Current and historic mining activity is prevalent in the area.

## Vegetation and Habitat

Vegetation composition is a result of the combination of geography, soils, and climate. Vegetation serves a variety of beneficial functions, such as providing habitat and food for animals, stabilizing soils, and providing products for human uses. The U.S. Geological Survey's (USGS) Gap Analysis Project (GAP) modeled terrestrial landcover and vegetation types using soil type, elevation, aerial imagery, and locality (Lowry et al. 2007). This information was used to determine the types of vegetation in the area (**Figure 2**).

*Figure 2 Vegetation classification map*



The vegetation communities found within each of the EIS alternatives were categorized into dominant habitat types based on the description of features and plants predominantly present within the vegetation communities. Habitats are defined as the specific spaces that fish and wildlife species occupy. Understanding which habitats are present helps in determining which species should be considered in the EIS analysis. **Table 1** summarizes the vegetation classification and corresponding habitat type found within each of the EIS alternative areas.

***Table 1. Vegetation classification and habitat type within EIS analysis area***

| Vegetation Classification | Vegetation Classification Description | Habitat Type | Approximate Acres[1] Within Alternative | | | |
|---|---|---|---|---|---|---|
| | | | B1[2] | B2[2] | C | D |
| Colorado Plateau Mixed Bedrock Canyon and Tableland | Typically barren and sparsely vegetated steep cliff faces, narrow canyons, and open tablelands predominantly composed of sedimentary rocks, such as sandstone, shale, and limestone. Plant cover is generally less than 10%. Composed of open coniferous tree canopy or scattered trees and shrubs. | Cliff & rocky outcrops | - | 5 | 16 | - |
| Inter-Mountain Basins Shale Badland | Typically occurs on rounded hills and plains. Consists of barren and sparsely vegetated areas (<10% plant cover) with high rate of erosion and deposition. Vegetation consists of sparse dwarf shrubs and herbaceous plants. | Cliff & rocky outcrops | - | 1 | - | - |
| Colorado Plateau Mixed Low Sagebrush Shrubland | Occurs in canyons, draws, hilltops, and dry flats. Consists of open shrubland and steppe habitats. Black sagebrush (*Artemisia nova*) or Bigelow sage (*A. bigelovii*) are the dominant species, with Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) co-dominant in some areas. Semiarid grasses are often present and may exceed 25% cover. | Sagebrush | - | 1 | - | - |
| Inter-Mountain Basins Big Sagebrush Shrubland | Common within intermountain basins in the western US. Often found in areas of deep, well-drained, non-saline, clay soils between 5,000 and 7,500 feet above mean sea level (amsl). Typically dominated by dense stands of tall Artemisia species sometimes interspersed with one-seed juniper. Common plants include big sagebrush (*Artemisia tridentata*), rabbitbrush, winterfat (*Krascheninnikovia lanata*), and a variety of xeric grasses. | Sagebrush | 60 | 237 | 855 | 168 |

| Vegetation Classification | Vegetation Classification Description | Habitat Type | Approximate Acres[1] Within Alternative | | | |
|---|---|---|---|---|---|---|
| | | | B1[2] | B2[2] | C | D |
| Colorado Plateau Pinyon-Juniper Shrubland | Characteristic of rocky slopes of the Colorado Plateau and western Colorado. Forms extensive, open shrublands dominated by dwarfed pinion pine (*Pinus edulis*) and one-seed juniper (*Juniperus osteosperma*). Other common species include sagebrush (*Artemisia* spp.), rabbitbrush (*Ericameria* spp.), blackbrush (*Coleogyne ramosissima*), and a variety of xeric grasses. | Pinyon-juniper | 171 | 79 | 281 | 104 |
| Colorado Plateau Pinyon-Juniper Woodland | Similar to a Colorado Plateau Pinyon-Juniper Shrubland, but with taller pinion pines and junipers. Occurs on dry mountain slopes, mesas, plateaus, and ridges with rocky soils. | | 114 | 369 | 2 | 20 |
| Cultivated Cropland | Areas where more than 20% of the total vegetation cover consists of pasture/hay or cultivated crops. | Agriculture | - | 7 | - | 4 |
| Inter-Mountain Basins Greasewood Flat | Found throughout the western US within intermountain basins and in the Great Plains. Typically found alongside drainages or on playas, with saline soils, a shallow water table, and an intermittent flooding regime. Common plants include greasewood (*Sarcobatus* spp., saltbush (*Atriplex* spp.), rabbitbrush (*Ericameria* spp.), cholla (*Cylindropuntia* spp.), winterfat (*Krascheninnikovia* spp.), and alkali sacaton (*Sporobolus airoides*). | Desert Shrubland | 27 | 10 | 22 | 25 |
| Inter-Mountain Basins Mixed Salt Desert Scrub | Characterized by open-canopy shrublands within saline basins, alluvial slopes, or plains, typically on saline soils. The shrublands are typically dense and dominated by various species of saltbush. Other common species include sagebrush, rabbitbush, ephedra (Ephedra spp.), and a variety of grasses. | | - | 41 | 105 | 92 |
| Inter-Mountain Basins Semi-Desert Shrub Steppe | Characterized by perennial grasses with an open shrub and dwarf shrub layer. | | - | 2 | 13 | 5 |

| Vegetation Classification | Vegetation Classification Description | Habitat Type | Approximate Acres[1] Within Alternative | | | |
|---|---|---|---|---|---|---|
| | | | B1[2] | B2[2] | C | D |
| Inter-Mountain Basins Semi-Desert Grassland | Common in the Western US, occurring on dry plains or mesas. Often occupy xeric swales, playas, plateaus, plains, or alluvial flats with well drained soils. Common grasses include Indian ricegrass (*Achnatherum hymenoides*), three-awn grass (*Aristida* spp.), blue gramma (*Bouteloua gracilis*), needle and thread (*Hesperostipa comate*), muhly grass (*Muhlenbergia* spp.), and James' galleta (*Pleuraphis jamesii*). | Arid grassland | - | 1 | 7 | 1 |
| Introduced Upland Vegetation - Annual Grassland | Dominated by non-native annual grass species. | | 2 | 51 | 224 | 63 |
| Introduced Upland Vegetation - Perennial Grassland and Forbland | Dominated by non-native perennial grass and forb species. | | - | 5 | - | - |
| Introduced Riparian and Wetland Vegetation | Vegetation dominated (typically >60% canopy cover) by introduced species. These are spontaneous, self-perpetuating, and not (immediately) the result of planting, cultivation, or human maintenance. Land occupied by introduced vegetation is generally permanently altered (converted) unless restoration efforts are undertaken. Specifically, land cover is significantly altered/disturbed by introduced riparian and wetland vegetation. | Riparian | 53 | <1 | 6 | - |
| Open Water (Fresh) | | Aquatic | 10 | - | - | - |
| Quarries, Mines, Gravel Pits, and Oil Wells | Areas with open-pit mines and quarries | - | - | 4 | 2 | 3 |

[1]Acreages rounded
[2]Acres for seismic survey area not included.

## Site Condition

The health of the vegetation community and the quality of habitat is determined by a site's condition. Multiple factors can degrade site conditions, such as noxious weeds (a.k.a. undesirable, exotic, and invasive species) and landscape disturbances, thereby decreasing native vegetation and habitat use. Field visits were conducted, and aerial photography was used to assess general site conditions at each of the alternative locations. Surveys and inventories were not conducted. General observations and assessments are discussed below. Site photographs were taken and are attached in (Attachment A. Any required vegetation surveys or inventories would be completed after a preferred alternative is selected. Vegetation observed during the field visits largely reflect the modeled vegetation classification descriptions discussed above. All areas are subjected to livestock grazing.

Alternative B1 Area

The Alternative B1 area (predominantly Reclamation land) is a low-lying area surrounded by sandstone cliffs. The area has little disturbance other than the existing injection well facility. Remnants of an old road continuing from the existing injection well towards the south are visible. The existing injection well site is graveled and devoid of vegetation other than shrub species (Photo 1). Vegetation on the flat uplands in the southern portion of Reclamation land tended to be primarily shrubs consisting of sagebrush, greasewood (*Sarcobatus vermiculatus*), prickly pear (*Opuntia spp*.), shadscale (*Atriplex confertifolia*), and xeric bunchgrasses (Photos 2 & 3). The Dolores River supports a sometimes narrow riparian floodplain (Photos 4 & 5). Native vegetation found along the river corridor and floodplain consists of coyote willow (*salix exigua*), desert olive privet (*Forestiera pubescens*), isolated cottonwoods (*Populus* spp.), salt grass (*Distichlis spicata*), rabbit brush (*Ericameria nauseosa*), Indian paintbrush (*Castilleja chromosa*), fishhook cactus (*Mammillaria dioica*), and sagebrush. Noxious weeds found along the river includes decadent tamarisk (*Tamarix* spp.), Russian knapweed (*Rhaponticum repens*), and hoary cress (*Cardaria draba*). The hillsides are dominated by pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) trees, with sparse understory primarily consisting of sagebrush (*Artemisia* spp.) and xeric bunchgrasses (Photo 6). The vegetation on Skein Mesa (BLM-administered land) above Reclamation land primarily consists of pinyon and juniper trees and sagebrush (Photo 7). Fragmentation from roads is apparent on Skein Mesa.

Alternative B2 Area

The Alternative B2 location on Monogram Mesa and Fawn Springs Bench is dominated by pinyon and juniper trees and sagebrush with scant understory (Photo 8). The area is disturbed from mining-related activities and fragmented by utilities and roads (Photos 9 & 10). The pipeline and utility line would primarily be routed along Colorado Highway 90, County Roads, Y11, EE21, and DD19. The vegetation along these travel routes is somewhat degraded from past disturbances and ongoing road maintenance. The GAP modeling data indicated a small amount of riparian vegetation existed along East Paradox Creek, near County Road Y11, where the brine pipeline would cross. Field investigations revealed a lack of riparian vegetation at this location other than tamarisk trees (Photos 11 & 12).

Alternative C Area

The evaporation pond (Alternative C) location in the Paradox Valley varies in topographic relief and vegetation composition. West of the East Paradox Creek (ephemeral drainage) and close to Highway 90 the land is relatively flat with sagebrush dominating the vegetation (Photo 13). Steep narrow drainages develop closer to East Paradox Creek. The East Paradox Creek is heavily incised in certain locations, and lacks riparian vegetation (Photo 14). The drainages support isolated occurrences of pinyon and juniper trees and rabbitbrush. East of East Paradox Creek the vegetation becomes sparse herbaceous vegetation, before transitioning into pinyon and juniper trees on the ridges (Photo 15).

Alternative D Area

Vegetation generally noted on the hillsides at the Alternative D (ZLD) location consisted predominantly of xeric bunch grasses, mat saltbush (*Atriplex corrugata*), greasewood, prickly pear cactus (*Opuntia sp.*), snakeweed (*Gutierrezia* spp.), sagebrush, and limited scattered junipers (Photos 16). Little disturbance is visible. A private residence is located south of the site.

# Fish and Wildlife Species

CPW and FWS have primary responsibilities for management of fish and wildlife species in the project area. Generally, CPW is responsible for managing wildlife, with an emphasis on sport and game species, while the FWS oversees migratory birds, eagles, and Federally threatened, endangered, proposed, or candidate species along with their proposed or designated critical habitats. Federally listed species are protected under the Endangered Species Act (ESA), migratory birds are protected under the Migratory Bird Treaty Act (MBTA), and eagles are protected under MBTA and the Bald and Golden Eagle Protection Act. On BLM-administered lands, the BLM is directly responsible for the management of habitat for fish and wildlife species and indirectly responsible for the health of fish and wildlife populations that are supported by these habitats. However, BLM has identified sensitive species, which are native species, and for which BLM has the capability to significantly affect the conservation of the species through land management decisions.

## Colorado Parks and Wildlife

One of CPW's primary goals is managing sustainable fish and wildlife populations to support fishing, hunting, and wildlife-viewing opportunities. CPW issues hunting and fishing licenses which allow for harvesting (killing) of specific species according to established laws and detailed regulations. License fees are one of the primary funding mechanisms for the agency. Primarily sport fish and big game animals (e.g. bighorn sheep, deer, elk, bear, pronghorn, mountain lion) have high public interest and recreational and economic value. Therefore, the presence and impacts to these species and their habitats should be carried forward in the EIS analysis.

### Fish

The Dolores River is the only fish habitat within any of the EIS alternative study areas. The segment of the Dolores River from the Big Gypsum Valley Bridge to the town of Bedrock, Colorado (referred to as Slickrock Canyon) is ~35 miles in length and is actively managed for native fish. This segment of river is an entrenched channel with few backwaters or complex habitat features. CPW conducted fish surveys in 2017. Native fish comprised 95% of the fish captured, making this segment of river the most intact native fishery in the Colorado River Basin. Three fish (flannelmouth sucker [*Catostomus latipinnis*], roundtail chub [*Gila robusta*], and bluehead sucker [*Catostomus discobolus*]) comprised 88% of the total catch. However, the relative abundance of the 3 fish species was low (16 fish per mile) compared to surveys done below the San Miguel River confluence (13-28 fish per mile). (CPW 2017).

The Dolores River, from the town of Bedrock, Colorado to the San Miguel River confluence (~12 miles in length) is not actively monitored. This section of river is affected by flow depletions during the late summer and fall and natural salt loading. Even with salinity control efforts conducted by Reclamation, high salinity concentrations are identified as a constituent of concern affecting the vitality of the native fishery in this segment of river and potentially creating a barrier that minimizes fish movement between the Dolores River below the San Miguel confluence and Slickrock Canyon (Lower Dolores River Working Group, 2014).

## Big Game

CPW has mapped areas of use for big game animals. Using CPW's species activity GIS mapping, a list of big game animals and their activity areas was generated for the EIS analysis. **Table 2** summarizes the species and the activity area(s) overlapped by each EIS alternative, and should, therefore, be addressed in the EIS analysis. Mapped sensitive activity areas, such as severe winter ranges or concentration areas, and production areas, are of interest for EIS analysis purposes due to the limited quantity and/or the sensitivity of these areas to disturbance.

***Table 2 CPW species activity mapping summary***

| Species | Activity Area[2] | Acreage Mapped Within Alternative Study Area[1] | | | |
|---|---|---|---|---|---|
| | | B (Area B1)[3] | B (Area B2)[3] | C | D |
| (Desert) Bighorn Sheep[4] (see Attachment C, map 1[5]) | Summer Range | 410 | 372 | 96* | 45* |
| | Production Area | 123 | - | - | - |
| | Water Source | 357 | - | - | 45* |
| | Winter Range | 410 | 372 | 97* | 47* |
| | Overall Range | 410 | 372 | 97* | 47* |
| Black Bear (see Attachment C, map 2) | Overall Range | 440 | 810 | 1,530 | 480 |
| Elk (see Attachment C, map 3[5]) | Resident Population | - | 40* | 86* | 71* |
| | Severe Winter Range | 91 | 810 | 1,518 | 480 |
| | Winter Concentration | - | 56* | 70* | 165 |
| | Winter Range | 90 | 810 | 1,518 | 480 |
| | Overall Range | 90 | 810 | 1,518 | 480 |
| Mountain Lion (see Attachment C map 4) | Overall Range | 440 | 810 | 1,530 | 480 |
| Mule Deer (see Attachment C map 5[5]) | Summer Range | - | 16* | 16* | 4* |
| | Severe Winter Range | 284 | 464 | 1,530 | 480 |
| | Winter Concentration | - | 91* | 535 | 223 |
| | Winter Range | 440 | 810 | 1,530 | 480 |
| | Overall Range | 440 | 810 | 1,530 | 480 |
| Pronghorn (see Attachment C map 6) | Resident Population | - | 22 | - | - |
| | Overall Range | - | 22 | - | - |

[1] Acreages rounded.
[2]Definitions of the activity areas are included in Attachment B
[3] Acres for seismic survey area not included.
[4] This is a BLM sensitive species and identified again in **Table 3**.
[5] Not all activity areas are clearly visible on map due to overlap with others.
* Habitat impacts would be from underground pipeline/utility corridors, which would be temporary (during construction) and short-term (areas would be revegetated).

### *Big Game Species Status and Management Objectives*

CPW relies on accurate and up-to-date herd management plans to make important decisions about hunting quotas and other management priorities for big game populations. CPW manages big game populations (i.e. bighorn sheep, bear, deer, elk, mountain lion, pronghorn), through the issuance of hunting licenses, to achieve population and sex ratio objectives. CPW establishes a Data Analysis Unit (DAU) for each species. A DAU is the geographic area that represents the year-round range of a big game herd and includes all the seasonal ranges (i.e. summer range, winter range, etc.) of the specific herd. A DAU plan is an integrated plan, involving CPW, land management agencies, and interested public, developed to balance the biological capabilities of the herd and its habitat with the public's demand for wildlife recreational opportunities. These plans are written about every 10 years. The population status and the management objectives for each of the big game species within the EIS analysis area based on the DAU plans and personnel communications with CPW biologists is summarized below.

<u>Desert Bighorn Sheep</u>: Desert bighorn sheep were first introduced to Colorado in 1979. CPW has conducted transplant operations and as a result, Colorado has three herds established. The herd that overlaps the EIS analysis area is referred to as the Dolores River DAU. The Dolores River DAU is situated along the Dolores River and encompasses almost 776,500 acres in parts of Montezuma, Montrose, San Miguel, and Dolores Counties. As of 2017, the population within the Dolores DAU was estimated at 175, with a statewide desert bighorn sheep population estimate of 540. Most of the desert bighorn sheep range occurs on BLM-managed lands. The desert bighorn sheep is designated as a BLM sensitive species. A limiting factor to this herd is mountain lion predation. Within the DAU, 20% is mapped winter range. Severe winter range and winter concentration areas makes up only 4% of the DAU; production areas make up 7%. Severe winter range and winter concentration areas are in the southern portion of the DAU. CPW is managing the desert bighorn sheep population for inventory, habitat protection and improvement, disease prevention, and research. The Dolores River DAU has the greatest potential for increased numbers. To increase the herd size, additional transplants and mountain lion control would be needed. (CPW 2009; CPW 2013)

<u>Bear:</u> – The bear DAU that is overlapped by the EIS analysis area is called B-5. It encompasses almost 3.7 million acres and includes Montrose and Ouray counties and parts of Delta, Gunnison, Hinsdale, Mesa, and San Miguel Counties. Almost 100% of the land in the DAU is mapped as overall range with 19% of the DAU classified as summer range and 25% mapped as primary habitat. Habitat use by black bears in B-5 primarily depends on the season and available forage. Most black bears appear to use the lower elevation pinyon-juniper habitats only in early spring and late fall as they are free of snow and have juniper berry or pinyon nut crops. Primarily, black bears in the DAU use higher elevation mountain shrub and aspen communities throughout the summer and fall as they have the most abundant and highest quality forage. However, there is higher than expected use of low elevation riparian areas by bears when berries are plentiful. The DAU represents some of the best bear habitat in the state, with abundant mountain shrub and aspen communities at the higher elevations. B-5 include a large amount of high-quality bear habitat on public land, allowing for significant opportunity to hunt bears. Most of the bears harvested are on the Uncompahgre Plateau. The bear population in B-5 is estimated to be 2,303. CPW is managing for a stable population based on habitat availability, human and agricultural conflict potential, and input received from the public. (CPW 2011)

<u>Elk</u>: The DAU that overlaps the EIS analysis area is referred to as the Disappointment Creek elk herd (E-24). The DAU encompasses 3.2 million acres in Dolores, Montezuma, Montrose, and San Miguel Counties. Elk generally occupy the entire DAU but occur at highest densities in the central montane areas comprised of pinyon-juniper, mountain shrub, ponderosa pine, aspen, spruce and fir. A lower density of elk are observed in the low desert and canyon areas.

Elk movement to winter range is usually initiated by increasing snow cover and decreasing forage availability, along with hunting pressure. This movement generally begins in late October and continues into December. The movement is elevational and generally to the west and to the north. Wintering concentrations of elk are usually found in Dry Creek Basin, Disappointment Valley, and southwest of

McPhee Reservoir and the Dolores River. In most winters, elk are fairly concentrated in these relatively large areas. Elk movement back to summer range usually follows the snowline and vegetation green-up, and in the summer and fall elk are distributed throughout the northeastern two-thirds of the DAU.

There is an abundance of public land in this DAU, with over half of the DAU under Federal or State management. In addition, over two-thirds of winter range, winter concentration areas, and severe winter range are on public lands. Public land management plays a crucial role in elk population and elk habitat management. A moderate proportion of the DAU is winter range (36%) and most (67%) of that is on public lands. A much smaller proportion of the DAU is severe winter range for elk (21%), and 71% of that is on public lands. Winter range is abundant in the DAU, but severe winter range is less widespread, and is mostly located in the Disappointment Valley and Dry Creek Basin areas. Although the bulk of the DAU is public land, the one-third of the unit that is privately owned provides a significant portion of the winter, severe winter ranges, and winter concentration areas.

The Disappointment Creek elk herd is an important resource which has an economic value to the State of Colorado of over 8 million dollars annually, to the local economy of over 4 million dollars annually, and provides hunting opportunities to over 12,000 hunters. In addition, it provides a watchable wildlife experience to many citizens, not only from Colorado, but nationwide. Management objectives for the Disappointment Creek herd include maintaining the population at a slightly reduced level from 2004 population estimates. The 2004 estimated population was 18,250. The management objective for this DAU is 16,000-18,000. CPW acknowledges the need to improve distribution. There are certain areas heavily impacted by elk on both public and private lands. The BLM preferred a reduced population level of 14,000 to 16,000 based on an observational inventory that the forage base is being fully utilized by wild and domestic ungulates. (CPW 2006)

<u>Mountain Lion</u>: The Dolores-Norwood Puma DAU (L-23) is in southwest Colorado, and includes most of San Miguel and Dolores Counties as well as parts of Montezuma and Montrose Counties. According to the 2004 management plan, CPW is managing for a stable or increasing population. Game damage problems or increasing human-lion encounters have not been an issue; therefore, population suppression was determined unwarranted. (CPW 2004)

<u>Mule Deer</u>: The mule deer herd that overlaps the EIS analysis area is referred to as the Groundhog mule deer DAU (D-24) and includes portions of Dolores, Montezuma, Montrose, and San Miguel Counties. It encompasses 1.8 million acres, of which 70% is located on public lands. Deer generally occupy the entire DAU but occur at highest densities in the central portions comprised of sagebrush, pinyon-juniper, mountain shrub, ponderosa pine, and aspen. A lower density of deer is observed in the low desert and canyon area as well as the higher heavily forested area. Deer movement to winter range generally begins in late October and continues into December. The movement is elevational and generally east to west. High concentrations of wintering deer are found in Dry Creek Basin, Disappointment Valley, and south of McPhee Reservoir and the Dolores River. In most winters, deer are fairly concentrated in these relatively large areas. Deer movement back to summer range usually follows the snowline, and in the summer and fall deer are distributed throughout the DAU.

The most significant issue concerning this herd is the decrease in population. The 2012 post-hunt population estimate was 14,500. The Groundhog mule deer DAU has been experiencing a decline over the past several decades. The current estimated population is less than half of what was estimated 30 years ago. Mule deer populations overall have experienced similar decreases. There hasn't been any factor pinpointed for the decline and it is most likely caused from a combination of reasons related to habitat availability and condition. Winter range is a limited habitat resource and can be considered the limiting factor for the Groundhog mule deer herd. Winter range is also the least protected habitat in the DAU specifically as it is related to human disturbance from rural development and recreation, overgrazing, and drought.

The area has experienced years of extreme drought over the past decade. There have been noticeable impacts to forage species on winter range with long lasting effects on individual plants. Extreme drought can have the same negative impact to a deer population as severe winter. Over the past decade there have also been winters with increased snow accumulation on winter range. Forage is less available, deer are restricted in distances they can move, and there is an increase energy demand on animals. The overall effect is a decrease in deer body condition and increased mortality.

Invasive vegetation is also an element that degrades habitat. These plants are introduced, usually unintentionally, and can outcompete native vegetation for nutrients, sunlight, and water. This causes a change to the landscape. A couple invasive species that are abundant throughout the lower elevations of the management area are cheatgrass (*Bromus tectorum*) and Russian knapweed (*Acroptilon repens*). These species have little or no value as a food source for deer.

Within the DAU, 55% is mapped winter range. Winter range is at the lower elevations within the western portions of the DAU. Severe winter range makes up 24% and winter concentration areas make up approximately 16% of the DAU. Deer winter concentrations during normal winters are found in Dry Creek Basin and along Disappointment Creek, and north of the Dolores Canyon. Quality sagebrush and mountain shrub winter forage are even more limited than acreages of winter range. The highest protein content and vertical structure created by these shrubs are invaluable when snow is deep. (CPW 2014)

Pronghorn: The pronghorn herd that overlaps the EIS analysis area does not have a DAU plan. CPW has transplanted pronghorn into the herd since the 1960s, but transplants stopped in the early 1990s. The population is estimated to be 50, with levels remaining stagnant. The herd resides primarily in Dry Creek Basin. (Personal communication, Banulis, 2019)

## BLM Sensitive Species

As previously mentioned, BLM does not actively manage species, but manages the land and habitat upon which they depend. Species designated as BLM sensitive are native species found on BLM-administered lands for which the BLM has the capability to significantly affect the conservation status of the species through land management and either:

1. There is information that a species has recently undergone, is undergoing, or is predicted to undergo a downward trend such that the viability of the species or a distinct population segment of the species is at risk across all or a significant portion of the species range, or

2. The species depends on ecological refugia or specialized or unique habitats on BLM-administered lands, and there is evidence that such areas are threatened with alteration such that the continued viability of the species in that area would be at risk.

All Federal candidate species, proposed species, and delisted species in the five years following delisting are considered BLM sensitive species. BLM sensitive species may also include Colorado State endangered and threatened species, and species of conservation concern (BLM 2008).

The objectives of the BLM special status species policy are to conserve and/or recover Federally-listed species and the habitats on which they depend so Federal protections are no longer needed and to proactively implement conservation measures that reduce or eliminate threats to sensitive species to minimize the likelihood of and need for Federal protection (BLM 2008).

The EIS alternative study areas cross and/or occur on BLM managed land. Given BLM's management considerations for these species, they should be carried forward in the EIS analysis. To determine which BLM sensitive species should be evaluated in the EIS, a sensitive species list was obtained (Attachment D), existing documents and literature reviews were conducted, CPW and BLM GIS databases were utilized, and discussions with BLM and CPW staff occurred. **Table 3** summarizes the BLM sensitive species for the BLM Tres Rios and Uncompahgre Field Offices, their suitable habitats, and their likelihood to occur or occurrence information in relation to the EIS alternatives.

***Table 3 BLM Sensitive Species for the Uncompahgre and Tres Rios Field Offices***

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| *FISH*[2] | | | |
| Bluehead sucker *Catostomus discobolus* | Large rivers and mountain streams, rarely in lakes; variable, from cold, clear mountain streams to warm, turbid streams; moderate to fast flowing water above rubble-rock substrate; young prefer quiet shallow areas near shoreline | X | This species is present in the Dolores River (CPW 2017). |
| Flannelmouth sucker *Catostomus latipinnis* | Warm moderate- to large-sized rivers, seldom in small creeks, absent from impoundments; pools and deeper runs often near tributary mouths; also riffles and backwaters; young usually in shallower water than are adults. | X | This species is present in the Dolores River (CPW 2017). |
| Roundtail chub *Gila robusta* | Warm-water rocky runs, rapids, and pools of creeks and small to large rivers; also large reservoirs in the upper Colorado River system; generally prefers cobble-rubble, sand-cobble, or sand-gravel substrate | X | This species is present in the Dolores River (CPW 2017). |
| Colorado River cutthroat trout *Oncorhynchus clarki pleuriticus* | Cool, clear streams or lakes with well-vegetated streambanks for shading cover and bank stability; deep pools, boulders, and logs; thrives at high elevations | - | Occurs in high-elevation, cold-water streams and lakes. Isolated populations occur and are restricted to mid- to high-elevation tributaries of the Dolores River (BLM 2016). The area lacks suitable habitat; therefore, this species is dismissed from inclusion in the EIS analysis. |
| *MAMMALS*[3] | | | |
| Rocky Mountain Bighorn *Ovis canadensis* | Steep, mountainous or hilly terrain dominated by grass, low shrubs, rock cover, and areas near open escape and cliff retreats. | - | The area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis (CPW 2009). |
| Desert bighorn sheep *Ovis canadensis nelsoni* | Steep, mountainous or hilly terrain dominated by grass, low shrubs, rock cover, and areas near open escape and cliff retreats. | X | The area, within known range of this species. Concentrated along the Dolores River corridor and canyons (CPW 2009). |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| White-tailed prairie dog *Cynomys leucurus* | Level to gently sloping open plant communities with well-drained soils. Primarily xeric habitats at relatively lower elevations (3700' – 8500'), such as intermountain basins, open shrublands, semi-arid to arid shortgrass steppes, and agricultural lands. | - | Within Montrose County, prairie dog colonies east of the Uncompahgre Plateau are white-tailed prairie dogs, while colonies west of the plateau are Gunnison's prairie dogs (Seglund et al. 2010); therefore, the area is outside the distribution range for this species and it is dismissed from inclusion in the EIS analysis. |
| Kit fox[E] *Vulpes macrotis* | Open desert, shrubby or shrub-grass habitat. In Colorado, habitat consists of sparsely vegetated semi-desert shrublands primarily dominated by saltbrush, shadscale and greasewood. | X | According to CPW species activity mapping data, the area is not included as historic overall range. Surveys suggest that kit fox are now extirpated, or nearly so, from Colorado (Reed-Eckert 2009). However, the species does occur in eastern Utah and suitable habitat exists in the Paradox Valley. Given the proximity of the EIS analysis area to the Utah border and the lack of surveys in the Paradox Valley, the species will be identified in the EIS. |
| Gunnison's prairie dog *Cynomys gunnisoni* | Level to gently sloping open plant communities with well-drained soils. Shortgrass and mid-grass prairies, grass-shrub habitats in low valleys, and mesic high elevation sites (5000' – 12000'). | X | CPW has the area mapped within Gunnison's prairie dog range (see Attachment C map 7). Suitable habitat occurs within the EIS alternative areas. Areas within Paradox Valley are occupied. Colonies in the area are small, occur at low densities, and are widely distributed. (Seglund et al. 2010) |
| Allen's (Mexican) big-eared bat *Idionycteris phyllotis* | Ponderosa pine, pinyon-juniper woodland, oak brush, riparian woodland (cottonwood); typically found near rocky outcrops, cliffs, and boulders; often forages near streams and ponds. | X | Suitable habitat exists, and species is likely to occur in the EIS analysis area (D. Neubaum, personal communication, February 26,2018). The species has been recorded (acoustically) in Colorado in western Montrose County (Hayes et al. 2009). |
| Spotted bat *Euderma maculatum* | Desert shrub, ponderosa pine, pinyon-juniper woodland, canyon bottoms, open pasture, and hayfields; roost in crevices in cliffs with surface water nearby. | X | Suitable habitat exists in EIS analysis area (D. Neubaum, personal communication, February 26,2018). This bat is expected to exist in major canyon systems in western Montrose County. |
| Townsend's big-eared bat *Corynorhinus townsendii* | Mesic habitats including coniferous forests, deciduous forests, sagebrush steppe, juniper woodlands, and mountain; maternity roosts and hibernation in caves and mines; does not use crevices or cracks; caves, buildings, and tree cavities for night roosts. | X | CPW has documented occurrences and suitable habitat exists in EIS analysis area. (D. Neubaum, personal communication, February 26,2018). See Attachment C, map 8. |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| Fringed myotis *Myotis thysanodes* | Desert, grassland, and woodland habitats including ponderosa pine, pinyon/juniper, greasewood, saltbush, and scrub oak; roosts in caves, mines, rock crevices, and buildings. | X | CPW has documented occurrences and suitable habitat exists in EIS analysis area. (D. Neubaum, personal communication, February 26,2018). See Attachment C, map 8. |
| *BIRDS*[3] | | | |
| Bald eagle *Haliaeetus leucocephalus* | Nests in forested rivers and lakes; winters in upland areas, often with rivers or lakes nearby. Common in the lower valleys and western mesas in winter. | X | An active nest is present along the Dolores River near the town of Bedrock, CO. All the EIS alternatives overlap winter range; Alterative B2 and D overlap winter forage and winter concentration areas (see Attachment C map 9). |
| Golden eagle *Aquila chrysaetos* | Lives in open and semiopen country featuring native vegetation; generally avoid developed areas and uninterrupted stretches of forest. Found primarily in mountains up to 12,000 feet, canyonlands, rimrock terrain, and riverside cliffs and bluffs. Nest on cliffs and steep escarpments in grassland, chapparal, shrubland, forest, and other vegetated areas. | X | Potential to occur. Suitable habitat exists in project area. eBird has recorded sightings near Bedrock as recent as 2017 (eBird 2019). |
| American peregrine falcon *Falco peregrines anatum* | Open country near cliff habitat, often near water such as rivers, lakes, and marshes; nests on ledges or holes on cliff faces and crags, rarely in trees. | X | Potential to occur. Suitable habitat and potentially active nests are in or near the EIS analysis area on cliff faces along or near the Dolores River (see Attachment C map 10) (CPW 2018). |
| Northern goshawk *Accipiter gentilis* | Nests in a variety of forest types including deciduous, coniferous, and mixed forests including ponderosa pine, lodgepole pine, or in mixed-forests with fir and spruce; also nest in aspen or willow forests; migrants and wintering individuals can be observed in all coniferous forest types | X | Suitable nesting habitat is absent in the EIS analysis area. The EIS analysis area could be used for foraging or by transient migrating individuals. There have been no recorded sightings on eBird in the last four years. A single recorded sighting on eBird was in 2006 near the town of Paradox (eBird 2019). |
| Ferruginous hawk *Buteo regalis* | Open, rolling and/or rugged terrain in grasslands and shrubsteppe communities; also grasslands and cultivated fields; nests on cliffs and rocky outcrops. This species is often observed near prairie dog colonies and other rodent populations | X | Suitable habitat exists in the EIS analysis area. eBird has recorded sightings near the town of Paradox as recent as 2017 (eBird 2019). |
| Burrowing owl[T] *Athene cunicularia* | Primarily found in grasslands and mountain parks, usually in or near prairie dog towns. Also uses well-drained steppes, deserts, prairies, and agricultural lands. Require rodent burrows, typically prairie dog, for shelter and nesting. | X | Suitable habitat is present in the EIS analysis area. eBird has a recorded sighting near the town of Bedrock as recent as 2018 (eBird 2019). |
| Brewer's sparrow *Spizella berweri* | Breeds primarily in sagebrush shrublands, but also in other shrublands such as mountain mahogany or rabbitbrush; migrants seen in wooded, brushy, and weedy riparian, agricultural, and urban areas; occasionally observed in pinyon-juniper. | X | Occurs in EIS analysis area. eBird has recorded sightings in Paradox Valley, as recently as 2017 (eBird 2019). |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| Black Swift *Cypseloides niger* | Nests on bare talus or cliffs near riparian or waterbodies in mountainous regions or along coastal cliffs. Prefers dark inaccessible sites with unobstructed flights paths. Typically found behind or next to waterfalls and wet cliffs and occasionally in limestone caves. | X | No nest sites have been identified in the EIS analysis area; however, cliffs are present and during wet years suitable habitat is available. According to eBird, black swifts have been observed in the last four years near Uravan and Nucla, as recently as 2018 (eBird 2019). |
| Columbian sharp-tailed grouse *Tympanuchus phasianellus columbian* | Prefer deciduous shrub or woodland communities with native grasses and perennial forbs. In Colorado, serviceberry provides critical winter food and cover. Grasses and forbs provide nesting cover and brood-rearing habitat. Other habitat types include sagebrush, Gambel oak, and aspen. | - | Presumed extirpated (BLM 2016). Recently reintroduced to Dolores, CO (CPW 2018). EIS analysis area is outside the known range for this species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| *REPTILES AND AMPHIBIANS*[3] | | | |
| Longnose leopard lizard *Gambelia wislizenii* | Desert and semidesert areas with scattered shrubs or other low plants; e.g., sagebrush; areas with abundant rodent burrows, typically below 5,000' in elevation | X | The known distribution of the species in Colorado includes Mesa County, primarily in the Grand Valley and the Dolores River valley, and western Montezuma County. The EIS analysis area is within suitable habitat but is outside of CPW's mapped distribution and there have been no species observations along the Dolores River within Montrose and San Miguel Counties. However, the lack of observations reflects inadequate data rather than absence of the species. (Hammerson 1999) |
| Midget faded rattlesnake [5] *Crotalus viridis concolor* | Depends on rocky outcrops for refuge and hibernacula, often found near riparian zones. | X | The EIS analysis area contains suitable habitat and is within the species range. There have been documented occurrences along the Dolores and San Miguel Rivers and tributaries (BLM 2016). |
| Northern leopard frog *Rana pipiens* | Springs, slow-moving streams, marshes, bogs, ponds,<br>canals, flood plains, reservoirs, and lakes; in summer, commonly inhabits wet meadows and fields; may forage along water's edge or in nearby meadows or fields | X | The EIS analysis area contains suitable habitat and is within the species range. There are several known populations along the Dolores and San Miguel river watersheds (BLM 2016). |
| Canyon treefrog *Hyla arenicolor* | Rocky canyon bottoms along intermittent or perennial streams in temporary or permanent pools or arroyos; semi-arid grassland, pinyon-juniper, pine-oak woodland, scrubland, and montane zones. | X | The EIS analysis area contains suitable habitat and is within the species range. There are several known populations along the Dolores and San Miguel river watersheds (BLM 2016). |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| Boreal (western or mountain) toad *Anaxyrus boreas (Bufo boreas)* | Found near mountain lakes, ponds, meadows, and wetlands primarily in subalpine or conifer forests (spruce, fir, lodgepole pine, aspen); elevation 8500' – 11500'. | - | EIS analysis area is outside the range for the boreal toad and suitable habitat is absent. CPW has the nearest mapped habitat on the Grand Mesa in Mesa County and in the San Juan Mountains in Hinsdale and Mineral Counties (CPW 2018). This species is dismissed from inclusion in the EIS analysis. |
| *PLANTS*[4] | | | |
| Jones' bluestar *Amsonia jonesii* | In dry, open areas with clay, sandy, or gravelly soils, in desert-steppe, rocky gorges and canyons, associated with pinyon pine and juniper, 4400' – 5800'. | - | Occurs in Mesa and Montezuma Counties in Colorado. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Crandall's rockcress *Arabis crandallii (Boechera crandallii)* | Grows in limestone chip-rock and stony areas, often among sagebrush, ridges, and steep hill slopes; grows in more open, sometimes windswept places, 8000'-10600'. | - | Plant is concentrated in the upper Gunnison Basin in Gunnison County, Colorado (Ladyman 2005). EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Grand Junction milkvetch *Astragalus linifolius* | Sparsely vegetated habitats in pinyon-juniper and sagebrush communities, often within Chinle and Morrison Formation and selenium-bearing soils; elevation 4800' – 6200' | - | Based on current knowledge, the species is confined to the east side of the Uncompahgre Plateau. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Naturita milkvetch *Astragalus naturitenis* | Cracks and ledges of sandstone cliffs and flat bedrock area typically with shallow soils, within pinyon-juniper woodland; elevation 5400' – 6700'. | X | Potential to occur. Suitable habitat exists in EIS analysis area. |
| San Rafael milkvetch *Astragalus rafaelensis* | Banks of sandy clay gulches and hills, at the foot of sandstone outcrops, or among boulders along dry watercourses in seleniferous soils derived from shale or sandstone formations; elevation 4500'– 300'. | X | Potential to occur. Suitable habitat exists in EIS analysis area. |
| Sandstone milkvetch *Astragalus sesquiflorus* | Sandstone rock ledges (Entrada formation), domed slickrock fissures, talus under cliffs, sometimes in sandy washes; elevation 5000' – 5500'. | X | BLM has mapped occurrences in Paradox Valley. Suitable habitat exists in EIS analysis area. |
| Gypsum valley cateye *Oreocarya revealii* | Scattered gypsum outcrops and grayish-white, often lichen-covered, soils of the Paradox Member of the Hermosa Formation at elevations from 5200' - 6500'. | X | There have been no documented occurrences in the Paradox Valley (CNHP 1997+, BLM 2016). However, the Paradox Valley supports suitable habitat. |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| Fragile rockbrake *Cryptogramma stelleri* | Cool, moist, sheltered calcareous cliff crevices and rock ledges, typically in coniferous forest or other boreal habitats. 7800' – 13500'. | - | Occurs in San Juan, Archuleta, Grand, Gunnison, Conehos, San Miguel, Summit, and Ouray Counties, Colorado. Restricted to higher elevation lands administered by the Forest Service. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Kachina fleabane (daisy) *Erigeron kachinensis* | Wet, seasonally flooded sites and in the shallow caves or hanging gardens of red sandstone cliffs at 4800' 8400'. | - | Based on CNHP and BLM GIS data, there have been no documented occurrences in quadrangles the EIS analysis area overlaps. The EIS analysis area lacks suitable habitat; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Comb Wash buckwheat *Eriogonum clavellatum* | Found in fine textured soils, sandy silt to clay silt. Dominant plant communities are shadscale and blackbrush associations; elevation 4800' - 6000'. | - | Occurs in Montezuma County, Colorado. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Lone Mesa snakeweed *Gutierrezia elegans* | Outcrops of grayish, argillaceous, bare Mancos shale outcrops with thin soil over the shale; elevation 7500' – 7800'. | - | Only occurs in Dolores County, Colorado. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Pagosa bladderpod *Physaria pruinosa* | Mancos Shale, open clay barrens surrounded by montane grasslands, sometimes in open ponderosa pine stands with gamble oak it can also be associated with Douglas fir and Englemann spruce communities; elevation 6800' – 8500. | - | Found in Archuleta and Hinsdale Counties, Colorado. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Montrose (Uncompahgre) bladderpod *Physaria vicina (Lesquerella vicina)* | Sandy-gravel soil mostly of sandstone fragments over Mancos Shale (heavy clays) mainly in pinyon-juniper woodlands or in the ecotone between it and salt desert scrub; also in sandy soils derived from Jurassic sandstones and in sagebrush steppe communities; elevation 5700' – 7500' | - | Endemic to Montrose, and Ouray Counties, Colorado. Occurrences of this species are east of the Uncompahgre Plateau, along the Uncompahgre River Valley from south Delta County through Montrose County to north Ouray County (BLM 2016). EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |

| Species | Habitat Description | Include in EIS Analysis | Potential and/or Known Occurrences within or Near the EIS Alternatives |
|---|---|---|---|
| Colorado (Adobe) desert parsley *Lomatium concinnum* | Adobe hills and plains on rocky soils derived from Mancos Formation shale; shrub communities dominated by sagebrush, shadscale, greasewood, or scrub oak; elevation 4300' – 7000' | - | The species is found east of the Uncompahgre Plateau, along the lower Uncompahgre and Gunnison River valleys in Montrose, Delta, and Ouray Counties (BLM 2016). EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Paradox Valley (Payson's) lupine *Lupinus crassus* | Pinyon-juniper woodlands, or clay barrens derived from Chinle or Mancos Formation shales, often in draws and washes with sparse vegetation; elevation 5000' – 5800' | X | BLM has mapped occurrences in Paradox Valley. Potential to occur in EIS analysis area; suitable habitat present. |
| Dolores River skeletonplant *Lygodesmia grandiflora* var. *doloresensis* | Juniper-shrub or juniper-grassland communities in reddish-purple alluvial soils derived from sandstone outcrops at 4,000 to 5,500 feet in elevation. Most of these plants are found along benches between canyon walls and the river in juniper, shadscale, or sagebrush communities. | - | Distribution includes Mesa County, Colorado, and Grand County, Utah. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| Paradox (Aromatic Indian) breadroot *Pediomelum aromaticum* | Open pinyon-juniper woodlands in sandy soils or adobe hills; elevation 4800' – 5700' | X | BLM has mapped occurrences in Paradox Valley within the EIS analysis area; suitable habitat present. |
| Cushion bladderpod *Physaria pulvinata* | Outcrops of grayish, argillaceous (Mancos) shale. It grows in openings between low shrubs and forbs; elevation 7500' – 8500' | - | Distribution includes San Miguel and Dolores Counties, Colorado. Less than 1% of distribution occurs on BLM. EIS analysis area is outside the known range of the species; therefore, this species is dismissed from inclusion in the EIS analysis. |
| *INVERTEBRATES* | | | |
| Great Basin silverspot butterfly *Speyeria nokomis Nokomis* | Found in streamside meadows and open seepage areas with an abundance of northern bog violets (a violet species the butterfly depends upon). BLM 2016 | - | Closest known population is in Unaweep Canyon in Mesa County, Colorado. The EIS analysis area is in the species historic range. According to BLM, there are historic records of this species in Paradox Valley, although the exact location is uncertain, and habitats do not appear suitable (BLM 2016). Since there are only historic records and suitable habitat is lacking, this species is dismissed from inclusion in the EIS analysis. |

[1] Based on Colorado BLM State Director's Sensitive Species List (Last update: July 15, 2015).
[2] Descriptions of suitable habitat obtained from NatureServe (NatureServe 2019).
[3] Descriptions of suitable habitat obtained from Amphibians and Reptiles in Colorado (Hammerson 1999)
[4] Plant habitat and distribution data obtained from Colorado rare plant field guide (CNHP 1997+), unless otherwise noted.
[5] Validity of subspecies designation is in question by taxonomists.
[E] State endangered
[T] State threatened

## Federally Listed Species

A species list was obtained from FWS IPaC, and is supplied in Attachment E. **Table 4** summarizes the Federal species included in the IPaC report, their suitable habitat, and presence of critical habitat in the EIS analysis area.

***Table 4 Federally listed species evaluated***

| **Species** | **Status** | **Suitable Habitat and Life History Description Summary**[1] | **Designated Critical Habitat in EIS Analysis Area** |
|---|---|---|---|
| BIRDS | | | |
| Gunnison Sage Grouse<br>*Centrocercus minimus* | Threatened | The Gunnison sage-grouse is a sagebrush obligate endemic to Colorado and Utah south of the Colorado River. Breeding grounds (leks) consist of open areas next to tall sagebrush offering cover and suitable nest sites. For nesting and rearing young, the species requires large contiguous patches of sagebrush (>200 acres) with an abundant and relatively tall herbaceous understory, interspersed with wet swales. Irrigated hay meadows near sagebrush are often used as brood-rearing habitat. Wintering sage-grouse reside in relatively large patches of sagebrush and feed exclusively on sagebrush leaves. Gunnison sage-grouse gather on leks to breed during March through May. Nesting occurs between April and June, and early brood rearing occurs from mid-May through July. (FWS 2014a; FWS 2014b) | Yes |
| Mexican Spotted Owl<br>*Strix occidentalis lucida* | Threatened | The Mexican spotted owl is a year-round occupant in Arizona, Colorado, New Mexico, Texas, and Utah. The common characteristics of preferred habitat includes multilayered, high canopy closure and stand density, and uneven-aged classes (typical of old growth mixed-conifer forests), located in canyons with rocky cliffs and steep sloped terrain. Within Colorado, Mexican spotted owls occur within the pinyon-juniper zone below mixed-conifer forests in narrow, shady, cool canyons in sandstone slickrock. (FWS 1993; FWS 2004) | No |
| Yellow-billed Cuckoo<br>*Coccyzus americanus* | Threatened | The yellow-billed cuckoo is a migratory songbird that breeds in the United States and winters in South America. They are late spring migrants and typically arrive in the U.S. mid-to late May. The preferred breeding habitat is low elevation old-growth cottonwood forests or woodlands with dense, scrubby understories of willows or other riparian shrubs. Habitats for the cuckoo include extensive cottonwood galleries and riparian willow thickets with dense undergrowth. (FWS 2014) | No* |

| Species | Status | Suitable Habitat and Life History Description Summary[1] | Designated Critical Habitat in EIS Analysis Area |
|---|---|---|---|
| FISHES | | | |
| Bonytail Chub<br>*Gila elegans* | Endangered | The bonytail is a warm-water species that appears to favor main-stem warm-water rivers regardless of turbidity, usually in or near deep swift water, in flowing pools and eddies just outside the main current. Spawning occurs in spring over rocky substrates. Flooded bottomland habitats are important for nursery habitats for young. (FWS 1994) | No |
| Colorado Pikeminnow<br>*Ptychocheilus lucius* | Endangered | The Colorado pikeminnow inhabit warm-water medium to large rivers in the upper Colorado River basin. Adults use various habitats including deep turbid strong flowing water, eddies, runs, flooded bottoms, or backwaters. Young prefer small, quiet backwaters. The adults are highly mobile, making extensive spawning migrations and immatures are sedentary. Spawning occurs under decreasing flow regiment with increasing temperatures in summer. (FWS 1994) | No |
| Humpback Chub<br>*Gila cypha* | Endangered | Humpback chubs inhabit warm-water large rivers. Current distribution is limited to the Colorado, Yampa, and Green Rivers in Colorado and Utah. Adults use various habitats, including deep turbulent currents, shaded canyon pools, areas under shaded ledges in moderate current, riffles, and eddies. Young occupy sandy runs and backwaters. Spawning occurs in spring shortly after peak flows. Data indicate limited species movement. (FWS 1994) | No |
| Razorback Sucker<br>*Xyrauchen texanus* | Endangered | Razorback suckers occur in medium to large warm-water rivers and reservoirs. Current distribution includes the Green, Yampa, White, Duchesne, Colorado, Gunnison, San Juan Rivers and reservoirs. This fish is often associated with sand, mud, and rock substrate in areas with sparse aquatic vegetation where temperatures are moderate to warm. Young require quiet, warm, shallow water, such as tributary mouths, backwaters, or inundated floodplain habitats in rivers and coves or shorelines in reservoirs. Spawning occurs in groups in late winter and spring within reservoirs and during rising water levels and warming with in river systems. Some populations exhibit seasonal movements while other populations are sedentary. (FWS 1994) | No |
| Greenback Cutthroat Trout<br>*Oncorhynchus clarki stomias* | Threatened | This species occurs in the tributary high elevation clear, swift-flowing cold-water streams and cold water lakes. Juveniles tend to shelter in shallow backwaters and lakes. Spawning occurs in riffles in spring or early summer. | No |

*critical habitat is proposed and not designated.

[1] Life history and habitat requirement information acquired from FWS species Federal register notices and Natureserve (NatureServe 2019).

*Federally Listed Species Status and Distribution*

The distribution information for the above species originated from a variety of sources ranging from Federal register notices, literature and document reviews, and numerous communications with state and Federal agency biologists. The species range in relation to the EIS analysis area and the determination to carry the species forward for analysis in the EIS is summarized below.

<u>Gunnison Sage Grouse</u>: Gunnison sage grouse occur in seven populations in Colorado. The San Miguel Basin population (mainly near Miramonte Reservoir, Colorado) is the closest population to the EIS analysis area (Attachment C map 11). In 2014, CPW estimated 206 individuals within this population. Within the San Miguel Basin population, there are six small subpopulations (Attachment C map 12). The closest subpopulation to the EIS analysis area is Dry Creek Basin, which makes up 62% of the San Miguel Basin population acreage but has the fewest Gunnison sage grouse numbers in the San Miguel Basin population. (FWS 2014a)

Studies of radio-collared females suggest that Gunnison sage-grouse hens typically nest within 4 miles of their leks (GSRSC 2005). The nearest known active lek is located in the Dry Creek Basin area (N. West 2017, personal communication; E. Phillips 2016, personal communication). There are 4 known leks in Dry Creek Basin, three are considered active and one is classified as inactive (BLM 2017). The EIS analysis area is over 5.5 miles from the nearest lek and outside of CPW mapped sage grouse production areas (Attachment C map 13). Global positioning system (GPS) satellite data have been collected for Gunnison sage grouse in the Dry Creek Basin since March 2014 (BLM 2017). There have not been any sage grouse detections on Monogram Mesa (N. West 2019, personal communication).

The Dry Creek Basin has some of the poorest quality sage grouse habitat, in the San Miguel Basin population; with the primary factors effecting habitat quality being invasive species and mineral development which contribute to habitat decline (FWS 2014a). Gunnison sage grouse require plant communities composed primarily of sagebrush (at least 25 percent of the primarily sagebrush land cover within a 0.9-mile radius of any given location) of sufficient size and configuration to encompass all seasonal habitats for a given population and facilitate movements within and among populations (FWS 2014b). Small isolated patches of sagebrush do not support sage grouse. Furthermore, data suggest that Gunnison's sage grouse avoid stands of sagebrush with conifer encroachment by 300 meters (BLM 2017). Due to the amount of conifer encroachment, there is a limited amount of preferred sagebrush habitat available on Monogram Mesa which makes it unlikely for sage grouse to utilize the area for any extended period (N. West, personal communication, March 21, 2019). However, designated critical habitat occurs on Monogram Mesa, within the EIS analysis area (Attachment C map 14).

The majority of critical habitat in the San Miguel Basin population occurs on BLM-administered lands. Within the Dry Creek Basin area, past management activities include: sagebrush removal through herbicide, mechanical and prescribed fire; pinyon-juniper removal using mechanical methods; natural gas development; saleable mineral mining; and livestock grazing. Approximately 1,770 acres of sagebrush have been mowed and 3,150 acres of sagebrush have received herbicide treatments. In contrast, approximately 150 acres have received habitat treatments to benefit sage grouse and 2,992 acres of pinyon-juniper have been removed to improve sage grouse habitat. The BLM is involved in ongoing efforts to conserve this species and its habitat. (BLM 2017)

FWS's primary concerns for sage grouse from the EIS alternatives relate to potential noise, increased traffic on county roads through critical habitat, timing of work, and loss of habitat (C. Clayton, personal communication, March 21, 2018). This species and critical habitat should be carried forward for analysis in the EIS.

Mexican Spotted Owl: Mexican spotted owls are not known to exist within the EIS analysis area. Although small isolated areas of suitable habitat may be present in the Dolores River canyon. The BLM has conducted numerous spotted owl surveys over the past 20 years in the major drainages of the Dolores and San Miguel watersheds, all with negative results. The nearest known populations are to the west around Moab, Utah, to the south near Mesa Verde National Park, and to the east around Canon City, Colorado (BLM 2016). FWS considers all suitable terrain in western Colorado to be potential habitat for Mexican spotted owls (BLM 2016; N. West, personal communication, March 21, 2019). There is no critical habitat in the EIS analysis area. Due to the negative BLM survey results in potentially suitable habitat and lack of critical habitat, this species is not carried forward for analysis in the EIS.

Yellow-billed Cuckoo: The western yellow-billed cuckoo is known to occur in Mesa and Montrose Counties, where it is an uncommon summer breeding resident. This species is not known to occur in the EIS analysis area. Summer observations of the species have been recently reported near the San Miguel River near Nucla, Colorado (T. Ireland, personal communication, Sept. 27, 2017). Proposed critical habitat does not occur in the EIS analysis area. Field investigations revealed a lack of suitable habitat (C. Clayton, personal communication, March 21, 2018). Due to the lack of suitable habitat and species presence, the western yellow-billed cuckoo was dismissed from analysis in the EIS.

Bonytail Chub: Critical habitat includes parts of the Colorado River downstream of the project area. Bonytails historically were found in the Gunnison River up to about Delta, Colorado. Currently, there are no self-sustaining populations of bonytail chub in the wild; only a small number of adults exist in the wild in the Green River and upper Colorado River. Hatchery-reared adults have been released into these rivers, and the stocked bonytail reproduction was confirmed in the Green River in 2015, 2016, and 2017 (FWS 2018). Bonytail are present in the lower portions of the Dolores River, primarily due to stocking (FWS 2018).

Colorado Pikeminnow: Designated critical habitat spans three states and includes portions of the Colorado, Green, Yampa, White, and San Juan Rivers in the Upper Basin of the Colorado River. Currently, three reproducing wild populations of Colorado pikeminnow occur in the Green River, San Juan River, and upper Colorado River sub-basins. In the Colorado River sub-basin, recruitment appears to support a sustainable population (FWS 2018). Antenna data from 2014-2017 indicate Colorado pikeminnow are present in the lower portions of the Dolores River during the summer months (FWS 2018).

Humpback Chub: Critical habitat includes parts of the Colorado River downstream of the project area. On the Colorado River, the humpback chub exists in three populations (Black Rocks, Westwater Canyon, and Cataract Canyon). At Black Rocks and Westwater Canyon, adult populations appear stable and juveniles increasing (FWS 2018). In 2018, FWS decided to pursue reclassification of humpback chub as a threatened species. This species does not exist in the project area.

The four endangered fish commonly referred to as the Colorado River endangered fishes include the Colorado pikeminnow, razorback sucker, bonytail chub, and humpback chub. Surveys of the Dolores River indicate that these fish have only been documented utilizing the lower section of the Dolores River (FWS 2018). The species do not occur in the EIS analysis area and there are no additional depletions associated with the EIS alternatives (Attachment E). Furthermore, these species evolved in a highly variable river system and are adapted to extremes in water quality that accompany extremes in hydrology, which includes salinity concentrations (D. Speas, personal communication, Oct. 31, 2018). Salt loads in the Dolores River originating from the Paradox Valley would be diluted from the San Miguel River and other tributaries prior to reaching the Colorado River. Any changes to salinity concentrations would be within the parameters in which this species adapted and impacts to fish populations would be nondiscernable. Since the Colorado River endangered fishes do not occur in the EIS analysis area, there is no critical habitat, and no downstream impacts from depletions or salinity concentrations, these species are dismissed from analysis in the EIS.

Razorback Sucker. The closest designated critical habitat to the project areas occurs downstream of the Dolores River on the Colorado River. The species mostly occurs in the mainstem of the Colorado River and Gunnison River. A reproducing population occurs in an off-channel pond in the Colorado River near Grand Junction. Hatchery-produced stocked fish form the foundation for reestablishing self-sustaining populations. Stocked razorback suckers are surviving and expanding their range into previously unoccupied areas and annually reproducing (FWS 2018). The razorback sucker has been detected in the lower portion of the Dolores River, typically during spring (FWS 2018).

Greenback Cutthroat Trout: Critical habitat is not designated for this species. The greenback cutthroat trout suitable habitat includes cold-water streams and lakes, typically associated with higher elevations. The Dolores River is not a cold-water stream. The only known populations are restricted to short stream segments in Delta County, south of the Grand Mesa (BLM 2016). Due to species absence and lack of suitable habitat, this species was dismissed from analysis in the EIS.

## Migratory Birds and Eagles

The FWS manages migratory birds and populations of bald and golden eagles, which are protected under the Migratory Bird Treaty Act (MBTA) and, for eagles, the Bald and Golden Eagle Protection Act (Eagle Act).

The Migratory Bird Treaty Act of 1981 (MBTA) prohibits the take, capture, or killing of any migratory birds, and any parts, nests, or eggs of any such birds [16 U.S.C. 703 (a)]. Under Executive Order 13186, Federal agencies are liable for both intentional and unintentional take of migratory birds.

The Bald and Golden Eagle Protection Act, as amended (16 U.S.C. 668-668c), provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part (includes feathers), nest, or egg thereof."

The 1988 amendment to the Fish and Wildlife Conservation Act mandates the USFWS to “identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act (ESA) of 1973.” The “Birds of Conservation Concern 2008” (FWS 2008) was an effort to carry out this mandate. The Birds of Conservation Concern are principally a subset of a larger list known as the Birds of Management Concern. Conservation concerns for these species are the result of population declines, natural or human-caused small ranges or population sizes, threats to habitat, or other factors.

Furthermore, FWS’s IPAC report produces a list of birds that are of particular concern for the EIS analysis area. The list of birds in the IPAC report is not intended to include all bird species that may occur in the area, but only those that warrant special consideration. The migratory birds identified in the IPAC report fall into one or more of the categories of concern:

1. “BCC Rangewide” birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere in the USA or USA territories;
2. “BCC-BCR” birds are BCCs that are of concern in a particular Bird Conservation Region (BCR) in the continental USA; and

3. “Non-BCC – Vulnerable” birds are not BCC species in the project area, but appear on the list either because of the Eagle Act (for eagles) requirements or (for non-eagles) potential susceptibilities in offshore areas for certain types of development or activities.

The IPAC report identified two species: Brewer’s sparrow and Grace’s warbler (*Dendroica graciae*) (Attachment E). The Brewer’s sparrow is a BLM sensitive species and was previously discussed (see **Table 3**). Grace’s warbler is associated with montane pine and pine-oak forests. Suitable habitat for Grace’s warbler is lacking in the EIS analysis area. Observations of this species are primarily in higher elevations on national forests. eBird has no reported sightings in the EIS analysis area. There was a single observation in the town of Paradox, Colorado in 2011 (eBird 2019).

A list of birds for Montrose and San Miguel Counties were generated using the eBird Explore Data Tool (Attachment F). Additionally, a list of bird species potentially present in the EIS analysis area was generated using the Avian Knowledge Network Phenology Tool (Attachment G). Both lists include hundreds of species. While it is important to avoid and minimize impacts to all birds, the FWS particularly emphasizes the need to avoid and minimize impacts to birds on the IPAC list. Therefore, these species will be listed and addressed in the EIS to cover the larger category of migratory birds.

Although eagles were not on the IPAC list for migratory birds, both occur in the area and should be included in the EIS analysis because of the Eagle Act. The status of the bald and golden eagles within the EIS analysis area were previously addressed in sections above (see **Table 3** for both species and **Table 2** for bald eagle). Moreover, other factors, such as public interest, BLM sensitive/State listing status, and recreation and economic value warrant the need to include other categories of birds (i.e. raptors [including eagles], waterfowl and shorebirds, upland game birds) in the EIS analysis. Similar to migratory birds, only a subset of species is used as representatives for each category, opposed to including list of all species that potentially inhabit the EIS analysis area.

# References


ACIS. 2018. AgACIS for Montrose County: Paradox 2N, CO. National Oceanic & Atmospheric Administration Regional Climate Centers, ACIS. Available from http://agacis.rcc-acis.org/?fips=08085 (accessed March 12, 2019).

Banulis, Brad. 2019. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: Brad Banulis, Colorado Parks and Wildlife, Montrose, Colorado. Re: Big Game Herd Management Plans. April 30, 2019.

BLM (U.S. Department of Interior, Bureau of Land Management). 2008. Manual 6840 - Special Status Species Management, Washington D.C. December 12, 2008.

____.2016. Uncompahgre Field Office—Draft Resource Management Plan and Environmental Impact Statement, Volume 1 (3.1.7), pp 72-85.

____. 2017. Tres Rios Field Office – Dry Creek Basin Pinyon-Juniper Removal. Environmental Assessment, DOI-BLM-CO-S010_2017-0004-EA. June 2017. pp.

Reclamation (U.S. Department of Interior, Bureau of Reclamation) 2017. Meeting Notes Re. Informal Meeting with Fish and Wildlife Service Concerning Paradox. Attendees from Bureau of Reclamation and Fish and Wildlife Service. January 18, 2017.

Chapman, S.S., Griffith, G.E., Omernik, J.M., Price, A.B., Freeouf, J., and Schrupp, D.L. 2006. Ecoregions of Colorado (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,200,000).

Clayton, Creed. 2018. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: Creed Clayton, U.S. Fish and Wildlife Service, Grand Junction, Colorado. Re: Paradox Salinity Control Project. March 21, 2018.

CNHP (Colorado Natural Heritage Program). 1997+. Colorado Rare Plant Guide. Colorado State University. Website: www.cnhp.colostate.edu (Latest update: August 24, 2017; accessed on May 1, 2019).

CPW (Colorado Department of Natural Resources, Parks and Wildlife, formerly Colorado Division of Wildlife [CDOW]).2004. Mountain Lion Data Analysis Unit L-23 Management Plan.

____.2006. Elk Data Analysis Unit E-24 Management Plan.

____.2009. Colorado Bighorn Sheep Management Plan, Special Report No. 81.

____.2011. Black Bear Data Analysis Unit B-5 Management Plan.

____.2013. Desert Bighorn Sheep Addendum to the Colorado Bighorn Sheep Management Plan 2009-2019.

____.2014. Mule Deer Data Analysis Unit D-24 Management Plan.

____.2017. Fish Survey –Dolores River2A (Slickrock Canyon) Report.

____.2018. Species Activity Maps. Natural Diversity Information Source. Internet Website: https://cpw.state.co.us/learn/Pages/Maps.aspx (updated 2019, for peregrine falcon) eBird. 2019. eBird: An online database of bird distribution and abundance [web application]. eBird, Ithaca, New York. Available: http://www.ebird.org. (Accessed May 2019).

FWS (U.S. Department of Interior, Fish and Wildlife Service). 1993. Endangered and Threatened Wildlife and Plants; Final Rule to List the Mexican Spotted Owl as a Threatened Species. US Fish and Wildlife Service, Washington, DC. Federal Register Vol. 58, No. 49, pp. 14248-14271.

____. 1994. Endangered and Threatened Wildlife and Plants; Determination of Critical Habitat for the Colorado River Endangered Fishes: Razorback Sucker, Colorado Squawfish, Humpback Chub, and Bonytail Chub. US Fish and Wildlife Service, Washington, DC. Federal Register Vol. 59, No. 54, pp. 13374–13400.

____. 2004. Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for the Mexican Spotted Owl. US Fish and Wildlife Service, Washington, DC. Federal Register Vol.69, No. 168, pp. 53182-53298.

____. 2014. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Western Distinct Population Segment of the Yellow-billed Cuckoo (Coccyzus americanus). US Fish and Wildlife Service, Washington, DC. Federal Register Vol. 79, No. 192, pp. 59992-60038.

____. 2014a. Endangered and Threatened Wildlife and Plants; Threatened Status for Gunnison Sage-Grouse. US Fish and Wildlife Service, Washington, DC. Federal Register Vol. 79, No. 224, pp. 69192-69310.

____. 2014b. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Gunnison Sage-Grouse. US Fish and Wildlife Service, Washington, DC. Federal Register Vol. 79, No. 224, pp. 69312-69362.

____. 2018. 2017-2018 Abbreviated Assessment of Sufficient Progress under the Upper Colorado River Endangered Fish Recovery Program in the Upper Colorado River Basin, and of Implementation of Action Items in the December 20, 1999, 15-Mile Reach Programmatic Biological Opinion, the December 4, 2009, Gunnison River Basin Programmatic Biological Opinion, and the January 10, 2005, Yampa River Basin Programmatic Biological Opinion (Sufficiency Memo). U.S. Fish and Wildlife Service, Denver, Colorado. December 19, 2018.

GSRSC (Gunnison Sage-grouse Rangewide Steering Committee). 2005. Gunnison sage-grouse rangewide conservation plan. Colorado Division of Wildlife, Denver, Colorado, USA.

Hammerson, Geoffrey A. 1999. *Amphibians and Reptiles in Colorado*. 2nd ed., University Press of Colorado.

Hayes, M., Navo K., Bonewell, L., Moshch, C., Adams, R. 2009. Allen’s Big-Eared Bat (Idionycteris Phyllotis) Documented in Colorado Based on Recordings of its Distinctive Echolocation Call. The Southwestern Naturalist, Vol. 54, No. 4 (DECEMBER 2009), pp. 499-501.

Ireland, Terry. 2017. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: Terry Ireland, U.S. Fish and Wildlife Service, Grand Junction, Colorado. Re: Nearest cuckoo to Paradox? September 27, 2017.

Ladyman, J.A.R. 2005. Boechera crandallii (B.L. Robinson) W.A. Weber (Crandall's rockcress): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Online. Available: http://www.fs.fed.us/r2/projects/scp/assessments/boecheracrandallii.pdf (Accessed 2019).

Lower Dolores River Working Group. 2014. Lower Dolores River Implementation, Monitoring and Evaluation Plan for Native Fish. June 2014. http://ocs.fortlewis.edu/drd/pdf/Lower-Dolores-River-Implementation-Monitoring-and-Evaluation-Plan-for-Native-Fish-June%202014.pdf.

Lowry, J., Ramsey, R., Thomas, K., Schrupp, D., Sajwaj, T., Kirby, J., Waller, E., Schrader, S., Falzarano, S., Langs, L., Manis, G., Wallace, C., Schulz, K., Comer, P., Pohs, K., Rieth, W., Velasquez, C., Wolk, B., Kepner, W., Boykin, K., O'Brien, L., Bradford, D., Thompson, B. and Prior-Magee, J. 2007. Mapping moderate-scale land-cover over very large geographic areas within a collaborative framework: A case study of the Southwest Regional Gap Analysis Project (SWReGAP). Remote Sensing of Environment, 108(1), pp.59-73.

NatureServe. 2019. NatureServe Explorer: An online encyclopedia of life [web application].Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: May 2019).

Neubaum, Dan. 2018. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: Dan Neubaum, Colorado Parks and Wildlife, Grand Junction, Colorado. Re: Another bat question. February 26, 2018.

Reed-Eckert, M. 2009. 2008 Year-End Survey Report: Non-Invasive Sampling Survey Results for Kit Fox (Vulpes macrotis) in West-Central Colorado. Unpublished Report, Colorado Division of Wildlife, Montrose, CO.

Seglund, A.E., Schnurr, P.M. 2010. Colorado Gunnison's and white-tailed prairie dog conservation strategy. Colorado Division of Wildlife, Denver, Colorado, USA.

Speas, David. 2018. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: David Speas, Bureau of Reclamation. Grand Junction, Colorado. Re: Salinity and endangered fish in the Colorado River Basin. October 31, 2018.

West, Nathaniel. 2019. Personal communication. Email To: Amanda Ewing, Bureau of Reclamation. From: Nathaniel West, Bureau of Land Management, Tres Rios Field Office, Dolores, Colorado. Re: Paradox Project and TES. March 21, 2019.

# Attachment A – Photo Log

*Photo 1 Reclamation property – Aerial view of existing injection well site. Picture taken April 26, 2017.*

*Photo 2 Reclamation property - Aerial picture taken from southern most portion of Reclamation property looking north towards existing injection well site (denoted by arrow) and Paradox Valley in distant background. Picture taken April 26, 2017.*

*Photo 3 Reclamation property – Ground view from southern portion of Reclamation property looking north towards existing injection well site and Paradox Valley in distant background (neither clearly visible in picture). Picture taken August 8, 2017.*

*Photo 4 Reclamation property -overview representation of riparian vegetation along Dolores River.  Picture taken August 8, 2017.*

*Photo 5 Reclamation property – representative view of riparian vegetation in Dolores River floodplain. Picture taken August 8, 2017.*

*Photo 6 Reclamation property – representative vegetation of pinyon and juniper community located on toe of slopes. Picture taken August 8, 2017.*

*Photo 7 Skein Mesa on BLM managed lands– aerial view of vegetation. Picture taken April 26, 2017.*

*Photo 8 Alternative B2 – Representation of vegetation on Monogram Mesa. Picture taken August 8, 2017.*

*Photo 9 Alternative B2 – aerial view of Monogram Mesa. Picture taken April 26, 2017.*

*Photo 10 Alternative B2 – view of Fawn Springs Bench. Picture taken August 8, 2017.*

*Photo 11 Alternative B2 (& Alternative C) – View of East Paradox Creek and County Road Y11 intersection, looking downstream towards the Dolores River.*

*Photo 12 Alternative B2 (& Alternative C) – View of East Paradox Creek and County Road Y11 intersection, looking upstream.*

*Photo 13  Alternative C – aerial view of evaporation pond location west of East Paradox Creek. Picture taken April 26, 2017.*

*Photo 14 Alternative C – East Paradox Creek. Picture taken August 8, 2017.*

*Photo 15 Alternative C – aerial view of landscape east of East Paradox Creek. Photo taken April 26, 2017.*

*Photo 16 Alternative D – representative vegetation at the ZLD location. Pictures taken August 8, 2017.*

# Attachment B – CPW Species Activity Area Definitions

## COLORADO PARKS AND WILDLIFE
## GIS SPECIES ACTIVITY MAPPING DEFINITIONS

**DIGITAL DATA DISCLAIMER:**

GIS Unit

This wildlife distribution map is a product and property of the Colorado Parks and Wildlife, a division of the Colorado Department of Natural Resources. Care should be taken in interpreting these data. Written documents may accompany this map and should be referenced. The information portrayed on these maps should not replace field studies necessary for more localized planning efforts. The data are typically gathered at a scale of 1:24000 or 1:50000; discrepancies may become apparent at larger scales. The areas portrayed here are graphic representations of phenomena that are difficult to reduce to two dimensions. Animal distributions are fluid; animal populations and their habitats are dynamic.

The Colorado Department of Natural Resources is not responsible and shall not be liable to the user for damages of any kind arising out of the use of data or information provided by the Department, including the installation of the data or information, its use, or the results obtained from its use.

ANY DATA OR INFORMATION PROVIDED BY THE DEPARTMENT OF NATURAL RESOURCES IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Data or information provided by the Department of Natural Resources shall be used and relied upon only at the user's sole risk, and the user agrees to indemnify and hold harmless the Department of Natural Resources, its officials, officers and employees from any liability arising out of the use of the data or information provided.

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Species Activity Mapping (SAM)
**ABERT'S SQUIRREL**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses the observed range of a population of Abert's Squirrel.

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Species Activity Mapping (SAM)
**BALD EAGLE**
Activity Area Definitions

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**ACTIVE NEST SITE:** A specific location in which a pair of bald eagles have at least attempted to nest within the last five years. Any nest location that can be directly tied to courtship, breeding, or brooding behavior is considered active. A buffer zone extends .5 miles around a known active nest.

**INACTIVE NEST SITE:** A former active nest location in which neither courtship, breeding, or brooding activity has been observed at any time during the last 5 years. A buffer zone of .5 mile extends around an inactive nest.

**NEST OF UNKNOWN STATUS:** A former active Bald Eagle nest that has not been checked in the past five years. A buffer zone of .5 mile extends around an unknown nest.

**NEST OF UNDETERMINED STATUS:** A Bald Eagle nest that has been monitored within the last five years, but the status could not be determined. A buffer zone of .5 mile extends around an undetermined nest.

**DESTROYED NEST SITE:** A Bald Eagle nest whose last recorded status noted that the nest was destroyed. A buffer zone of .5 mile extends around a destroyed nest.

**ROOST SITE:** Groups of or individual trees that provide diurnal and/or nocturnal perches for less than 15 wintering bald eagles; includes a buffer zone extending 1/4 mile around these sites. These trees are usually the tallest available trees in the wintering area and are primarily located in riparian habitats.

**COMMUNAL ROOST:** Groups of or individual trees that provide diurnal and/or nocturnal perches for more than 15 wintering bald eagles; these trees are usually the tallest available trees in the wintering area.

**WINTER RANGE:** Those areas where bald eagles have been observed between November 15 and April 1.

**WINTER CONCENTRATION AREA:** Areas (tree, islands, etc) within an existing winter range where eagles concentrate between November 15 and April 1. These areas may be associated with roost sites.

**SUMMER FORAGING RANGE:** Foraging areas frequented by breeding bald eagles from March 15 to July 31. These areas are almost always associated with nesting pairs.

**WINTER FORAGING RANGE:** Foraging areas frequented by wintering bald eagles between November 15 and March 15. May be a large area radiating from preferred roosting sites. In western Colorado preferred roosting sites are within dominant riparian zones.

Species Activity Mapping (SAM)
**BIGHORN SHEEP**
Seasonal Activity Area Definitions

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a bighorn sheep population.

**SUMMER RANGE:** That part of the overall range where 90% of the individuals are located between spring green-up and the first heavy snowfall. Summer range is not necessarily exclusive of winter range; in some areas winter range and summer range may overlap.

**SUMMER CONCENTRATION AREA:** Those areas where bighorn sheep concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance may be characteristic of these areas to meet the high energy demands of lactation, lamb rearing, horn growth, and general preparation for the rigors of fall and winter.

**PRODUCTION AREA:** That part of the overall range of bighorn sheep occupied by pregnant females during a specific period of spring. This period is May 1 to June 30 for Rocky Mountain bighorn sheep and February 28 to May 1 for desert bighorn sheep.

**WINTER RANGE:** That part of the overall range where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each DAU.

**WINTER CONCENTRATION AREA:** That part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.

**SEVERE WINTER RANGE:** That part of the winter range where 90% of the individual animals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. Not all populations exhibit migratory behavior during severe winters, many will stay within the defined winter range regardless of conditions. Thus, some populations may not have a mapped severe winter range distribution.

**MIGRATION PATTERN:** A subjective indication of the general direction of the movements of migratory ungulate herds.

**MIGRATION CORRIDOR:** A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

**MINERAL LICK:** Specific natural sites known to be utilized by bighorn sheep for obtaining minerals to meet basic nutritional needs.

**WATER SOURCE:** Water sources known to be utilized by bighorn sheep in dry, water scarce areas. Up to a 1.6km radius should be described around a point source, and up to a 1.6 km band be drawn along a river or stream and clipped to Overall Range.

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Species Activity Mapping (SAM)
**BLACK BEAR**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of black bear.

**SUMMER CONCENTRATION AREA:** That portion of the overall range of the species where activity is greater than the surrounding overall range during that period from June 15 to August 15.

**FALL CONCENTRATION AREA:** That portion of the overall range occupied from August 15 until September 30 for the purpose of ingesting large quantities of mast and berries to establish fat reserves for the winter hibernation period.

**HUMAN/BEAR CONFLICT AREA:** That portion of the overall range where two or more confirmed black bear complaints per season were received which resulted in CPW investigation, damage to persons or property (cabins, tents, vehicles, etc), and/or the removal of the problem bear(s). This **does not** include damage caused by bears to livestock.

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Species Activity Mapping (SAM)
**BLACK-FOOTED FERRET**
Seasonal Activity Area Definitions

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**RELEASE SITES:** Areas showing reintroduction release sites of Black-Footed Ferrets in Colorado since 2001. Releases on public lands are depicted by the administrative boundary of the property ferrets were released. Due to state statutory requirements and agreements made with individual landowners to protect their privacy, release sites occurring on private land have been generalized to the county in which they occurred. Ferrets will not be found within all areas of these boundaries and will only likely occur in areas with active prairie dog colonies.

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Species Activity Mapping (SAM)
**BLACK-TAILED PRAIRIE DOG**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** An area which encompasses all known seasonal activity areas within the range of a population of prairie dogs.

**COLONY POTENTIAL OCCURRENCE:** Depicts the probability of black-tailed prairie dog colonies occurring within the Overall Range within Colorado. CPW staff delineated and categorized these areas of potential occurrence based on the results of a 2016 rangewide survey (see Howlin, S., J. Mitchell. December 2016. Monitoring Black-Tailed Prairie Dogs in Colorado with the 2015 NAIP Imagery.)

**H - High Colony Potential Occurrence**. 2016 survey indicated a large number of colonies and/or individual colonies of substantially larger size. These areas have a higher likelihood of containing a larger number of colonies and/or large individual colonies.

**M - Medium Colony Potential Occurrence.** 2016 survey indicated a moderate number of colonies of small to intermediate size. These areas have a medium likelihood of containing colonies of small to intermediate size.

**L - Low Colony Potential Occurrence.** 2016 survey indicated a low number of colonies of small to intermediate size. These areas have a lower likelihood of containing colonies of small to intermediate size.

**PRAIRIE DOG HABITAT AFFINITIES:**

**Black-Tailed Prairie Dog:** An area typically associated with shortgrass or mixed-grass prairie in eastern Colorado.

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Species Activity Mapping (SAM)
**BOBWHITE QUAIL**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of bobwhite quail.

**CONCENTRATION AREA:** Areas within overall range where densities of bobwhite quail are much higher than surrounding ranges.

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Species Activity Mapping (SAM)
**BOREAL TOAD**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of boreal toads.

Species Activity Mapping (SAM)
**BRAZILIAN FREE-TAILED BAT**
Seasonal Activity Area Definitions

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of Brazilian Free-tailed bats.

Species Activity Mapping (SAM)
**COLUMBIAN SHARP-TAILED GROUSE**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all mapped seasonal activity areas within the observed range of a population of Columbian sharp-tailed grouse.

**WINTER RANGE:** Observed winter range of Columbian sharp-tailed grouse usually in a tall shrub vegetative type (greater than or equal to 2 meters); within 5 km of lek sites. Shrub height should allow feeding on buds by birds above normal snow depths.

**PRODUCTION AREA:** An area that include 90% of Columbian sharp-tailed grouse nesting or brood rearing habitat. This is mapped as a buffer zone of 1.25 miles around active dancing grounds and clipped to Overall Range.

Species Activity Mapping (SAM)
**ELK**
Seasonal Activity Area Definitions

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of an elk population.

**WINTER RANGE:** That part of the overall range of a species where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each DAU. Winter range is not delineated for elk on the Eastern Plains.

**WINTER CONCENTRATION AREA:** That part of the winter range of elk where densities are at least 200% greater than the surrounding winter range density during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Data Analysis Unit.

**SEVERE WINTER RANGE:** That part of the range of a species where 90 percent of the individuals are located when the annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. The winter of 1983-84 is a good example of a severe winter.

**HIGHWAY CROSSING:** Those areas where elk movements traditionally cross roads, presenting potential conflicts between elk and motorists.

**MIGRATION CORRIDOR:** A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

**MIGRATION PATTERN:** A subjective indication of the general direction of the movements of migratory ungulate herds.

**PRODUCTION AREA:** That part of the overall range of elk occupied by the females from May 15 to June 15 for calving. (Only known areas are mapped and this does not include all production areas for the DAU).

**RESIDENT POPULATION AREA:** An area used year-round by a population of elk. Individuals could be found in any part of the area at any time of the year; the area cannot be subdivided into seasonal ranges. It is most likely included within the overall range of the larger population.

**SUMMER RANGE:** That part of the range of a species where 90% of the individuals are located between spring green-up and the first heavy snowfall, or during a site specific period of summer as defined for each DAU. Summer range is not necessarily exclusive of winter range; in some areas winter range and summer range may overlap.

**SUMMER CONCENTRATION AREA:** Those areas where elk concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance are characteristics of these areas to meet the high energy demands of lactation, calf rearing, antler growth, and general preparation for the rigors of fall and winter.

**LIMITED USE AREA:** An area within the overall range which is occasionally inhabited by elk and/or contains a small scattered population of elk.

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Species Activity Mapping (SAM)

**GEESE**

Seasonal Activity Area Definitions

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**CANADA GEESE WINTER RANGE:** That part of the overall range occupied by Canada geese from November 1 to March 1. Includes winter loafing/resting and foraging areas.

**CANADA GEESE WINTER CONCENTRATION AREA:** That part of the winter range occupied by loafing/resting Canada geese where densities are significantly greater than the surrounding winter range density. Generally, an extensive area of open water such as large reservoirs, rivers, and sloughs that are relatively ice free and free from human disturbance.

**CANADA GEESE FORAGING AREA:** That portion of the winter range where Canada geese move to feed, such as agricultural fields or reservoir shorelines.

**CANADA GEESE PRODUCTION AREA:** That part of the overall range used by nesting and brooding Canada geese.

**CANADA GEESE BROOD CONCENTRATION AREA:** Brood areas, within production areas, where Canada geese traditionally congregate in high numbers.

**CANADA GEESE MOLTING AREA:** Areas of water used primarily by non-breeding birds, that cannot positively be assigned as originating from specific nesting areas during molt.

**SNOW GEESE WINTER RANGE:** That part of the overall range occupied by Snow geese from November 1 to March 1. Includes winter loafing/resting and foraging areas.

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Species Activity Mapping (SAM)
**GREAT BLUE HERON**
Seasonal Activity Area Definitions

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**NESTING AREA (ROOKERY):** Groups of or individual trees containing nest platforms and a buffer zone extending 500 meters around a known active or inactive nest site. Nest platforms are usually located in dominant trees associated with riparian habitats. In Colorado, human activity at active sites should be restricted from March 1 to July 1.

**HISTORIC NESTING AREA:** A formerly active nesting area that has either been destroyed or in which no courtship, breeding, or brooding activity has been observed at any time during the past 5 years.

**FORAGING AREA:** Areas where great blue herons are known to feed. Appropriate habitat includes shallow water areas associated with reservoirs, lakes, ponds, streams, and backwater areas of major rivers with abundant fish populations. On large irrigation reservoirs, these areas will fluctuate with changing water levels.

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Species Activity Mapping (SAM)
**GREATER PRAIRIE CHICKEN**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** An area which encompasses all known seasonal activities within the observed range of the greater prairie chicken. Does not include historic range.

**HISTORIC RANGE:** Areas where greater prairie chickens have been known to occur prior to

1955. Taken from Aldrich and Duvall (1955).

**PRODUCTION AREA:** An area which includes all nesting and brood rearing habitat of the greater prairie chicken. Currently defined as a 2.2 mile buffer zone around each active lek and clipped to Overall Range.

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Species Activity Mapping (SAM)

**GREATER SAGE GROUSE**

Seasonal Activity Area Definitions

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**OVERALL RANGE:** An area which encompasses all mapped seasonal activity areas within the observed range of a population of sage grouse.

**WINTER RANGE:** Observed winter range.

**SEVERE WINTER RANGE:** That part of the winter range where 90 percent of the individuals are located when annual snow pack is at its' maximum and/or temperatures are at a minimum in the two worst winters out of ten. The winters of 1983-84, or 96-97 are good examples.

**BROOD AREA:** Areas supporting sage grouse broods. This generally includes wet areas such as meadows, springs, ponds and streams which all function as important brood rearing sites. To be mapped as a 200m (.124 mile) buffer zone around the edges of such wet sites.

**PRODUCTION (NESTING) AREA:** An area that would include the majority of important sage grouse nesting habitat. Mapped as a buffer zone of 4 miles around Active leks and clipped to Overall Range.

**HISTORIC HABITAT:** The data set was created by mapping efforts of the Colorado Parks and Wildlife biologists for the Statewide conservation plan in 2005. This dataset was based on the historic grouse range delineated by Schroeder et al 2004 and was further refined by biologists in the Colorado Statewide Greater Sage Grouse Conservation Plan Committee.

**LINKAGES:** Greater sage grouse GIS dataset identifying linkage areas between sage grouse populations. The data set was created by mapping efforts of the Colorado Division of Wildlife (now Colorado Parks and Wildlife) biologists for the Statewide conservation plan in 2005, and further refined in early 2012. The linkage areas were delineated based on a selection of vegetation classes in the Colorado Basin-wide dataset. The following list shows the vegetation classes used to assist the biologists in delineating the areas. Linkages Vegetation Classes Determined by Pam Schnurr and Brad Petch on 11/20/2005 from Basinwide Vegetation classes Agriculture Land Bitterbrush Community Bitterbrush/Grass Mix Disturbed Rangeland Disturbed Soil Dryland Ag Foothill and Mountain Grasses Forb Dominated Grass Dominated Grass/Forb Mix Grass/Forb Rangeland Grass/Misc. Cactus Mix Grass/Yucca Mix Greasewood Irrigated Ag Juniper/Mtn Shrub Mix Juniper/Sagebrush Mix Mesic Mountain Shrub Mix PJ-Mtn Shrub Mix PJ-

Oak Mix PJ-Sagebrush Mix Rabbitbrush/Grass Mix Rangeland Sagebrush Community Sagebrush/Gambel Oak Mix Sagebrush/Grass Mix Sagebrush/Greasewood Sagebrush/Mesic Mtn Shrub Mix Sagebrush/Rabbitbrush Mix Salt Desert Shrub Community Saltbrush Community Serviceberry/Shrub Mix Shrub/Brush Rangeland Shrub/Brush/Forb Mix Snowberry Snowberry/Shrub Mix Sparse Juniper/Shrub/Rock Mix Sparse PJ/Shrub/Rock Mix Winterfat/Grass Mix Xeric Mountain Shrub Mix Update: In August 2012, this dataset was modified to correct topology errors between the Linkages dataset and the PPH and PGH dataset.

**PRELIMINARY PRIORITY HABITAT (PPH) / PRELIMINARY GENERAL HABITAT (PGH):** Greater sage-grouse GIS data set identifying Preliminary Priority Habitat (PPH) and Preliminary General Habitat (PGH) within Colorado. This data is a combination of mapped grouse occupied range, production areas, and modeled habitat (summer, winter, and breeding).

PPH is defined as areas of high probability of use (summer or winter, or breeding models) within a 4 mile buffer around leks that have been active within the last 10 years. Isolated areas with low activity were designated as general habitat.

PGH is defined as Greater sage-grouse Occupied Range outside of PPH.

Datasets used to create PPH and PGH:Summer, winter, and breeding habitat models. Rice, M. B., T. D. Apa, B. L. Walker, M. L. Phillips, J. H. Gammonly, B. Petch, and K. Eichhoff. 2012. Analysis of regional species distribution models based on combined radio-telemetry datasets from multiple small-scale studies. Journal of Applied Ecology in review.

Production Areas are defined as 4 mile buffers around leks which have been active within the last 10 years (leks active between 2002-2011).

Occupied range was created by mapping efforts of the Colorado Division of Wildlife (now Colorado Parks and Wildlife – CPW) biologists and district officers during the spring of 2004, and further refined in early 2012. Occupied Habitat is defined as areas of suitable habitat known to be used by sage-grouse within the last 10 years from the date of mapping. Areas of suitable habitat contiguous with areas of known use, which do not have effective barriers to sage-grouse movement from known use areas, are mapped as occupied habitat unless specific information exists that documents the lack of sage-grouse use. Mapped from any combination of telemetry locations, sightings of sage grouse or sage grouse sign, local biological expertise, GIS analysis, or other data sources. This information was derived from field personnel. A variety of data capture techniques were used including the SmartBoard Interactive Whiteboard using stand-up, real-time digitizing at various scales (Cowardin, M., M. Flenner. March 2003. Maximizing Mapping Resources. GeoWorld 16(3):32-35).

Update: In August 2012, this dataset was modified to correct topology errors and clipped to the Colorado boundary.

Species Activity Mapping (SAM)
**GUNNISON'S PRAIRIE DOG**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all known seasonal activity areas within the range of a population of prairie dogs.

**PRAIRIE DOG HABITAT AFFINITIES:**

**Gunnison's Prairie Dog:** An area, typically associated with grasslands and semi desert montane shrublands in southwestern and south-central Colorado.

Species Activity Mapping (SAM)
**GUNNISON'S SAGE GROUSE**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all mapped seasonal activity areas within the observed range of a population of sage grouse.

**WINTER RANGE:** Observed winter range.

**SEVERE WINTER RANGE:** That part of the winter range where 90 percent of the individuals are located when annual snow pack is at its' maximum and/or temperatures are at a minimum in the two worst winters out of ten. The winters of 1983-84, or 96-97 are good examples.

**BROOD AREA:** Areas supporting sage grouse broods. This generally includes wet areas such as meadows, springs, ponds and streams which all function as important brood rearing sites. To be mapped as a 200m (.124 mile) buffer zone around the edges of such wet sites.

**PRODUCTION (NESTING) AREA:** An area that would include the majority of important sage grouse nesting habitat. Mapped as a buffer zone of 4 miles around Active leks. As of 9/8/2016 these buffer zones are no longer clipped to Overall Range per directive from Jon Holst, CPW Energy Resource Specialist – SW Region.

**HISTORIC HABITAT:** The original sage-grouse historic range was delineated by Schroeder et. al. 2004 and was further refined by CPW personnel and the Range-wide Conservation Plan Committee for the Gunnison Sage-grouse Range-wide Conservation Plan - 2004. The Comments field labels the areas the Committee considered uncertain grouse species.

Species Activity Mapping (SAM)
**INTERIOR LEAST TERN**
Seasonal Activity Area Definitions

**PRODUCTION AREA:** An area that includes nesting habitat and contains one or more active or previously active and aggressively defended territories.

**FORAGING AREA:** An area which generally is associated with a nesting area and which provides a source of food for Least Terns. Appropriate habitat includes shallow water areas in lakes, ponds, and river backwater areas with abundant small fish populations. These areas generally are within one-half mile of the nesting area. On large irrigation reservoirs, these areas fluctuate with changing water levels.

Species Activity Mapping (SAM)
**KIT FOX**
Seasonal Activity Area Definitions

**HISTORIC OVERALL RANGE:** Areas known to have been utilized by kit fox in Colorado. Kit Fox were last observed in Colorado in the 1990's.

Species Activity Mapping (SAM)
**LESSER PRAIRIE CHICKEN**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all known seasonal activities within the observed range of the lesser prairie chicken. This does not include historic range.

**HISTORIC RANGE:** Areas where lesser prairie chickens have been known to occur prior to 1955. Taken from Aldrich and Duvall (1955).

**PRODUCTION AREAS:** An area which includes all nesting and brood rearing habitat of the lesser prairie chicken. Currently defined as a 2.2 mile buffer zone around each active lek and clipped to LPChickenOverallRange.

Species Activity Mapping (SAM)
**LYNX**
Seasonal Activity Area Definitions

**POTENTIAL HABITAT:** Areas having the highest potential of lynx occurrences in the state.

These areas usually contain positive, probable, or possible reports. This information was derived from modeling potential lynx habitat.

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Species Activity Mapping (SAM)
**MOOSE**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of moose.

**WINTER RANGE:** That part of the overall range where 90 percent of the individuals are located during the winter months. This winter time frame will be delineated with specific start/end dates for each moose population within the state (ex: November 15 to April 1).

**SUMMER RANGE:** That part of the overall range where 90% of the individuals are located during the summer months. This summer time frame will be delineated with specific start/end dates for each moose population within the state (ex: May 1 to Sept 15). Summer range is not necessarily exclusive of winter range.

**CONCENTRATION AREA:** That part of the range of a species where densities are 200% higher than the surrounding area during a specific season.

**MIGRATION PATTERN:** A subjective indication of the general direction of the movements of moose.

**PRIORITY HABITAT:** Habitat types associated with the food and cover requirements of moose. Significant loss of these habitats would change moose distribution and/or would adversely affect the population. These habitat types include but are not limited to willow dominated riparian areas, sub-climax coniferous forest mixed with shrub lands, and dense climax coniferous forests.

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Species Activity Mapping (SAM)
**MOUNTAIN GOAT**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** An area which encompasses all known seasonal activity areas within the observed range of a population of mountain goat.

**WINTER RANGE:** That part of the overall range of a species where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each management unit.

**SUMMER RANGE:** That part of the home range of a species where 90 percent of the individuals are located during summer. This range may overlap winter range areas in some instances. Summer range will include what has traditionally been known as spring and fall transitional ranges.

**PRODUCTION AREA:** That part of the home range of a species occupied by the females during a specific period of spring. This period is May 15 to June 30 for mountain goats.

**CONCENTRATION AREAS:** That part of the overall range where densities are at least 200% greater than the surrounding area.

**MINERAL LICK:** Specific natural sites known to be utilized as lick areas by mountain goat.

**MIGRATION CORRIDOR:** A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

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Species Activity Mapping (SAM)
**MOUNTAIN LION**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of mountain lion.

**PERIPHERAL RANGE:** An area of mountain lion overall range where habitat is limited and populations are isolated. Population density may be lower than in the central part of their range.

**HUMAN CONFLICT AREA:** An area where a mountain lion has been involved in an incident (conflict with a human that may have serious results), an attack on a human, predation on domestic pets, or depredation on livestock held within close proximity to human habitation.

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Species Activity Mapping (SAM)
**MULE DEER**
Seasonal Activity Area Definitions

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**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a mule deer population.

**SUMMER RANGE:** That part of the overall range where 90% of the individuals are located between spring green-up and the first heavy snowfall. Summer range is not necessarily exclusive of winter range; in some areas winter range and summer range may overlap.

**CONCENTRATION AREA:** That part of the overall range where higher quality habitat supports significantly higher densities than surrounding areas. These areas are typically occupied year round and are not necessarily associated with a specific season. Includes rough break country, riparian areas, small drainages, and large areas of irrigated cropland.

**WINTER RANGE:** That part of the overall range where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each DAU. Winter range is only delineated for migratory populations. On the Eastern Plains winter range is defined as areas that provide thermal cover for deer. Examples are riparian areas dominated by trees and shrubs, areas of pinyon/juniper, topographic cover such as gullies, draws, canyons, shelter belts and CRP fields that provide adequate cover.

**WINTER CONCENTRATION AREA:** That part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.

**SEVERE WINTER RANGE:** That part of the overall range where 90% of the individuals are located when the annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

**RESIDENT POPULATION AREA:** An area that provides year-round range for a population of mule deer. The resident mule deer use all of the area all year; it cannot be subdivided into seasonal ranges although it may be included within the overall range of the larger population.

**LIMITED USE AREA:** An area within the overall range of mule deer that is only occasionally inhabited and/or contains only a small population of scattered mule deer.

**MIGRATION PATTERN:** A subjective indication of the general direction of the movements of migratory ungulate herds.

**MIGRATION CORRIDOR:** A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

**HIGHWAY CROSSING:** Those areas where mule deer movements traditionally cross roads or railroads, presenting potential conflicts between mule deer and motorists/trains. (More than six highway mortalities per mile of highway or railroad per year is a guide that may be used to indicate highway crossings).

Species Activity Mapping (SAM)
**NEW MEXICO MEADOW JUMPING MOUSE**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses the probable range of New Mexico Meadow Jumping Mouse in Colorado. New Mexico Meadow Jumping Mouse is primarily associated with riparian corridors of small intermittent and perennial streams where riparian herbaceous and riparian shrub (primarily willow) dominate.

Species Activity Mapping (SAM)
**OSPREY**
Seasonal Activity Area Definitions

**ACTIVE NEST SITE:** A specific location in which a pair of ospreys have at least attempted to nest within the last five years. Any nest location that can be directly tied to courtship, breeding, or brooding behavior is considered active. A buffer zone extends .5 miles around a known active nest.

**INACTIVE NEST SITE:** A former active nest location in which neither courtship, breeding, or brooding activity has been observed at any time during the last 5 years. A buffer zone of .5 mile extends around an inactive nest.

**NEST OF UNKNOWN STATUS:** A former active osprey nest that has not been checked in the past five years. A buffer zone of .5 mile extends around an unknown nest.

**NEST OF UNDETERMINED STATUS:** An osprey nest that has been monitored within the last five years, but the status could not be determined. A buffer zone of .5 mile extends around an undetermined nest.

**DESTROYED NEST SITE:** An osprey nest whose last recorded status noted that the nest was destroyed. A buffer zone of .5 mile extends around a destroyed nest.

**FORAGING AREA:** Open water areas, typically associated with larger rivers, lakes, and reservoirs with abundant fish populations, utilized by both resident and transient osprey for feeding purposes.

Species Activity Mapping (SAM)
**PEREGRINE FALCON**
Seasonal Activity Area Definitions

**NESTING AREA:** An area which includes good nesting sites and contains one or more active or inactive nest locations. The boundaries are drawn based on professional judgment to include most known nesting habitat in the vicinity. Usually these areas are mapped as polygons around cliffs and include a 0.5 mile buffer surrounding the cliffs.

**POTENTIAL NESTING AREA:** An area which appears to include the necessary components for peregrine falcon nesting, but in which no known active or inactive nest sites are present.

---

Species Activity Mapping (SAM)
**PIPING PLOVER**
Seasonal Activity Area Definitions

---

**PRODUCTION AREA:** An area that includes nesting habitat and contains one or more active or previously active and aggressively defended territories.

**FORAGING AREA:** An area generally associated with a nesting area and which provides a source of food for Piping Plovers. Appropriate habitat includes shallow water areas along exposed beach substrates associated with lakes, ponds, and beaches, and dry, barren sandbars along backwater river areas which provide abundant macro invertebrate and insect populations. These areas fluctuate with changing water levels on large irrigation reservoirs.

---

Species Activity Mapping (SAM)
**PLAINS SHARP-TAILED GROUSE**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** An area which encompasses all mapped seasonal activity areas within the observed range of a population of plains sharp-tailed grouse.

**PRODUCTION AREA:** An area that includes 90% of sharp-tailed grouse nesting and brood rearing habitat. This is mapped as a buffer zone of 1.25 miles around active dancing grounds and clipped to Overall Range.

---

Species Activity Mapping (SAM)
**PREBLE'S MEADOW JUMPING MOUSE**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** An area which encompasses the probable range of Preble's Meadow Jumping Mouse along the Front Range of Colorado below 7600' elevation eastward to include those hydrounits identified by the Preble's Technical Working Group. Preble's Meadow Jumping Mouse is primarily associated with riparian corridors of small intermittent and perennial streams where riparian herbaceous and riparian shrub (primarily willow) dominate.

Species Activity Mapping (SAM)
**PRONGHORN ANTELOPE**
Seasonal Activity Area Definitions

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of pronghorn antelope.

**WINTER RANGE:** That part of the overall range where 90 percent of the individuals are located between the first heavy snowfall and spring green-up during the average five winters out of ten OR for a site specific period defined by CPW personnel for that DAU. Winter range is only delineated for migratory populations. On the Eastern Plains winter range is defined as specific areas where pronghorn are known to migrate to on a consistent basis.

**WINTER CONCENTRATION AREA:** That part of the winter range where animal densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.

**SEVERE WINTER RANGE:** That part of the winter range where 90% of the individuals are located when the annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

**CONCENTRATION AREAS:** That part of the overall range where densities are at least 200% greater than the surrounding area during a season other than winter.

**MIGRATION PATTERN:** A subjective indication of the general direction of the seasonal movements of pronghorn antelope.

**MIGRATION CORRIDOR:** A specific mappable site through which large numbers of animals migrate and the loss of which would change migration routes.

**PERENNIAL WATER:** Sources of water known to be important to antelope survival in late summer or other drought periods. A four-mile radius should be described around a point source and four mile band be drawn along a river or stream.

**RESIDENT POPULATION AREA:** An area that provides year round range for a population of pronghorns. The resident animals use all of the area all year long; it cannot be subdivided into seasonal ranges. A resident population may be found within the overall range of a larger, migratory population.

**LIMITED USE AREA:** An area within the overall range of pronghorn that is occasionally inhabited and/or contains a small, scattered population of antelope.

Species Activity Mapping (SAM)
**REPTILES**
Seasonal Activity Area Definitions

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of reptiles.

**POTENTIAL HABITAT:** The areas which meet environmental parameters necessary for the survival of a population of reptiles. Typically modeled based on vegetation and elevation.

**SPECIES:** Black-necked Gartersnake, Bullsnake, Coachwhip, Common Gartersnake, Common Kingsnake, Common Lesser Earless Lizard, Common Sagebrush Lizard, Common Side-blotched Lizard, Desert Nightsnake, Desert Spiny Lizard, Diploid Checkered Whiptail, Eastern Collared Lizard, Eastern Hog-nosed Snake, Glossy Snake, Great Plains Ratsnake, Great Plains Skink, Hernandez's Short-horned Lizard, Lined Snake, Long-nosed Leopard Lizard, Long-nosed Snake, Many-lined Skink, Massasauga, Milksnake, North American Racer, Northern Watersnake, Ornate Box Turtle, Ornate Tree Lizard, Painted Turtle, Plains Black-headed Snake, Plains Gartersnake, Plains Hog-nosed Snake, Plateau Striped Whiptail, Prairie Lizard, Prairie Rattlesnake, Ring-necked Snake, Round-tailed Horned Lizard, Six-lined Racerunner, Smith's Black-headed Snake, Smooth Greensnake, Snapping Turtle, Spiny Softshell, Striped Whipsnake, Terrestrial Gartersnake, Texas Threadsnake, Texas-horned Lizard, Tiger Whiptail, Triploid Checkered Whiptail, Variable Skink, Western Groundsnake, Western Ribbon Snake, Yellow Mud Turtle.

Species Activity Mapping (SAM)
**RING-NECKED PHEASANT**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all known seasonal activity areas within the range of a population of pheasants.

**CONCENTRATION AREA:** An area within the overall range in which pheasant densities are at least 200% greater than in the surrounding overall range.

Species Activity Mapping (SAM)
**RIVER OTTER**
Seasonal Activity Area Definitions

**OVERALL RANGE:** An area which encompasses all mapped seasonal activity areas within the observed range of a population of river otters.

**WINTER RANGE:** Areas used by otters during the period when ice cover is prevalent. Will normally, but not necessarily, be smaller than overall range.

**CONCENTRATION AREA:** Areas where otters are known to concentrate. Otter sightings and signs of otter activity are higher in these areas than in overall range.

---

Species Activity Mapping (SAM)
**SANDHILL CRANE**
(Greater & Lesser)
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** The area below 9500 feet which encompasses all known seasonal activity areas of the Colorado subpopulation of sandhill crane.

---

Species Activity Mapping (SAM)
**SCALED QUAIL**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of scaled quail.

**CONCENTRATION AREA:** Areas where Scaled Quail are known to concentrate; scaled quail sightings and signs of scaled quail activity are more frequent in these areas than in their overall range.

---

Species Activity Mapping (SAM)
**SWIFT FOX**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** Areas known to be utilized by swift fox in Colorado.

---

Species Activity Mapping (SAM)
**WHITE PELICAN**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of white pelicans.

**FORAGING AREA:** Those bodies of water used by a minimum of 15 birds on four days out of seven from April 15 through September 15.

**NESTING AREA:** Those islands and/or beach areas where any pelican nests are found. Human disturbance should be eliminated from these areas from April 15 to August 15.

---

Species Activity Mapping (SAM)
**WHITE-TAILED DEER**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of white-tailed deer.

**CONCENTRATION AREA:** Corridors of riparian habitat along river or stream courses that support higher populations of white-tailed deer, serve as travel corridors and are considered critical habitat for white-tailed deer.

**WINTER RANGE:** That part of the range of a species where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each DAU.

**HIGHWAY CROSSING:** Specific highway areas where white-tailed deer movements traditionally cross roads or railroads, presenting potential conflicts between white-tailed deer and motorists/trains. (More than six highway mortalities per mile of highway or railroad per year is a guide that may be used to indicate highway crossings).

---

Species Activity Mapping (SAM)
**WHITE-TAILED PRAIRIE DOG**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** An area which encompasses all known seasonal activity areas within the range of a population of prairie dogs.

**PRAIRIE DOG HABITAT AFFINITIES:**

**White-Tailed Prairie Dog:** An area typically associated with open shrublands, semi desert grasslands, and mountain valleys in northwestern and west-central Colorado.

---

Species Activity Mapping (SAM)
**WHITE-TAILED PTARMIGAN**
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** An area encompassing all known seasonal activity areas of the white-tailed ptarmigan.

**WINTER RANGE:** An area utilized in winter most frequently where drainage basins at or above treeline and stream courses below treeline from 2,591 to 3,810m elevation (8,500 to 12,500ft) where food (willow) and roosting sites (soft snow) are readily available. Winter range is typically defined from late October thru mid-April. The CDOW Special Report Number 38, Wintering Areas and Winter Ecology of White-tailed Ptarmigan in Colorado published in 1976 was used as the based data for development of the ptarmigan winter range dataset.

---

Species Activity Mapping (SAM)
**WILD TURKEY**
(Merriam's & Rio Grande)
Seasonal Activity Area Definitions

---

**OVERALL RANGE:** The area which encompasses all known seasonal activity areas within the observed range of a population of wild turkeys.

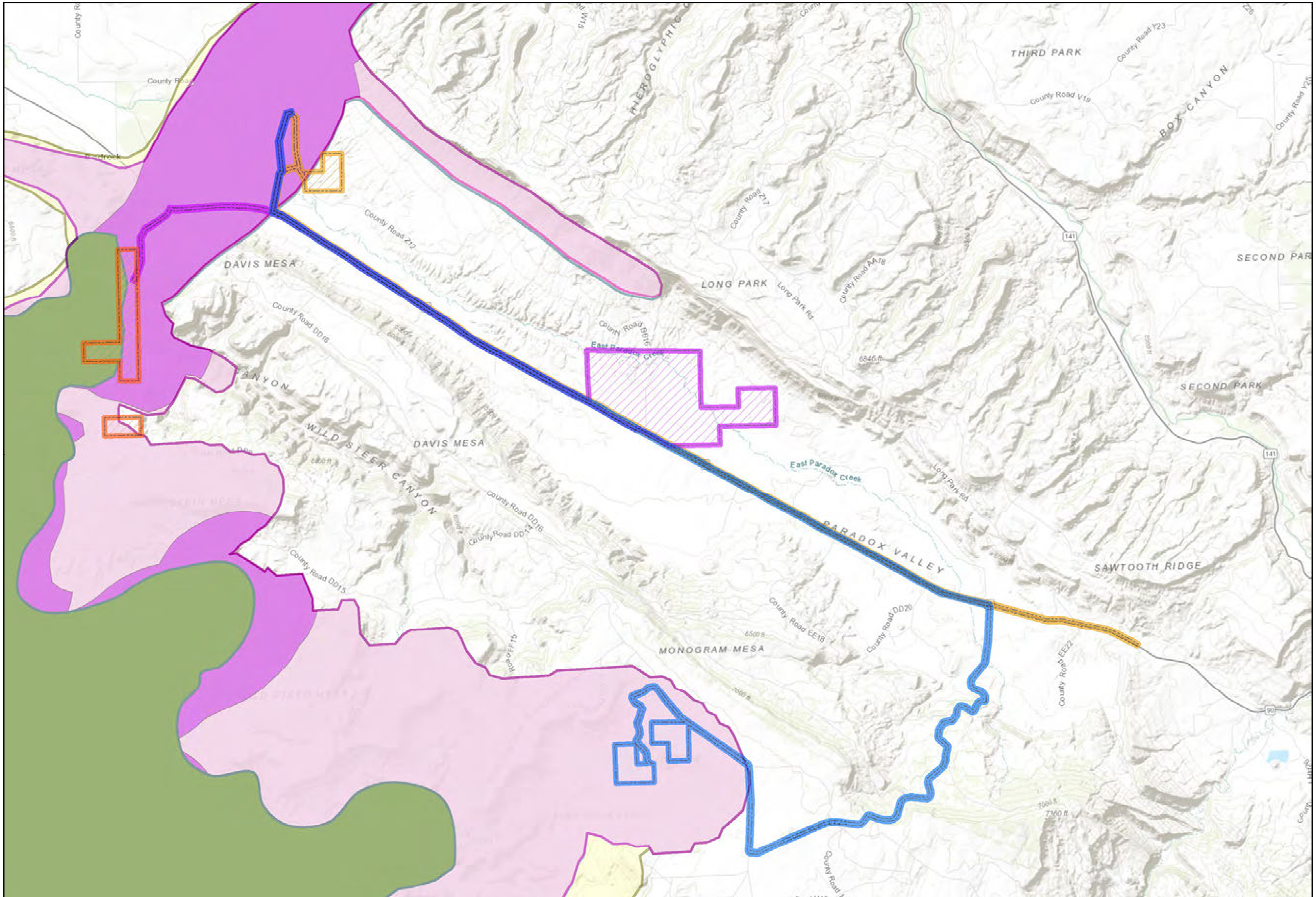
**WINTER RANGE:** That part of the overall range where 90% of the individuals are located from November 1 to April 1 during the average five winters out of ten.

**WINTER CONCENTRATION AREA:** That part of the winter range where densities are at least 200% greater than the surrounding winter range density.

**PRODUCTION AREA:** Those area(s) that are used by turkeys for nesting during the period from March 15 to August 15. Human activity should be restricted in these areas during this period.

**ROOST SITE:** Ponderosa pine and cottonwood trees of at least 10" dbh used by turkeys for diurnal and nocturnal perches.

# Attachment C – Maps




N

1:80,000
1 inch = 1.26 miles

# Desert Bighorn Sheep

Attachment C Map 1

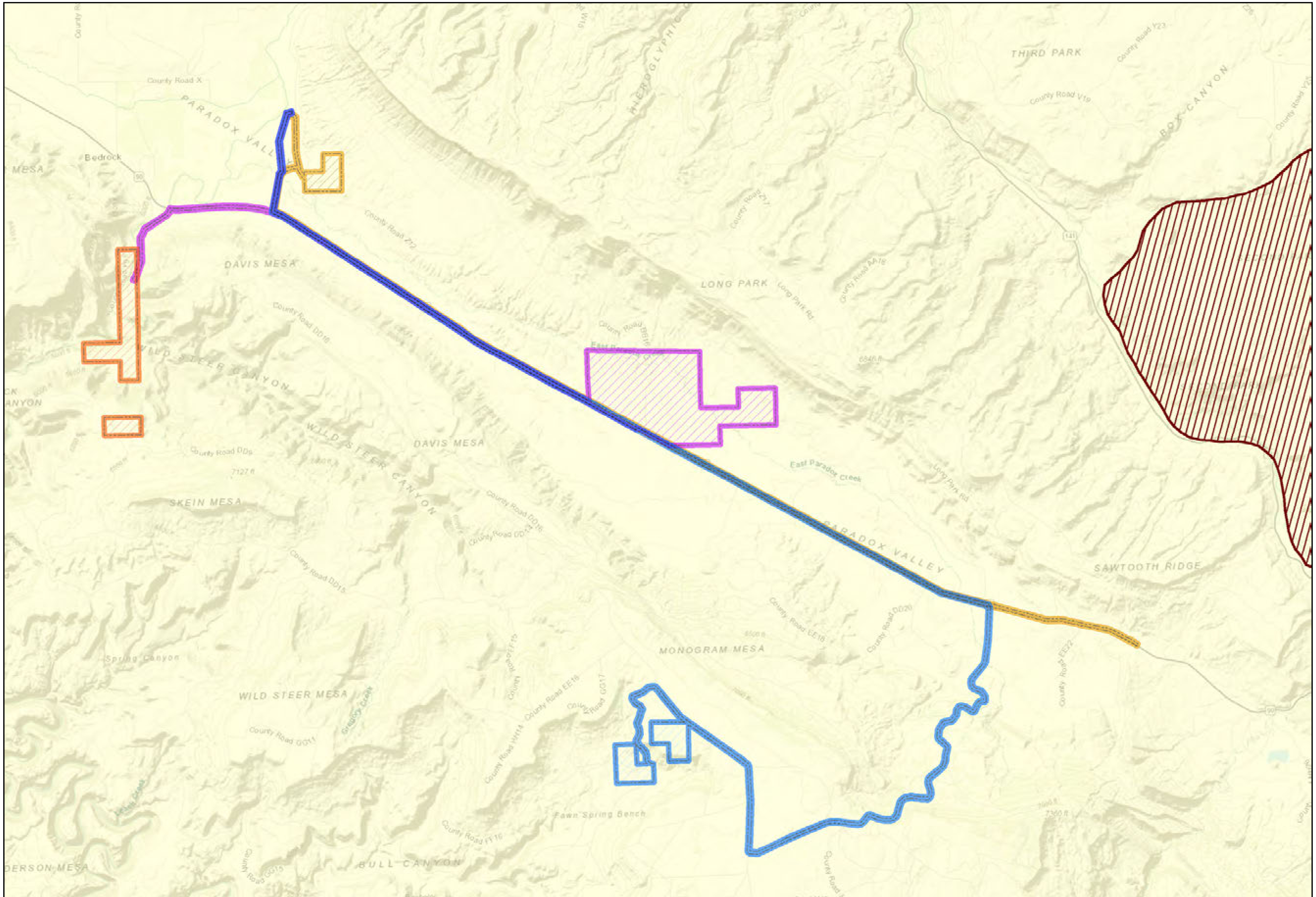
## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Summer Range
- Production Area
- Water Source
- Winter Range
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

# RECLAMATION
*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000
1 inch = 1.26 miles

# Black Bear

Attachment C Map 2

## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Human Conflict Area
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

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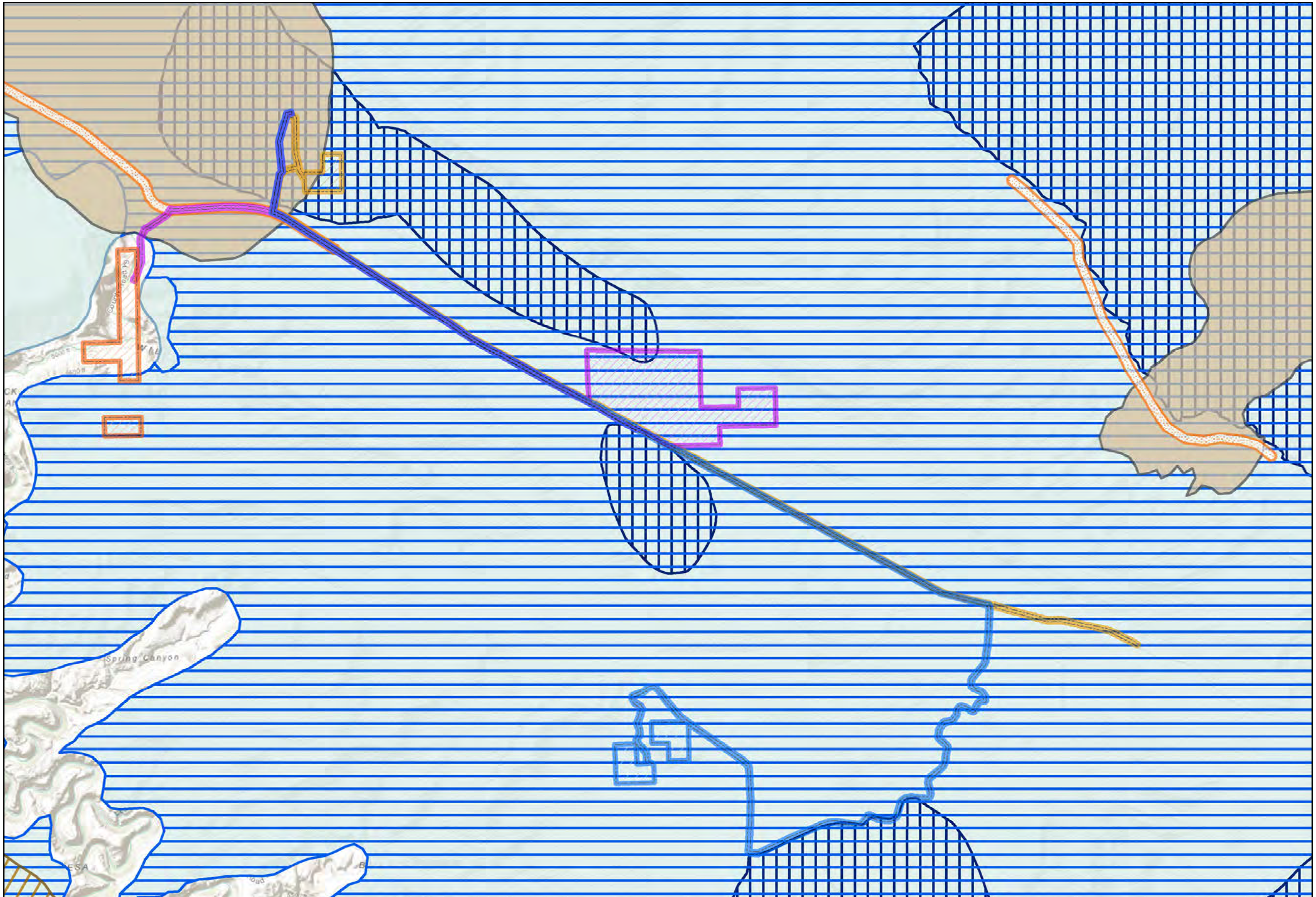
# RECLAMATION
*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000
1 inch = 1.26 miles

# Elk

Attachment C Map 3

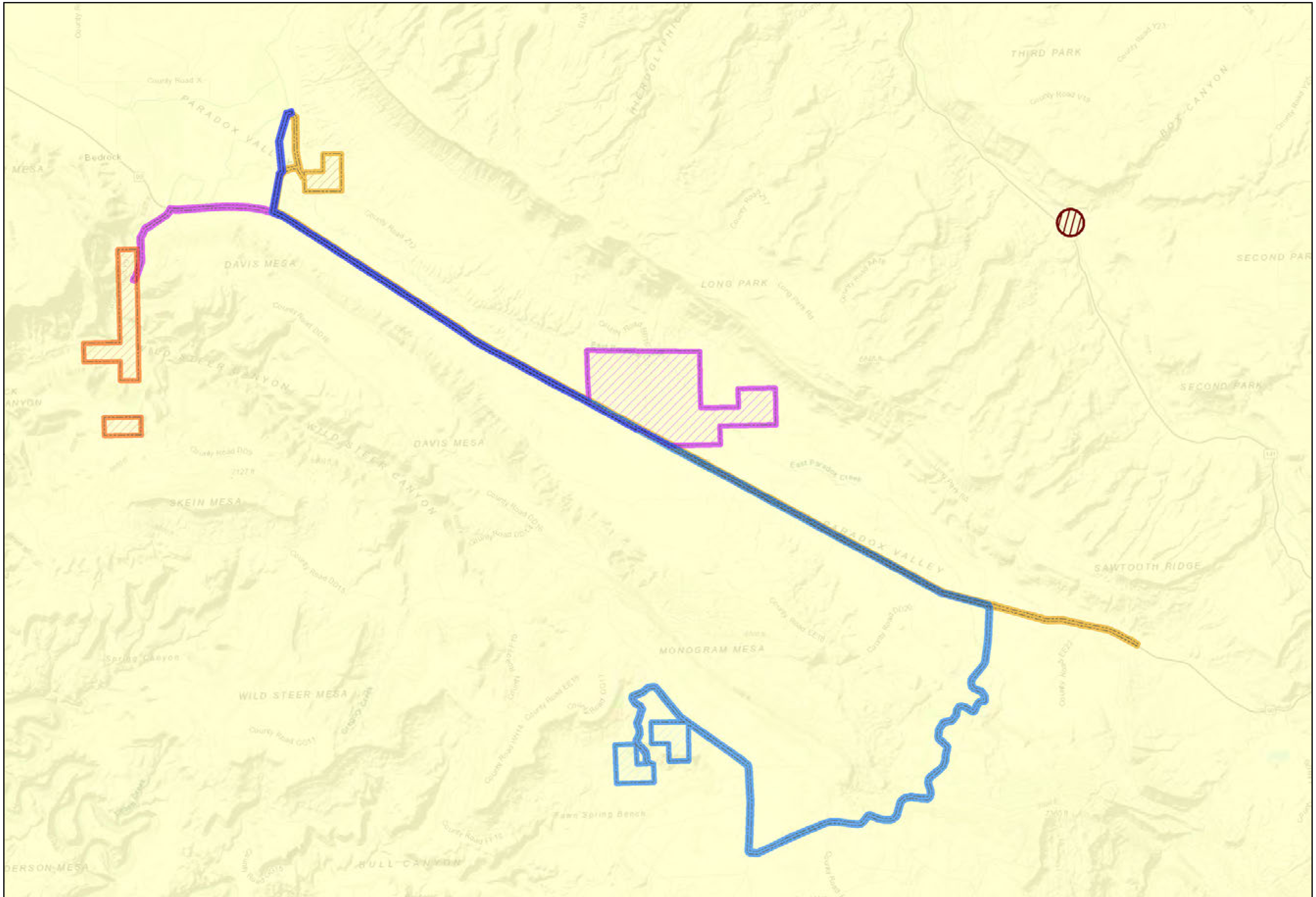
## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Highway Crossings
- Production Area
- Limited Use Area
- Resident Population Area
- Severe Winter Range
- Winter Concentration Area
- Winter Range
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

# RECLAMATION
*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000
1 inch = 1.26 miles

## Mountain Lion

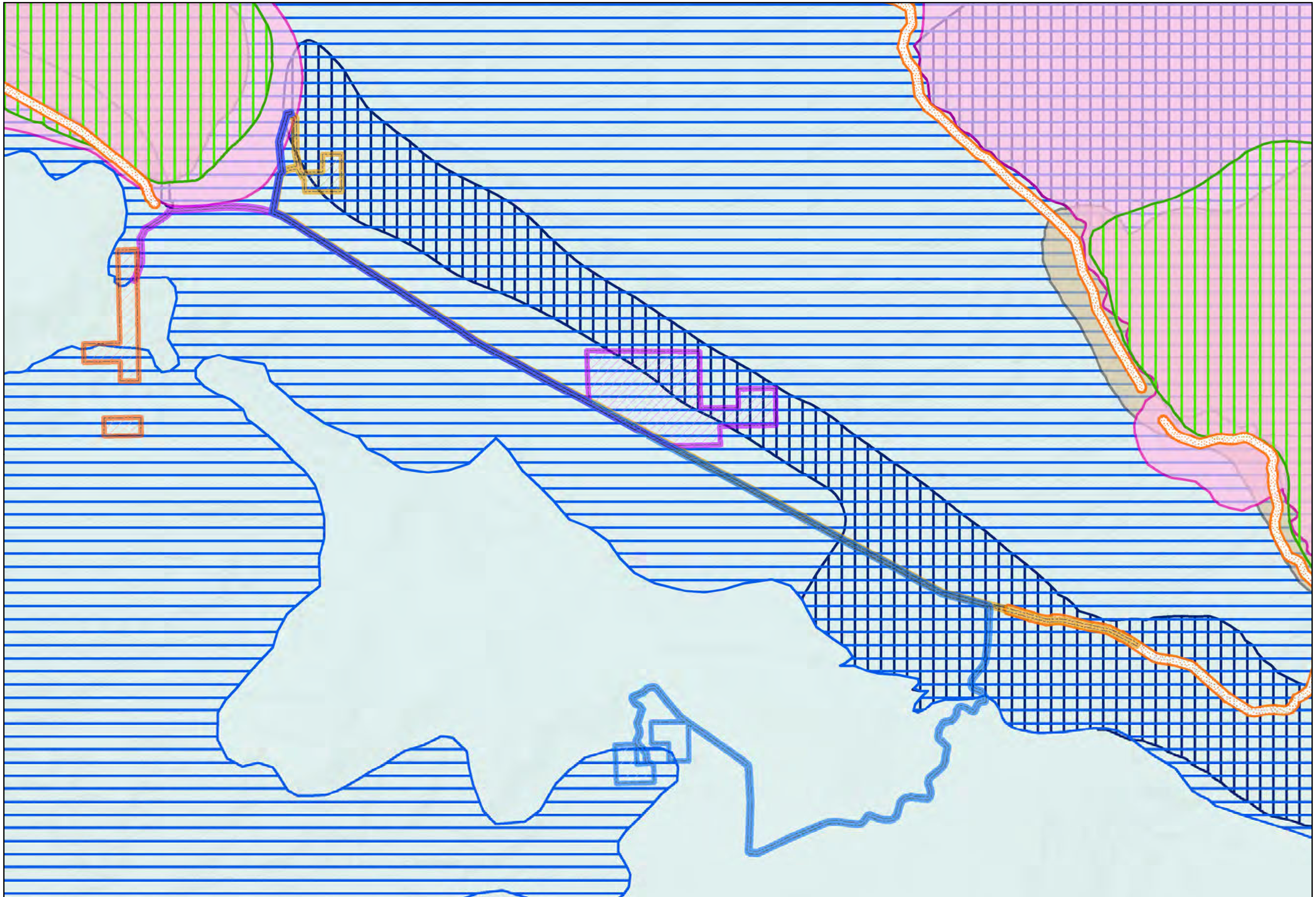
Attachment C Map 4

### Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Human Conflict Area
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

DISCLAIMER: No warranty is made by the Bureau of Reclamation as to the accuracy, reliability, or completeness of these data.Original data were compiled from various sources. This information may not meet National Map Accuracy Standards. This project was developed through digital means and may be updated without notice. Map produced by Western Colorado Area Office, Bureau of Reclamation, Grand Junction, CO



N
1:80,000
1 inch = 1.26 miles

# Mule Deer

Attachment C Map 5

## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Highway Crossing
- Concentration Area
- Summer Range
- Resident Population Area
- Severe Winter Range
- Winter Concentration Area
- Winter Range
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

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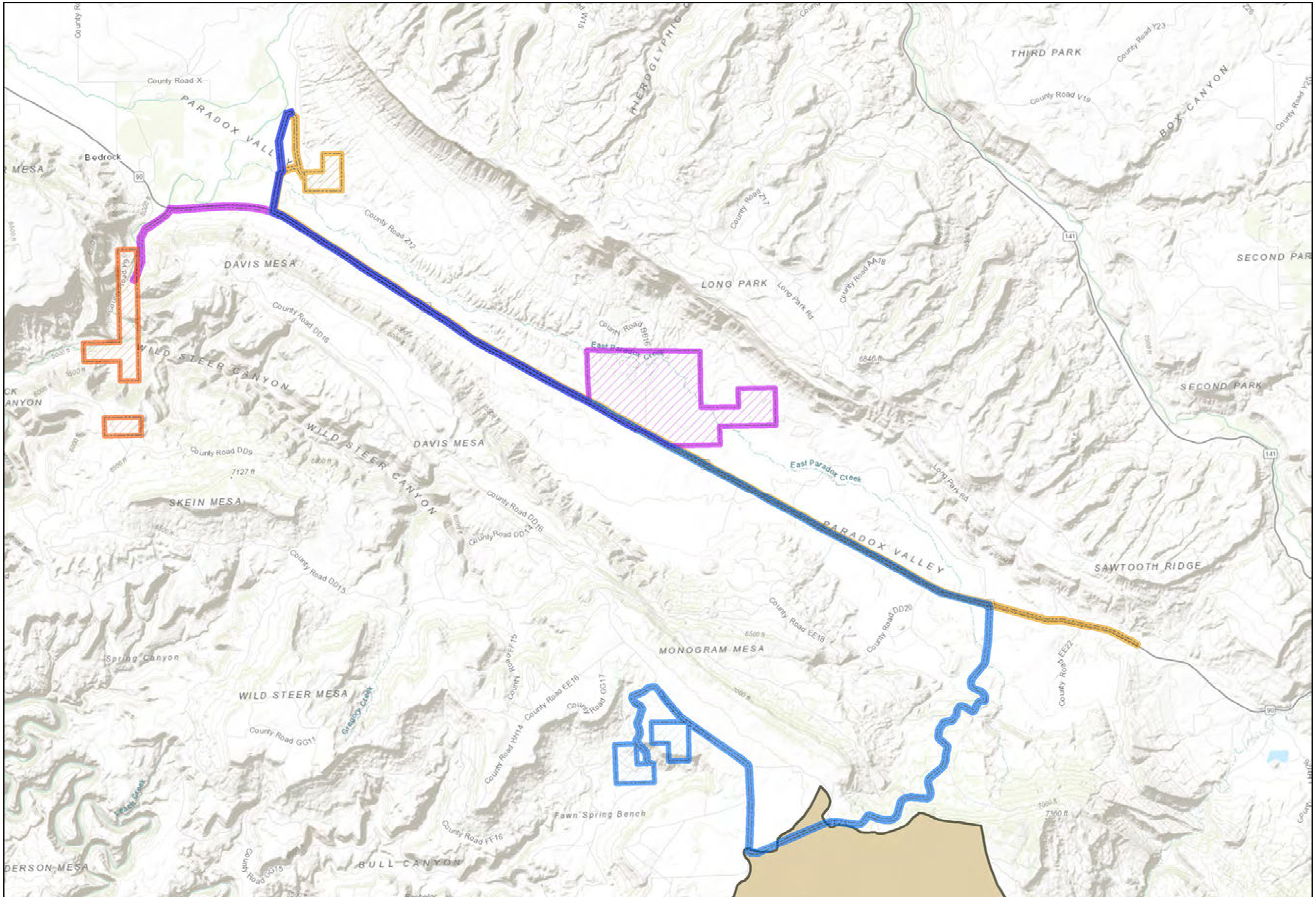
# RECLAMATION

*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000

1 inch = 1.26 miles

# Pronghorn

Attachment C Map 6

## Legend

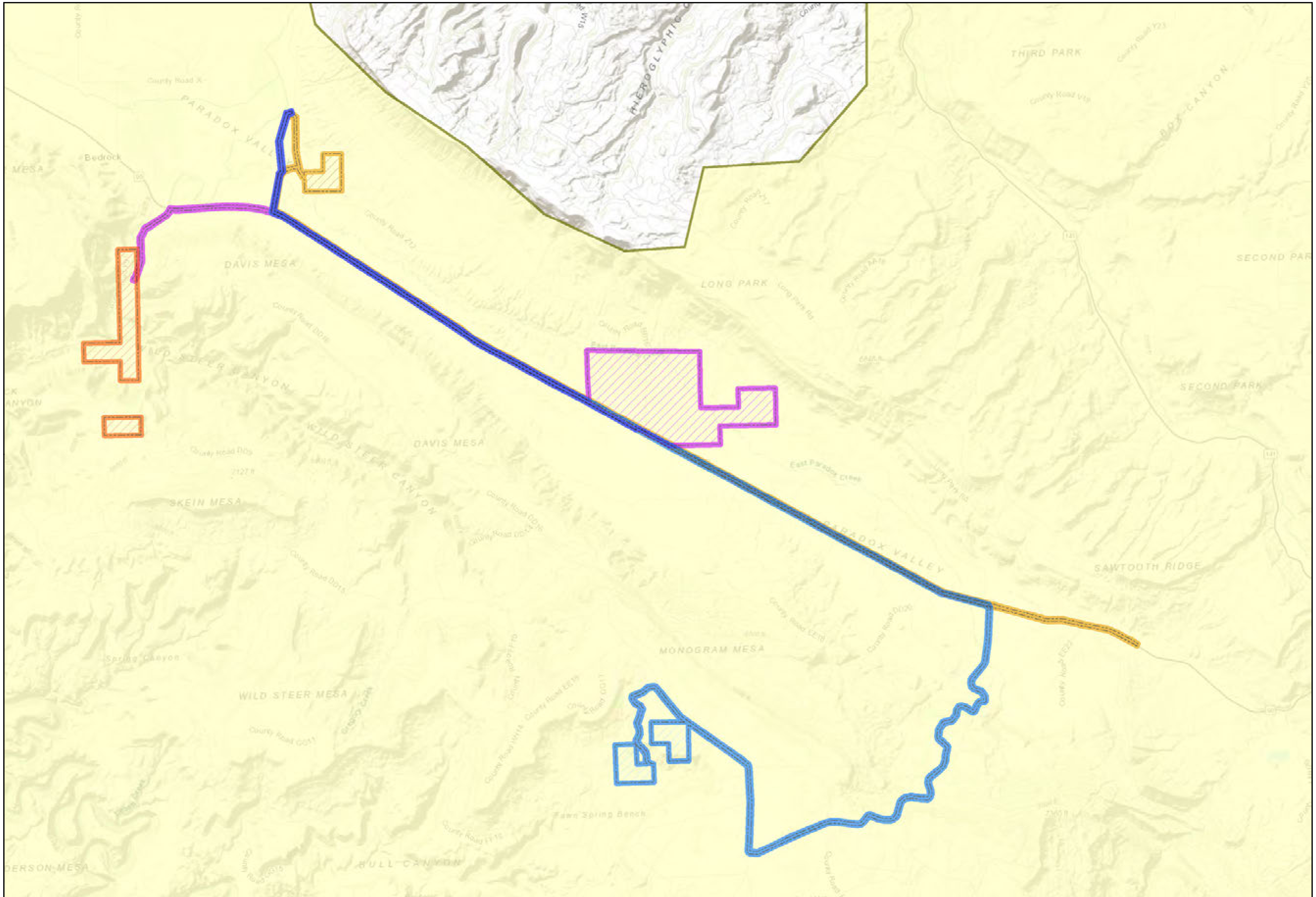
- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Resident Population Area
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

# RECLAMATION

*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000
1 inch = 1.26 miles

## Gunnison's Prairie Dog

Attachment C Map 7

### Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

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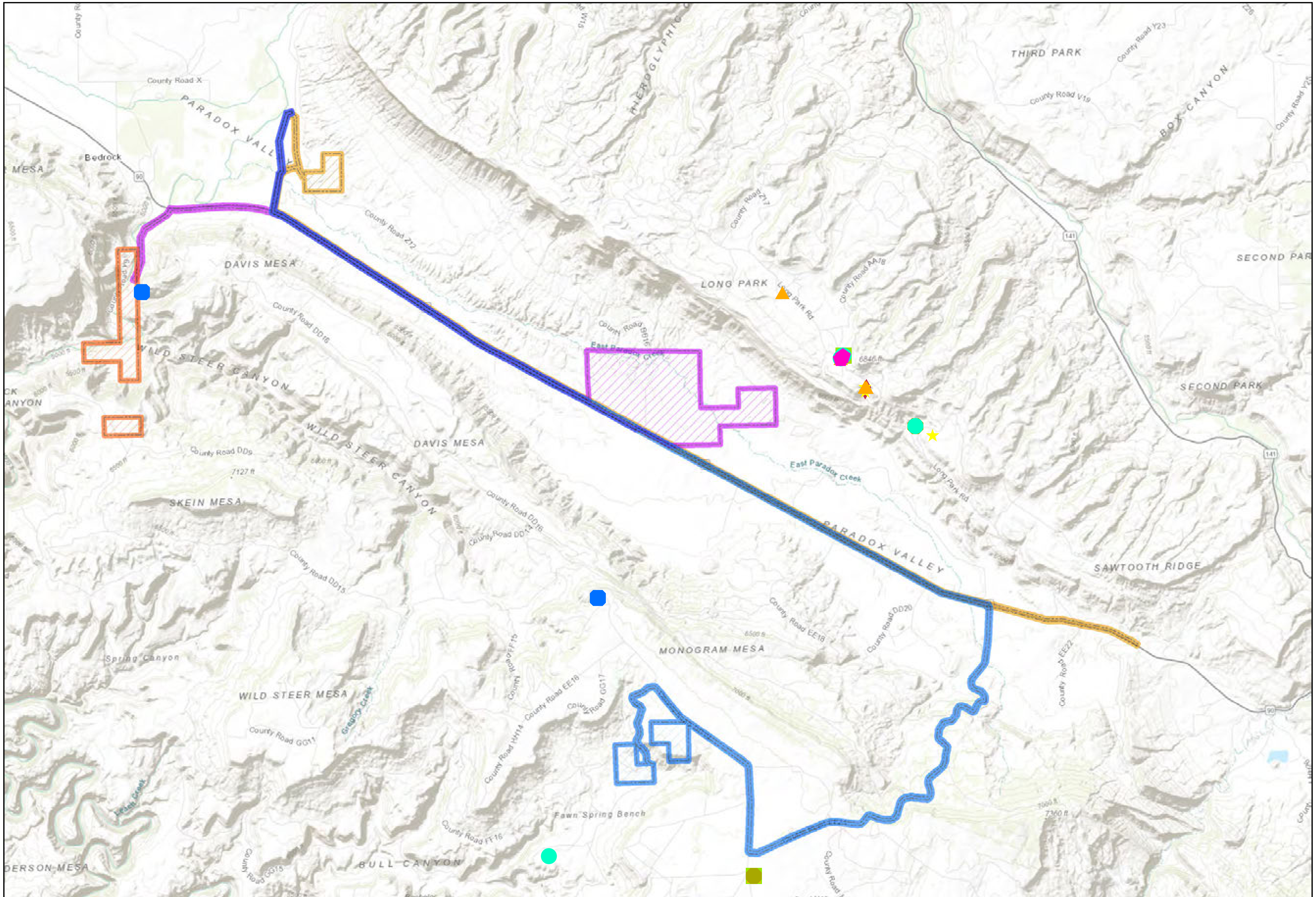
# RECLAMATION
*Managing Water in the West*

***Paradox Valley Salinity Control Project - Biological Review***




N

1:80,000
1 inch = 1.26 miles

# Bat Locations

Attachment C Map 8

## Legend

**Bat Species**

- Townsend's big-eared
- Big brown bat
- California myotis
- Western small-footed myotis
- Long-eared myotis
- Fringed myotis
- Long-legged myotis
- Yuma myotis
- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge

Data Source: CPW Species Activity Mapping (CPW 2018)

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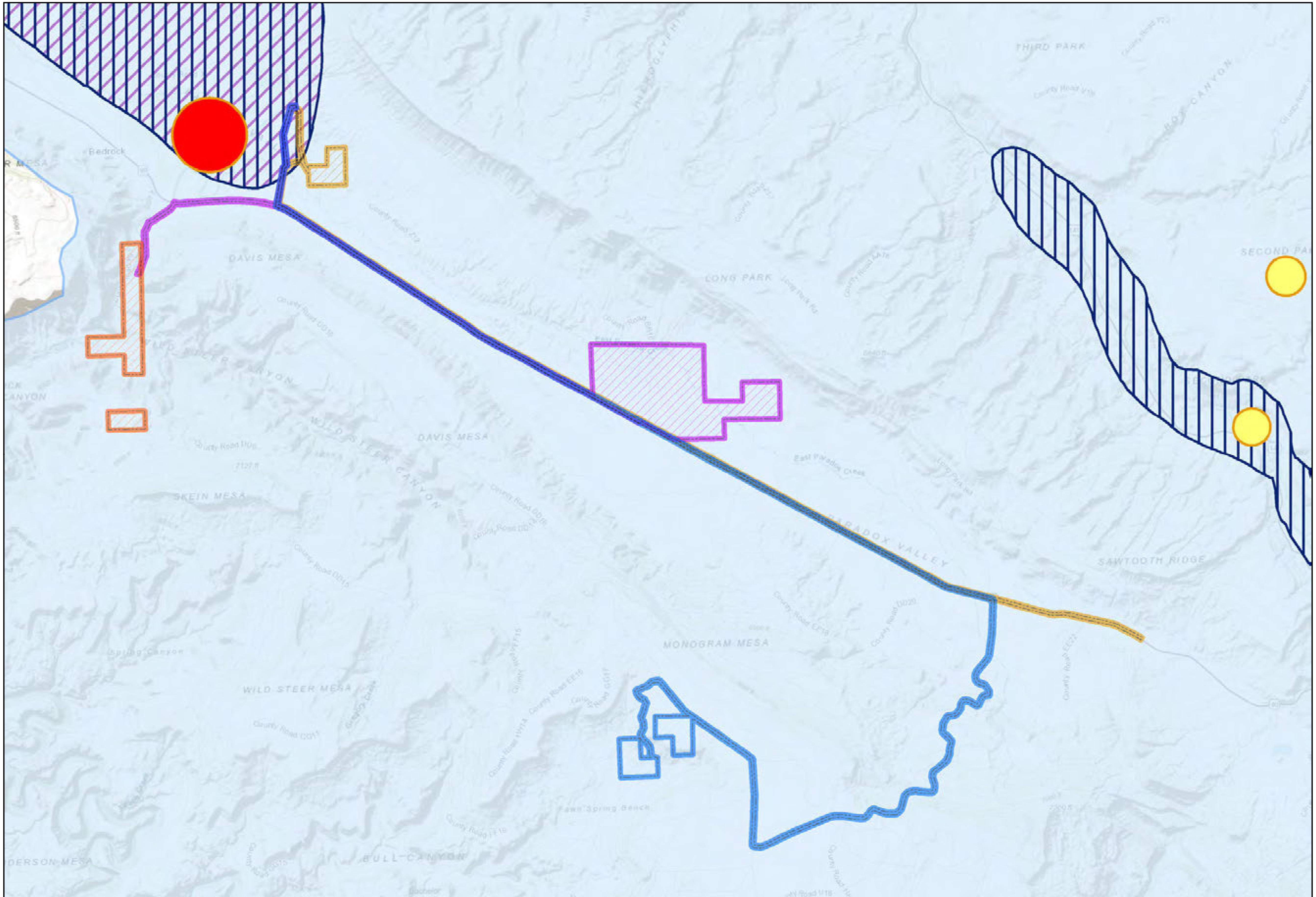



N

1:80,000
1 inch = 1.26 miles

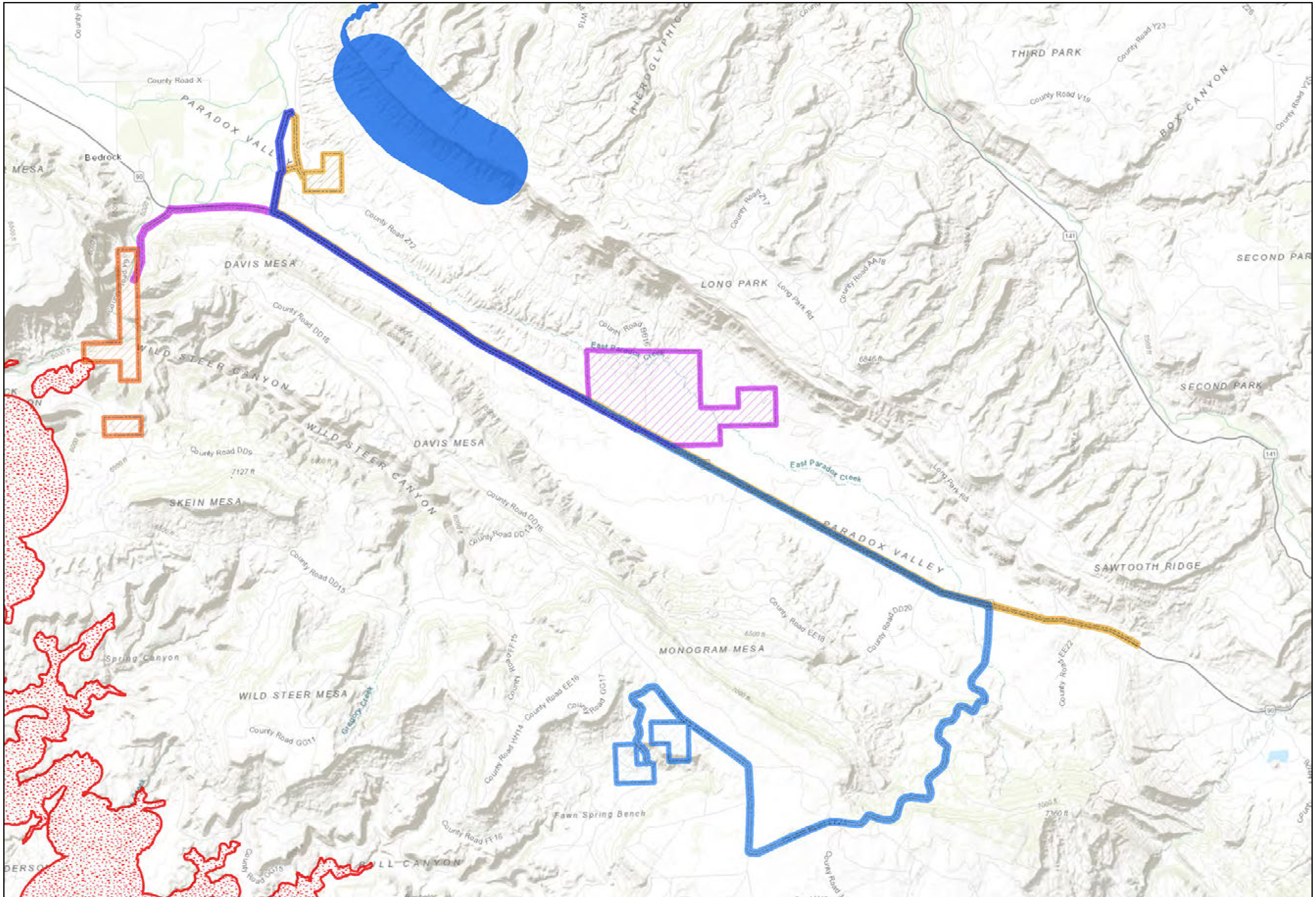
# Bald Eagle

Attachment C Map 9

## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Active Nest
- Roost Sites
- Winter Concentration
- Winter Forage
- Winter Range

Data Source: CPW Species Activity Mapping (CPW 2018)




N

1:80,000
1 inch = 1.26 miles

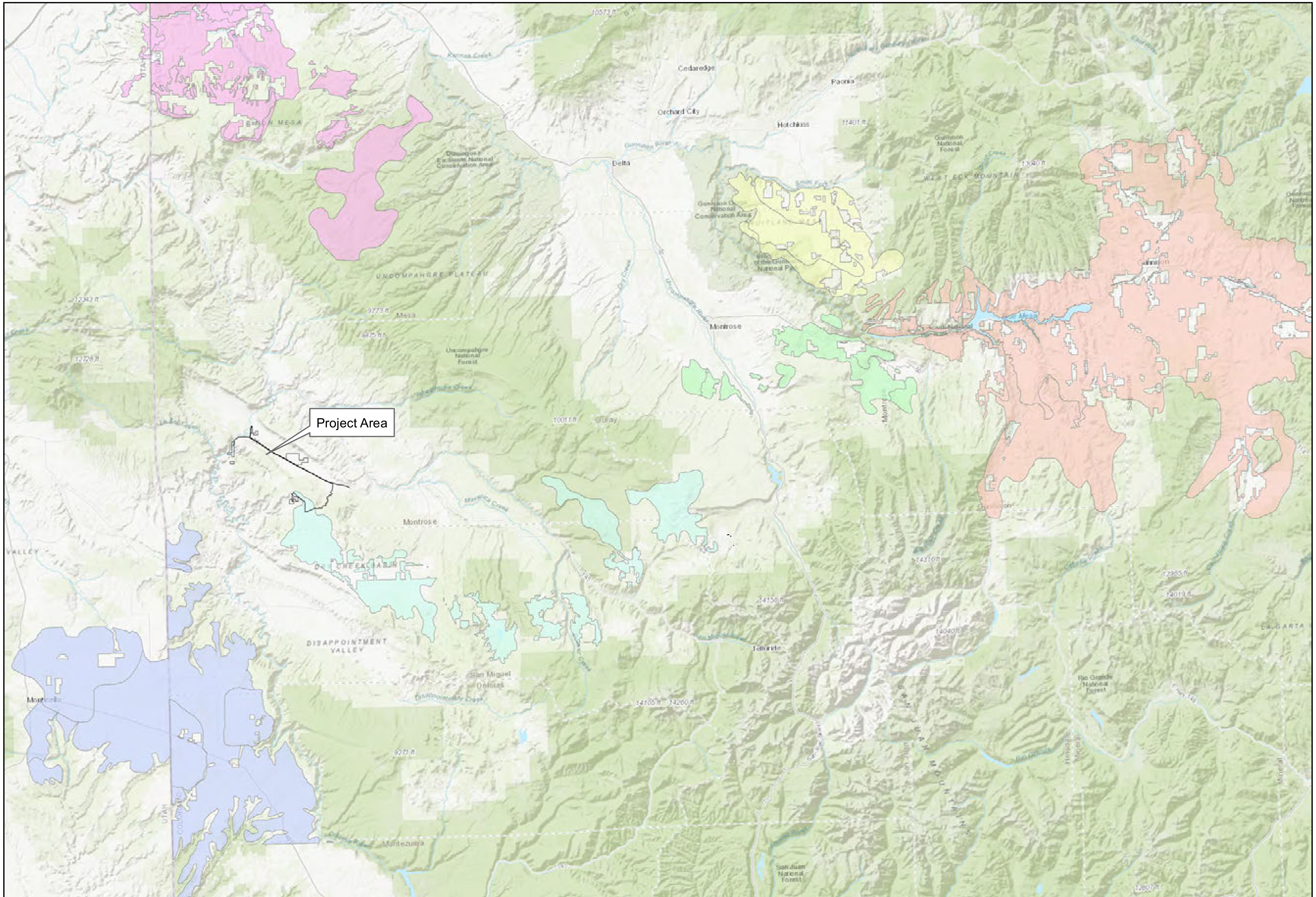
# Peregrine Falcon

Attachment C Map 10

## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Nesting Area
- Potential Nesting

Data Source: CPW Species Activity Mapping (CPW 2018)




N

1:688,952
1 inch = 10.87 miles

# Gunnison Sage Grouse (GUSG) Populations

Attachment C Map 11

## Legend

**GUSG Population**

- Cimarron/Cerro/Sims Mesa
- Crawford
- Gunnison Basin
- Monticello-Dove Creek
- Pinon Mesa
- San Miguel Basin

Data Source: FWS Environmental Conservation Online System

https://ecos.fws.gov/ecp/report/table/critical-habitat.html



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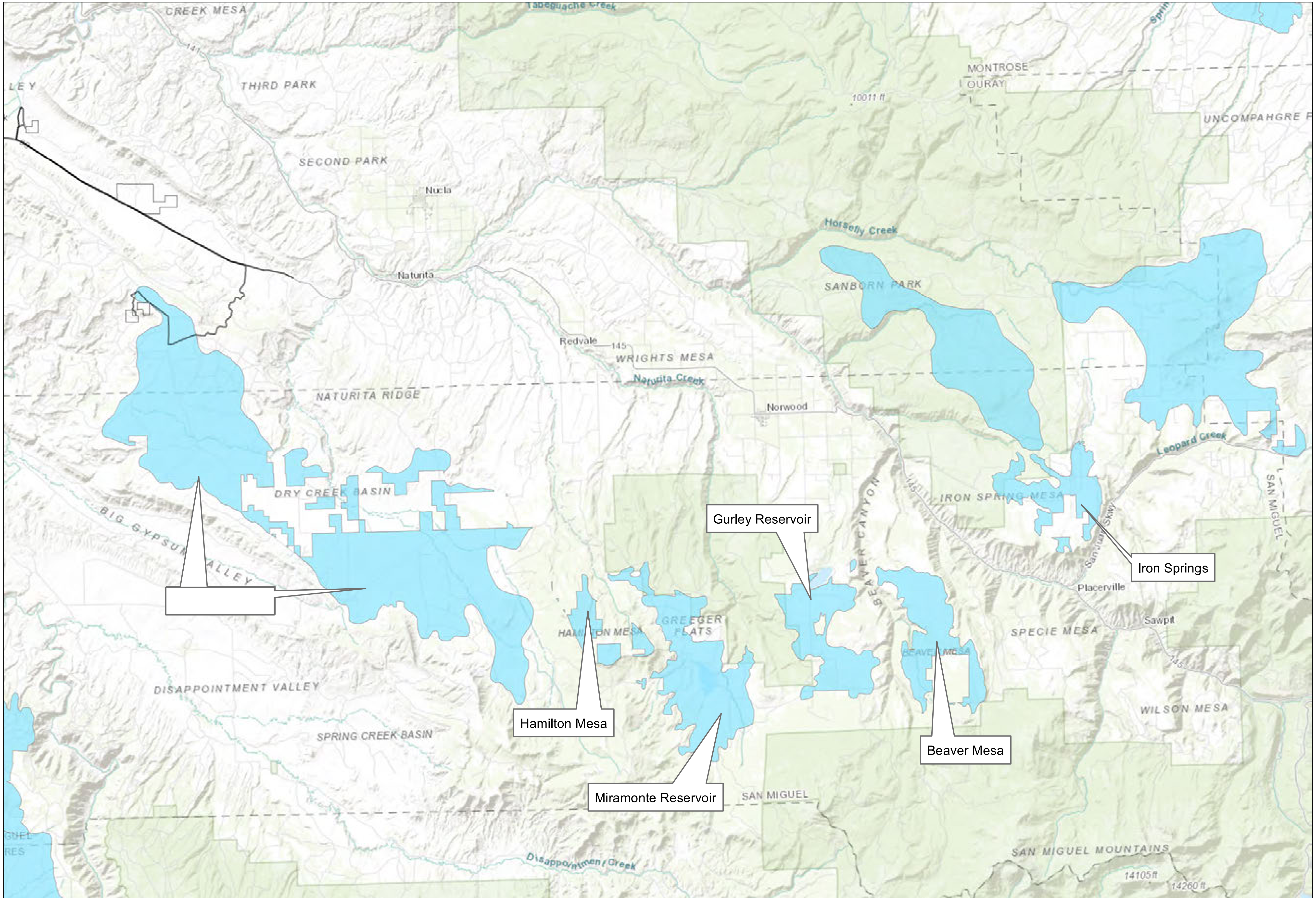


N

1:250,000
1 inch = 3.95 miles

# Gunnison Sage Grouse (GUSG) San Miguel Sub-populations

Attachment C Map 12

## Legend

GUSG Critical Habitat

Data Source: FWS Environmental Conservation Online System
https://ecos.fws.gov/ecp/report/table/critical-habitat.html

DISCLAIMER: This map is meant as an aide for Reclamation employees only. This map may graphically depict property boundaries. Property boundaries are for general reference only and do not represent legal descriptions.

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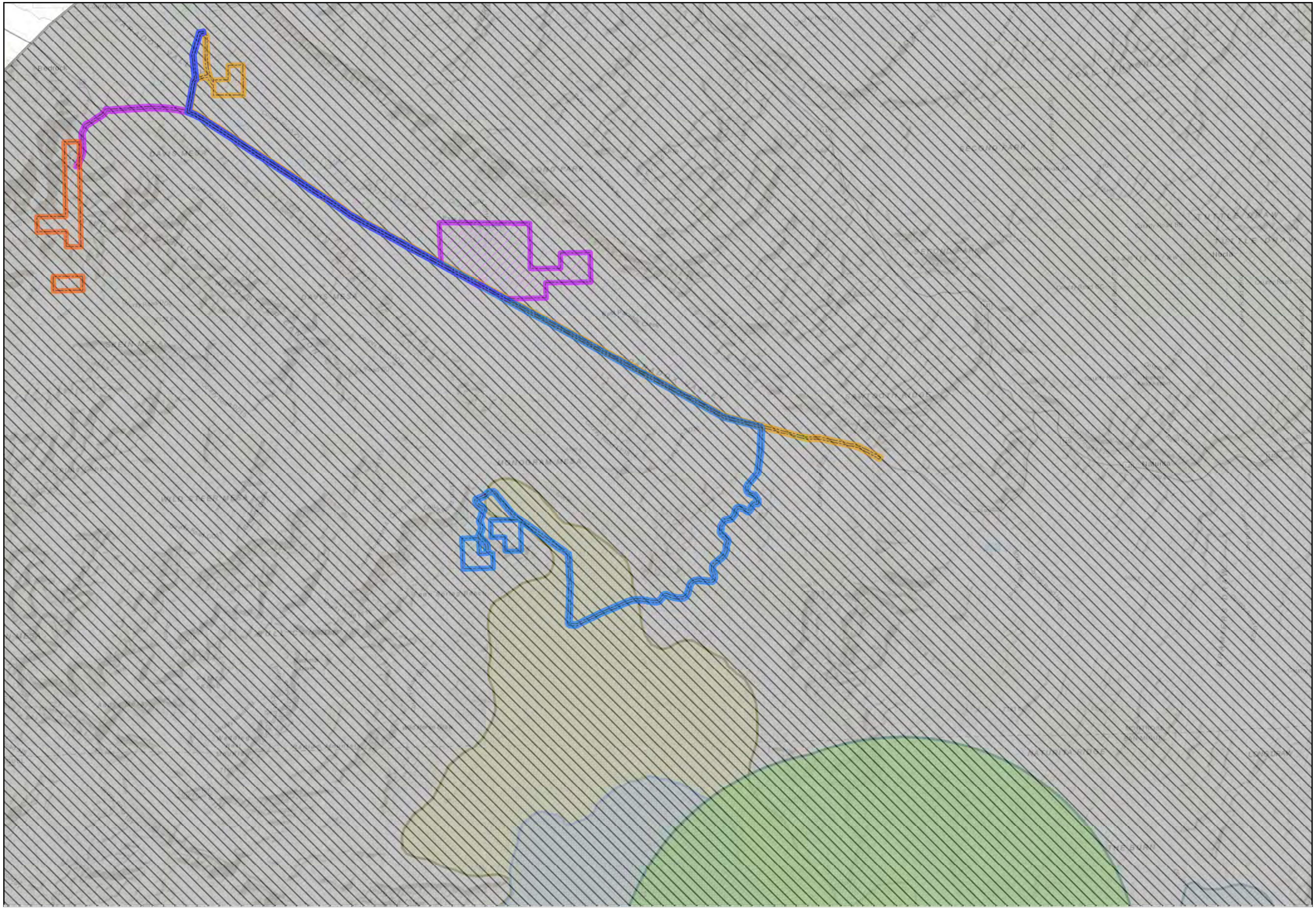

N

1:100,000
1 inch = 1.58 miles

# Gunnison Sage Grouse Habitat Use Areas

Attachment C Map 13

## Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Historic Habitat
- Production Area
- Severe Winter Range
- Winter Range
- Overall Range

Data Source: CPW Species Activity Mapping (CPW 2018)

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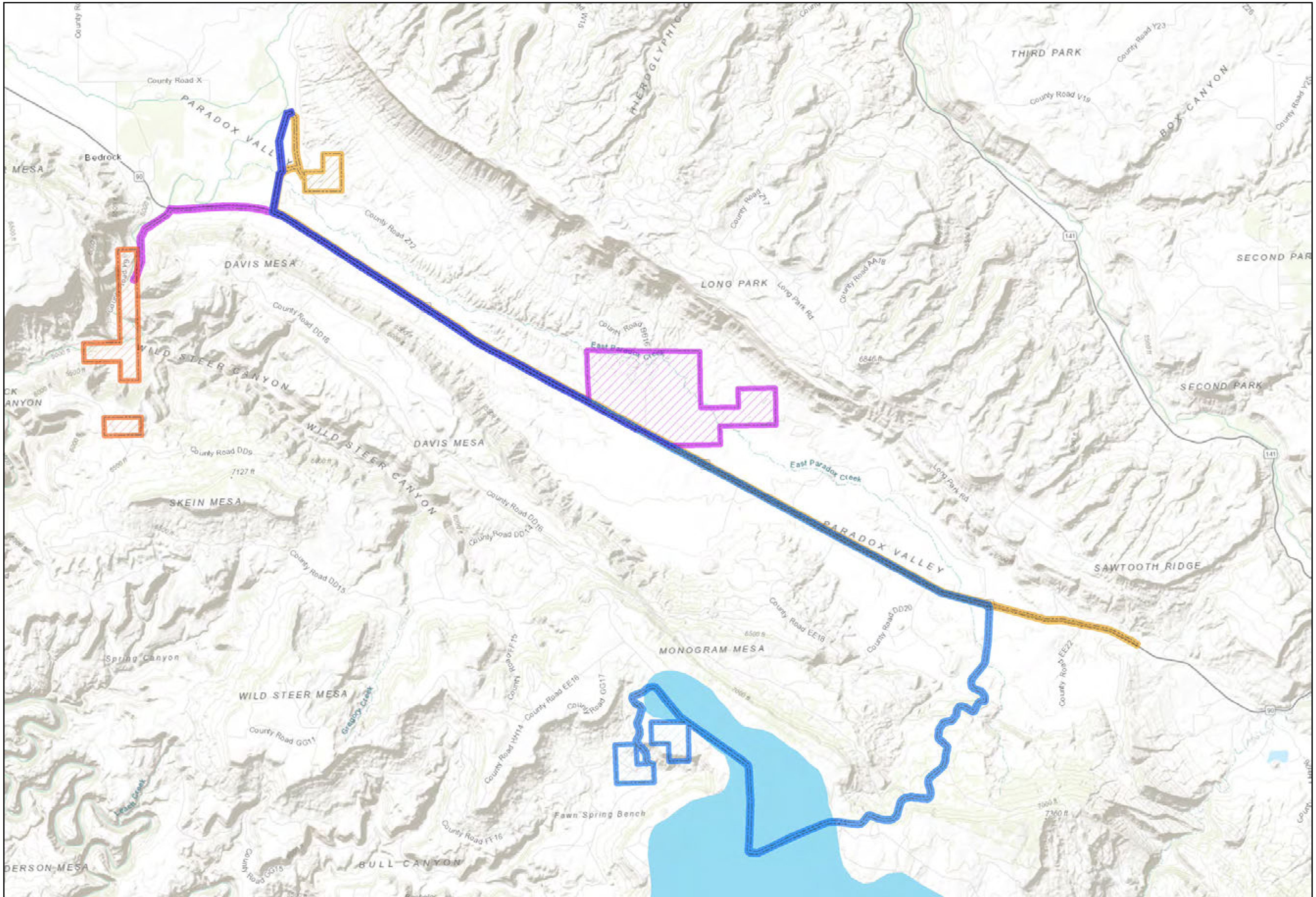


N

1:80,000

1 inch = 1.26 miles

## Gunnison Sage Grouse Critical Habitat

Attachment C Map 14

### Legend

- Alt B - Injection Well (Area B1)
- Alt B2- Injection Well (Area B2)
- Alt C- Evaporation Ponds
- Alt D- Zero Liquid Discharge
- Critical Habitat

Data Source: FWS Environmental Conservation Online System

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# Attachment D – BLM Sensitive Species List

| Common Name | Scientific Name | **Designation of other agencies:** CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | **Occurrence in BLM Districts/ Field Offices/NLCS Units** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| MAMMALS | | | | | | | | |
| Townsend's big-eared bat | *Corynorhinus townsendii pallescens* | G3G4T3T4/S2, FS, SGCN Tier 1, SC | GJ, CRV, WR | DENCA, MCNCA | TR, UN | CANM, DENCA, GGNCA | SLV, RG | BC |
| Gunnison's prairie dog | *Cynomys gunnisoni* | G5/S5, FS, SGCN Tier 1 | | | GN, TR, UN | | SLV, RG | BC |
| White-tailed prairie dog | *Cynomys leucurus* | G4/S4, FS, SGCN Tier 1 | GJ, K, LS, WR | DENCA | UN | DENCA, GGNCA | | |
| Black-tailed prairie dog | *Cynomys ludovicianus* | G4/S3, FS, SGCN Tier 1, SC | | | | | RG | |
| Spotted bat | *Euderma maculatum* | G4/S2, FS, SGCN Tier 1 | CRV, GJ, LS, WR | DENCA | TR, UN | CANM, DENCA, GGNCA | SLV | |
| Allen's (Mexican) big-eared bat | *Idionycteris phyllotis* | G4/S2S3, FS, SGCN Tier 2 | | | TR, UN | CANM | SLV | |
| Fringed myotis | *Myotis thysanodes* | G4/S3, FS, SGCN Tier 1 | GJ, CRV, WR | DENCA | TR, UN | CANM, DENCA, GGNCA | RG, SLV | BC |
| Rocky mountain bighorn sheep | *Ovis canadensis* | G4S4, SGCN Tier 2 | K, GJ, CRV | | UN GU TR | GGNCA | SLV RG | BC |
| Desert bighorn sheep | *Ovis canadensis nelsoni* | G4T4; FS, SGCN Tier 2 | GJ | DENCA MCNCA | TR, UN | DENCA, | | |
| Kit fox | *Vulpes macrotis* | G4/S1, FS, SGCN Tier 1, SE | GJ | DENCA MCNCA | UN | DENCA, GGNCA | | |
| Swift fox | *Vulpes velox* | G3/S3, FS, SGCN Tier 1, SC | | | | | RG, SLV | |
| BIRDS | | | | | | | | |

| **Common Name** | **Scientific Name** | **Designation of other agencies:** CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | **Occurrence in BLM Districts/ Field Offices/NLCS Units** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| Northern goshawk | *Accipter gentilis* | G5/S3B, FS, SGCN Tier 1 | GJ, CRV, K, LS, WR | | GN, TR, UN | | SLV, RG | BC |
| Golden Eagle | *Aquila chrysaetos* | G5/S3S4B, SGCN Tier 1, population stable, [ranking in other states: S4 in AZ, ID, NV, UT, WY] | GJ, CRV, K, LS, WR | MCNCA DENCA | GN, TR, UN | CANM, DENCA, GGNCA | SLV, RG | BC |
| Burrowing owl | *Athene cunicularia* | G4/S4B, FS, ST, SGCN Tier 1 | GJ, LS, WR, K | MCNCA DENCA | TR, UN GU | CANM, DENCA, GGNCA | SLV RG | BC |
| Ferruginous hawk | *Buteo regalis* | G4/S3BS4N, FS, SGCN Tier 1, SC | GJ, LS, K, WR CRV | DENCA MCNCA | TR, UN GU | DENCA, GGNCA | SLV, RG | BC |
| Greater sage-grouse | *Centrocercus urophasianus* | *Federal Candidate*, G3G4/S4, FS, SGCN Tier 1, SC | GJ, CRV, K, LS, WR | | | | | |
| Western snowy plover (breeding only) | *Charadrius alexandrinus nivosus* | G3T3/S1B, SGCN Tier 1, SC | | | | | SLV, RG | |
| Mountain plover | *Charadrius montanus* | G3/S2B, FS, SGCN Tier 1, SC | LS, K, WR | MCNCA | | | SLV, RG | |
| Black swift | *Cypseloides niger* | G4/S3B, FS, SGCN Tier 2 | CRV | | GN, TR | | SLV | |

| Common Name | Scientific Name | Designation of other agencies: CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | Occurrence in BLM Districts/ Field Offices/NLCS Units | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| American peregrine falcon | *Falco peregrinus anatum* | G4T4/S2B, FS, SGCN Tier 1, SC | LS, CRV, WR, K GJ | DENCA MCNCA | TR, UN GU | CANM, DENCA, GGNCA | SLV RG | BC |
| Bald eagle | *Haliaeetus leucocephalus* | G5/S1B/S3N, FS, SGCN Tier 1, SC | GJ, CRV, LS, WR, K | MCNCA DENCA | GN, TR, UN | DENCA, GGNCA CANM | SLV, RG | BC |
| Long-billed curlew (breeding only) | *Numenius americanus* | G5/S2B, FS, SGCN Tier 1, SC | | | | | SLV RG | |
| White-faced ibis (breeding only) | *Plegadis chihi* | G5/S2B, SGCN Tier 2 | | | | | SLV RG | |
| American white pelican (breeding only) | *Pelecanus erythrorhynchos* | G4/S1B, SGCN Tier 2, population stable | | | | | SLV, RG | |
| Brewer's sparrow | *Spizella berweri* | G5/S4B, SGCN Tier 1 | GJ, K, LS, WR CRV | DENCA MCNCA | GN, TR, UN | CANM, DENCA, GGNCA | SLV, RG | BC |
| Columbian sharp-tailed grouse | *Tympanuchus phasianellus columbian* | G4T3/S2, FS, SGCN Tier 1, population trend stable, SC [ranking in other states: S1 in ID, NV, OR, and WY] | LS, WR, K CRV | | TR, | | | |
| FISH | | | | | | | | |
| Bluehead sucker | *Catostomus discobolus* | G4/S4, FS, SGCN Tier 2 | GJ, CRV, K, LS, WR | DENCA MCNCA | TR, UN | CANM, DENCA, GGNCA | | |

| Common Name | Scientific Name | Designation of other agencies: CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | Occurrence in BLM Districts/ Field Offices/NLCS Units | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| Flannelmouth sucker | *Catostomas latipinnis* | G3G4/S3, FS, SGCN Tier 2 | GJ, CRV, K, LS, WR | DENCA MCNCA | TR, UN | CANM, DENCA, GGNCA | | |
| Mountain sucker | *Catostomas platyrhynchus* | G5/S2?, FS, SGCN Tier 2, SC | CRV, LS, WR | | | | | |
| Rio Grande sucker | *Catostomus plebeius* | G3G4/S1, FS, SGCN Tier 1, SE | | | | | SLV | |
| Arkansas darter | *Etheostoma cragini* | *Federal Candidate*, G3G4/S2, SGCN Tier 1, ST | | | | | RG | |
| Rio Grande chub | *Gila pandora* | G3/S1?, FS, SGCN Tier 1, SC | | | | | SLV | |
| Roundtail chub | *Gila robusta* | G3/ S2, FS, SGCN Tier 1, SC | GJ, CRV, LS, WR | DENCA MCNCA | TR, UN | CANM, DENCA, GGNCA | | |
| Colorado River cutthroat trout | *Oncorhynchus clarki pleuriticus* | G4T3/S3, FS, SGCN Tier 1, SC | GJ, CRV, K, LS, WR | DENCA | GN, TR, UN | DENCA, GGNCA | | |
| Rio Grande cutthroat trout | *Oncorhynchus clarki virginalis* | G4T3/S3, FS, SGCN Tier 1, SC | | | | | SLV, | |
| REPTILES | | | | | | | | |
| Midget faded rattlesnake | *Crotalus viridis concolor* | G5T4/S3?, SGCN Tier 2, SC | GJ, CRV, LS, WR | DENCA MCNCA | UN, TR | DENCA, GGNCA | | |
| Longnose leopard lizard | *Gambelia wislizenii* | G5/S1, SGCN Tier 2, SC | GJ | MCNCA | TR, UN | CANM | | |
| Common kingsnake | *Lampropeltis getula* | G5/S1, SGCN Tier 2, SC | | | | | RG | |
| Massasauga | *Sistrurus catenatus* | G3G4/S2, FS, SGCN Tier 1, SC | | | | | RG | |

| Common Name | Scientific Name | Designation of other agencies: CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | Occurrence in BLM Districts/ Field Offices/NLCS Units | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| AMPHIBIANS | | | | | | | | |
| Northern cricket frog | *Acris crepitans* | G5/SH, SGCN Tier 2, SC | | | | | RG | |
| Boreal toad | *Anaxyrus boreas boreas* | G4T1Q/S1, FS, SGCN Tier 1, SE, | LS, WR CRV KR | | GN, TR | | SLV RG | BC |
| Canyon treefrog | *Hyla arenicolor* | G5/ S2, SGCN Tier 2 | GJ | DENCA MCNCA | TR, UN | DENCA, GGNCA | | |
| Plain's leopard frog | *Rana blairi* | G5/S3, FS, SGCN Tier 1, SC | | | | | RG | |
| Northern leopard frog | *Rana pipiens* | G5/S3, FS, SGCN Tier 1, SC | GJ, CRV, K, LS, WR | DENCA MCNCA | TR, UN GN | DENCA, GGNCA CANM | RG, SLV | BC |
| INVERTEBRATES | | | | | | | | |
| Butterfly, Great Basin silverspot | *Speyeria nokomis nokomis* | G3T1/S1, FS, SGCN Tier 2 | GJ | | TR, UN | | | |
| PLANTS | | | | | | | | |
| Narrow-stem gilia | *Aliciella stenothyrsa (Gilia stenothyrsa)* | G3/S1 | GJ, WR | | | | | |
| Jones' bluestar | *Amsonia jonesii* | G4/S1 | GJ | MCNCA | TR | | | |
| Rydberg's golden columbine | *Aquilegia chrysantha var. rydbergii* | G4T1/S1; FS | | | | | RG | |
| Crandall's rockcress | *Arabis crandallii (Boechera crandallii)* | G4/S2 | | | UN | | RG | BC |
| Dwarf milkweed | *Asclepias uncialis* | G3G4/T2T3/S2; FS | | | | | RG | |
| Gunnison milkvetch | *Astragalus anisus* | G3/G2 | | | GN | | | |
| DeBeque milkvetch | *Astragalus debequaeus* | G2/S2 | GJ, CRV | | | | | |
| Horseshoe milkvetch | *Astragalus equisolensis* | G5T1/S1 | GJ | | | | | |
| Debris milkvetch | *Astragalus detritalis* | G3/S2 | WR | | | | | |

| Common Name | Scientific Name | Designation of other agencies: CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | Occurrence in BLM Districts/ Field Offices/NLCS Units | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| Duchesne milkvetch | *Astragalus duchesnensis* | G3/S1S2 | LS, WR | | | | | |
| Grand Junction milkvetch | *Astragalus linifolius* | G3Q/S3 | GJ | DENCA | UN | DENCA | | |
| Skiff milkvetch | *Astragalus microcymbus* | G1/S1 Federal candidate | | | GN | | | |
| Ferron's milkvetch | *Astragalus musiniensis* | G3/S1 | GJ | | | | | |
| Naturita milkvetch | *Astragalus naturitensis* | G2G3/S2S3 | GJ, CRV | DENCA | TR, UN | DENCA | | |
| Fisher milkvetch | *Astragalus piscator* | G2G3 | GJ | | | | | |
| San Rafael milkvetch | *Astragalus rafaelensis* | G3Q/S1 | GJ | | UN | | | |
| Ripley's milkvetch | *Astragalus ripleyi* | G3/S2; FS | | | | | SLV | |
| Sandstone milkvetch | *Astragalus sesquiflorus* | G3/S1? | | | UN | | | |
| Grand Junction suncup | *Camissonia eastwoodiae* | G2/S1 | GJ | MCNCA | | | | |
| Slender spiderflower | *Cleome multicaulis* | G2G3/S2S3 | | | | | SLV | |
| Crescent bugseed | *Corispermum navicula* | G1?/S1 | K | | | | | |
| Tufted cryptantha | *Cryptantha caespitosa (Oreocarya caespitosa)* | G3/S2 | LS, WR | | | | | |
| Gypsum Valley cateye | *Oreocarya revealii* | G2/S2 | GJ | | TR | | | |
| Osterhout's cryptantha | *Cryptantha osterhoutii (Oreocarya osterhoutii)* | G3/S1S2 | GJ | MCNCA | GN | | | |
| Rollins' cryptantha | *Cryptantha rollinsii (Oreocarya rollinsii)* | G4/S2 | WR | | | | | |
| Fragile rockbrake | *Cryptogramma stelleri* | G5/S2 | K | | TR | | SLV | |
| Uinta Basin springparsley | *Cymopterus duchesnensis* | G3/S1 | LS | | | | | |
| Kachina fleabane | *Erigeron kachinensis* | G2/S1 | GJ | | TR | | | |
| Singlestem buckwheat | *Eriogonum acaule* | G3/S1 | LS | | | | | |
| Brandegee's buckwheat | *Eriogonum brandegeei* | G1G2/S1S2; FS | | | | | RG | BC |
| Comb Wash buckwheat | *Eriogonum clavellatum* | G2/S1 | | | TR | | | |
| Colorado buckwheat | *Eriogonum coloradense* | G3/S2 | | | GN | | RG | |

| Common Name | Scientific Name | Designation of other agencies: CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | Occurrence in BLM Districts/ Field Offices/NLCS Units | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| Grand buckwheat | *Eriogonum contortum* | G3/S2 | GJ | MCNCA | | | | |
| Ephedra buckwheat | *Eriogonum ephedroides* | G3/S1 | WR | | | | | |
| Woodside buckwheat | *Eriogonum tumulosum* | G3Q/S2 | LS | | | | | |
| Clay hill buckwheat | *Eriogonum viridulum* | G4Q/S1 | LS | | | | | |
| Tufted frasera | *Frasera paniculata* | G4/S1 | GJ | | | | | |
| Cathedral Bluff dwarf gentian | *Gentianella tortuosa* | G3?/S1 | WR | | | | | |
| Lone Mesa snakeweed | *Gutierrezia elegans* | G1/S1 | | | TR | | | |
| Piceance bladderpod | *Physaria parviflora* | G2/S2 | GJ, WR | | | | | |
| Pagosa Springs bladderpod | *Physaria pruinosa* | G2/S2; FS | | | TR | | | |
| Uncompaghre bladderpod | *Physaria vicina* | G2/S2 | | DENCA | UN | DENCA, GGNCA | | |
| Adobe desertparsley | *Lomatium concinnum* | G2G3/S2S3 | | | UN | GGNCA | | |
| Canyonlands biscuitroot | *Lomatium latilobum* *(Aletes latilobus)* | G1/S1 | GJ | MCNCA | | | | |
| Paradox lupine | *Lupinus crassus* | G2/S2 | | | UN | | | |
| Dolores River skeletonplant | *Lygodesmia grandiflora* var. *doloresensis* | G1G2/S1S2 | GJ | MCNCA | TR | | | |
| Gold blazingstar | *Mentzelia chrysantha* *(Nuttallia chrysantha)* | G2/S2 | | | | | RG | |
| Royal Gorge blazingstar | *Mentzelia densa* *(Nuttallia densa)* | G2/S2 | | | | | RG | |
| Roan cliffs blazingstar | *Mentzelia rhizomata* *(Nuttallia argillosa, Mentzelia argillosa)* | G2/S2 | GJ, CRV | | | | | |
| Rock-loving neoparrya | *Neoparrya lithophila* *(Aletes lithophilus)* | G3/S3; FS | | | | | SLV, RG | |
| Flaming Gorge evening | *Oenothera acutissima* | G2/S2 | LS, | | | | | |

| **Common Name** | **Scientific Name** | **Designation of other agencies:** CNHP Global and State Ranking: G_/ S_; Forest Service Sensitive: FS; Colorado Parks and Wildlife: SGCN Tier_, and State Listed S_. | **Occurrence in BLM Districts/ Field Offices/NLCS Units** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northwest Dist. | | Southwest Dist. | | Front Range Dist. | |
| | | | FO | NLCS | FO | NLCS | FO | NLCS |
| primrose | | | WR | | | | | |
| Bessey locoweed | *Oxytropis besseyi var. obnapiformis* | G5T2/S2 | WR | | | | | |
| Few-flower ragwort | *Packera pauciflora* | G4G5/S1S2 | | | | | RG | |
| Colorado feverfew | *Parthenium ligulatum (Bolophyta ligulata)* | G3/S2 | LS, WR | | | | | |
| Aromatic Indian breadroot | *Pediomelum aromaticum* | G3/S2 | GJ | MCNCA | TR, UN | | | |
| Degener's beardtongue | *Penstemon degeneri* | G2/S2 | | | | | RG | |
| Gibbens' beardtongue | *Penstemon gibbensii* | G1G2/S1 | LS | | | | | |
| Graham's beardtongue | *Penstemon grahamii* | G2/S1 | WR | | | | | |
| Harrington's beardtongue | *Penstemon harringtonii* | G3/S3; FS | CRV, K | | | | | |
| White River beardtongue | *Penstemon scariosus* var. *albifluvis* | G4T1/S1 | WR | | | | | |
| Yampa beardtongue | *Penstemon acaulis var.yampaensis (Penstemon yampaensis)* | G3T2/S2 | LS | | | | | |
| Cushion bladderpod | *Physaria pulvinata* | G1/S1 | | | TR | | | |
| Pale blue-eyed grass | *Sisyrinchium pallidum* | G2G3/S2 | K | | | | RG, SLV | |
| Rock tansy | *Sphaeromeria capitata* | G3/S1 | LS | | | | | |
| Cathedral Bluff meadow-rue | *Thalictrum heliophilum* | G2/S2, FS | GJ, CRV, WR | | | | | |
| Hairy Townsend daisy | *Townsendia strigosa* | G4/S1 | LS, GJ | | | | | |
| Rolland's bulrush | *Trichophroum pumilum (Scirpus rollandii)* | G5/S2 | | | GN | | RG | |

*Field Offices:
CRV = Colorado River Valley
GJ = Grand Junction

GN = Gunnison
K = Kremmling
LS = Little Snake
RG = Royal Gorge
SLV = San Luis Valley
TR = Tres Rios
UN = Uncompahgre
WR = White River

*NLCS Units:
BC – Browns Canyon National Monument
CANM = Canyons of the Ancients NM
DENCA = Dominguez-Escalante NCA
GGNCA = Gunnison Gorge NCA
MCNCA = McInnis Canyons NCA

# Attachment E – FWS IPaC Report

# United States Department of the Interior

FISH AND WILDLIFE SERVICE
Western Colorado Ecological Services Field Office
445 West Gunnison Avenue, Suite 240
Grand Junction, CO 81501-5711
Phone: (970) 628-7180 Fax: (970) 245-6933
http://www.fws.gov/mountain-prairie/es/Colorado/
http://www.fws.gov/platteriver/


In Reply Refer To: March 23, 2020
Consultation Code: 06E24100-2017-SLI-0520
Event Code: 06E24100-2020-E-00532
Project Name: Paradox EIS

Subject: Updated list of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
- Wetlands

# Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

**Western Colorado Ecological Services Field Office**
445 West Gunnison Avenue, Suite 240
Grand Junction, CO 81501-5711
(970) 628-7180

## Project Summary

Consultation Code: 06E24100-2017-SLI-0520

Event Code: 06E24100-2020-E-00532

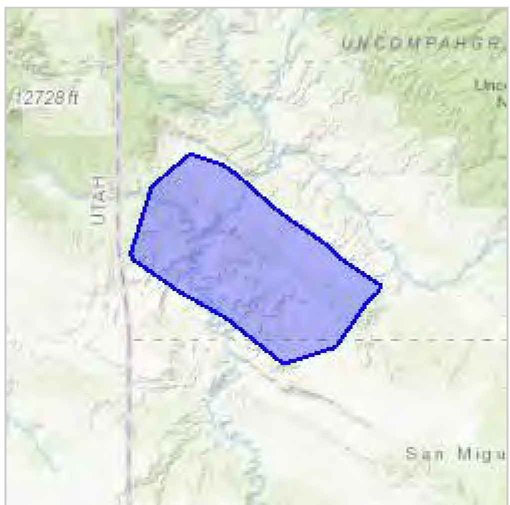
Project Name: Paradox EIS

Project Type: ** OTHER **

Project Description: Analyzing alternatives via an EIS regarding methods to control salinity in the Paradox Valley.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/38.254950312226626N108.86884868957468W




Counties: Montrose, CO | San Miguel, CO

# Endangered Species Act Species

There is a total of 8 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Note that 4 of these species should be considered only under certain conditions.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

## Birds

| NAME | STATUS |
|---|---|
| Gunnison Sage-grouse *Centrocercus minimus*<br>There is **final** critical habitat for this species. Your location overlaps the critical habitat.<br>Species profile: https://ecos.fws.gov/ecp/species/6040 | Threatened |
| Mexican Spotted Owl *Strix occidentalis lucida*<br>There is **final** critical habitat for this species. Your location is outside the critical habitat.<br>Species profile: https://ecos.fws.gov/ecp/species/8196 | Threatened |
| Yellow-billed Cuckoo *Coccyzus americanus*<br>Population: Western U.S. DPS<br>There is **proposed** critical habitat for this species. Your location is outside the critical habitat.<br>Species profile: https://ecos.fws.gov/ecp/species/3911<br>Species survey guidelines:<br>https://ecos.fws.gov/ipac/guideline/survey/population/6901/office/65413.pdf | Threatened |

## Fishes

| NAME | STATUS |
|---|---|
| Bonytail *Gila elegans* | Endangered |

There is **final** critical habitat for this species. Your location is outside the critical habitat.
This species only needs to be considered under the following conditions:

- Water depletions in the upper Colorado River basin adversely affect this species and its critical habitat. This species does not need to be considered if the project is outside of its occupied habitat and does not deplete water from the basin.

Species profile: https://ecos.fws.gov/ecp/species/1377

Colorado Pikeminnow (=squawfish) *Ptychocheilus lucius* — Endangered

Population: Wherever found, except where listed as an experimental population
There is **final** critical habitat for this species. Your location is outside the critical habitat.
This species only needs to be considered under the following conditions:

- Water depletions in the upper Colorado River basin adversely affect this species and its critical habitat. This species does not need to be considered if the project is outside of its occupied habitat and does not deplete water from the basin.

Species profile: https://ecos.fws.gov/ecp/species/3531

Greenback Cutthroat Trout *Oncorhynchus clarkii stomias* — Threatened

No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/2775

Humpback Chub *Gila cypha* — Endangered

There is **final** critical habitat for this species. Your location is outside the critical habitat.
This species only needs to be considered under the following conditions:

- Water depletions in the upper Colorado River basin adversely affect this species and its critical habitat. This species does not need to be considered if the project is outside of its occupied habitat and does not deplete water from the basin.

Species profile: https://ecos.fws.gov/ecp/species/3930

Razorback Sucker *Xyrauchen texanus* — Endangered

There is **final** critical habitat for this species. Your location is outside the critical habitat.
This species only needs to be considered under the following conditions:

- Water depletions in the upper Colorado River basin adversely affect this species and its critical habitat. This species does not need to be considered if the project is outside of its occupied habitat and does not deplete water from the basin.

Species profile: https://ecos.fws.gov/ecp/species/530

## Critical habitats

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

| NAME | STATUS |
|---|---|
| Gunnison Sage-grouse *Centrocercus minimus* | Final |

https://ecos.fws.gov/ecp/species/6040#crithab

# USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

THERE ARE NO REFUGE LANDS OR FISH HATCHERIES WITHIN YOUR PROJECT AREA.

# Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

---

1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the E-bird data mapping tool (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

| NAME | BREEDING SEASON |
| --- | --- |
| Brewer's Sparrow *Spizella breweri*<br>This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA<br>https://ecos.fws.gov/ecp/species/9291 | Breeds May 15 to Aug 10 |
| Grace's Warbler *Dendroica graciae*<br>This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA | Breeds May 20 to Jul 20 |

# Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ “Proper Interpretation and Use of Your Migratory Bird Report” before using or attempting to interpret this report.

**Probability of Presence** (■)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

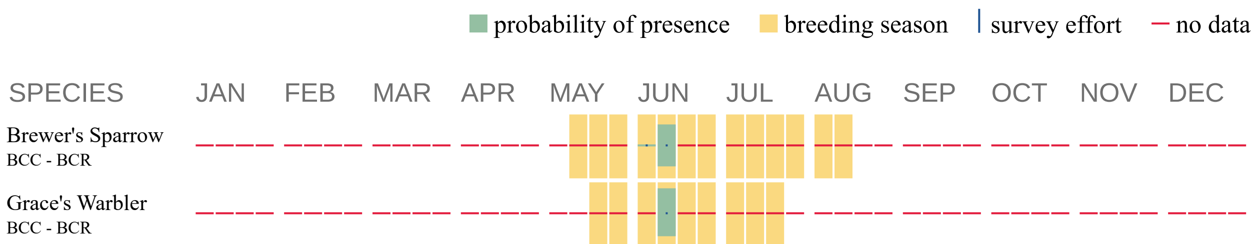
**Breeding Season** (■)
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

**Survey Effort** (|)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

**No Data** (–)
A week is marked as having no data if there were no survey events for that week.

**Survey Timeframe**

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.




Additional information can be found using the following links:

- Birds of Conservation Concern http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php
- Measures for avoiding and minimizing impacts to birds http://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php
- Nationwide conservation measures for birds http://www.fws.gov/migratorybirds/pdf/management/nationwidestandardconservationmeasures.pdf

## Migratory Birds FAQ

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures and/or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the AKN Phenology Tool.

**What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?**
The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets .

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

**How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?**
To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

**What are the levels of concern for migratory birds?**
Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

**Details about birds that are potentially affected by offshore projects**
For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

**What if I have eagles on my list?**
If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

**Proper Interpretation and Use of Your Migratory Bird Report**
The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ “What does IPaC use to generate the migratory birds potentially occurring in my specified location”. Please be aware this report provides the “probability of presence” of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the “no data” indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ “Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds” at the bottom of your migratory bird trust resources page.

# Wetlands

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

FRESHWATER POND

- Palustrine

RIVERINE

- Riverine

# Attachment F – eBird Bird Observation Species List

https://ebird.org/barchart?byr=1900&eyr=2019&bmo=1&emo=12&r=US-CO-085,US-CO-113

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# Bird Observations

**Date Range:** Change Date

Jan-Dec, 1900-2019

Change Location [ San Miguel ] [ Montrose ]

302 species (+86 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Snow Goose

Ross's Goose

Snow/Ross's Goose

Greater White-fronted Goose

Cackling Goose

Canada Goose

Cackling/Canada Goose

goose sp.

Trumpeter Swan

Tundra Swan

Wood Duck

Blue-winged Teal

Cinnamon Teal

Blue-winged x Cinnamon Teal (hybrid)

Blue-winged/Cinnamon Teal

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Northern Shoveler

Blue-winged Teal x Northern Shoveler (hybrid)

Gadwall

American Wigeon

Mallard

Mallard (Domestic type)

Mexican Duck

Mallard x Mexican Duck (hybr id)

Northern Pintail

Green-winged Teal

teal sp.

dabbling duck sp.

Canvasback

Redhead

Ring-necked Duck

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Greater Scaup

Lesser Scaup

Greater/Lesser Scaup

Surf Scoter

White-winged Scoter

scoter sp.

Long-tailed Duck

Bufflehead

Common Goldeneye

Barrow's Goldeneye

Common/Barrow's Goldeneye

Hooded Merganser

Common Merganser

Red-breasted Merganser

Ruddy Duck

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

duck sp.

Gambel's Quail

Chukar

Ring-necked Pheasant

Gunnison Sage-Grouse

White-tailed Ptarmigan

Dusky Grouse

Wild Turkey

Pied-billed Grebe

Horned Grebe

Red-necked Grebe

Eared Grebe

Horned/Eared Grebe

Western Grebe

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clark's Grebe | | | | | | | | | | | | |
| Western/Clark's Grebe | | | | | | | | | | | | |
| grebe sp. | | | | | | | | | | | | |
| Rock Pigeon | | | | | | | | | | | | |
| Band-tailed Pigeon | | | | | | | | | | | | |
| Eurasian Collared-Dove | | | | | | | | | | | | |
| Inca Dove | | | | | | | | | | | | |
| White-winged Dove | | | | | | | | | | | | |
| Mourning Dove | | | | | | | | | | | | |
| pigeon/dove sp. | | | | | | | | | | | | |
| Yellow-billed Cuckoo | | | | | | | | | | | | |
| Black-billed Cuckoo | | | | | | | | | | | | |
| Lesser Nighthawk | | | | | | | | | | | | |
| Common Nighthawk | | | | | | | | | | | | |
| nighthawk sp. | | | | | | | | | | | | |
| Common Poorwill | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black Swift | | | | | | | | | | | | |
| Chimney Swift | | | | | | | | | | | | |
| White-throated Swift | | | | | | | | | | | | |
| swift sp. | | | | | | | | | | | | |
| Ruby-throated Hummingbird | | | | | | | | | | | | |
| Black-chinned Hummingbird | | | | | | | | | | | | |
| Broad-tailed Hummingbird | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rufous Hummingbird | | | | | | | | | | | | |
| Calliope Hummingbird | | | | | | | | | | | | |
| Selasphorus sp. | | | | | | | | | | | | |
| hummingbird sp. | | | | | | | | | | | | |
| Virginia Rail | | | | | | | | | | | | |
| Sora | | | | | | | | | | | | |
| American Coot | | | | | | | | | | | | |
| Sandhill Crane | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| Black-necked Stilt | | | | | | | | | | | | |
| American Avocet | | | | | | | | | | | | |
| Black-bellied Plover | | | | | | | | | | | | |
| Snowy Plover | | | | | | | | | | | | |
| Semipalmated Plover | | | | | | | | | | | | |
| Killdeer | | | | | | | | | | | | |
| Long-billed Curlew | | | | | | | | | | | | |
| Marbled Godwit | | | | | | | | | | | | |
| Stilt Sandpiper | | | | | | | | | | | | |
| Sanderling | | | | | | | | | | | | |
| Baird's Sandpiper | | | | | | | | | | | | |
| Least Sandpiper | | | | | | | | | | | | |
| Pectoral Sandpiper | | | | | | | | | | | | |
| Semipalmated Sandpiper | | | | | | | | | | | | |
| Western Sandpiper | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| Semipalmated/Western Sandpiper | | | | | | | | | | | | |

peep sp.

Long-billed Dowitcher

Short-billed/Long-billed Dowitcher

Wilson's Snipe

Wilson's Phalarope

Red-necked Phalarope

Spotted Sandpiper

Solitary Sandpiper

Greater Yellowlegs

Willet

Lesser Yellowlegs

Greater/Lesser Yellowlegs

large shorebird sp.

shorebird sp.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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Sabine's Gull

Bonaparte's Gull

Franklin's Gull

Ring-billed Gull

California Gull

Herring Gull

Larus sp.

gull sp.

Least Tern

Caspian Tern

Black Tern

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forster's Tern | | | | | | | | | | | | |
| tern sp. | | | | | | | | | | | | |
| Pacific Loon | | | | | | | | | | | | |
| Common Loon | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neotropic Cormorant | | | | | | | | | | | | |
| Double-crested Cormorant | | | | | | | | | | | | |
| American White Pelican | | | | | | | | | | | | |
| Great Blue Heron | | | | | | | | | | | | |
| Great Egret | | | | | | | | | | | | |
| Snowy Egret | | | | | | | | | | | | |
| Cattle Egret | | | | | | | | | | | | |
| Black-crowned Night-Heron | | | | | | | | | | | | |
| Glossy Ibis | | | | | | | | | | | | |
| White-faced Ibis | | | | | | | | | | | | |
| Glossy/White-faced Ibis | | | | | | | | | | | | |
| Turkey Vulture | | | | | | | | | | | | |
| Osprey | | | | | | | | | | | | |
| Golden Eagle | | | | | | | | | | | | |
| Mississippi Kite | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| Northern Harrier | | | | | | | | | | | | |
| Sharp-shinned Hawk | | | | | | | | | | | | |
| Cooper's Hawk | | | | | | | | | | | | |
| Sharp-shinned/Cooper's Hawk | | | | | | | | | | | | |
| Northern Goshawk | | | | | | | | | | | | |


Cooper's Hawk/Northern Goshawk
Accipiter sp.
Bald Eagle
Broad-winged Hawk
Swainson's Hawk
Red-tailed Hawk
Rough-legged Hawk
Ferruginous Hawk
Buteo sp.
Buteo/eagle sp.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
hawk sp.
eagle sp.
Barn Owl
Flammulated Owl
Western Screech-Owl
Great Horned Owl
Northern Pygmy-Owl
Burrowing Owl
Spotted Owl
Long-eared Owl
Boreal Owl
Northern Saw-whet Owl
owl sp.
Belted Kingfisher
Williamson's Sapsucker

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| Yellow-bellied Sapsucker | | | | | | | | | | | | |
| Red-naped Sapsucker | | | | | | | | | | | | |
| sapsucker sp. | | | | | | | | | | | | |
| Lewis's Woodpecker | | | | | | | | | | | | |
| American Three-toed Woodpecker | | | | | | | | | | | | |
| Downy Woodpecker | | | | | | | | | | | | |
| Hairy Woodpecker | | | | | | | | | | | | |
| Downy/Hairy Woodpecker | | | | | | | | | | | | |
| Northern Flicker | | | | | | | | | | | | |
| woodpecker sp. | | | | | | | | | | | | |
| American Kestrel | | | | | | | | | | | | |
| Merlin | | | | | | | | | | | | |
| Peregrine Falcon | | | | | | | | | | | | |
| Prairie Falcon | | | | | | | | | | | | |
| large falcon sp. | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| small falcon sp. | | | | | | | | | | | | |
| falcon sp. | | | | | | | | | | | | |
| Olive-sided Flycatcher | | | | | | | | | | | | |
| Western Wood-Pewee | | | | | | | | | | | | |
| pewee sp. (Contopus sp.) | | | | | | | | | | | | |
| Willow Flycatcher | | | | | | | | | | | | |
| Alder/Willow Flycatcher (Traill's Flycatcher) | | | | | | | | | | | | |
| Hammond's Flycatcher | | | | | | | | | | | | |
| Gray Flycatcher | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
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| Dusky Flycatcher | | | | | | | | | | | | |
| Gray/Dusky Flycatcher | | | | | | | | | | | | |
| Hammond's/Dusky Flycatcher | | | | | | | | | | | | |
| Cordilleran Flycatcher | | | | | | | | | | | | |
| Pacific-slope/Cordilleran Flycatcher (Western Flycatcher) | | | | | | | | | | | | |
| Empidonax sp. | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black Phoebe | | | | | | | | | | | | |
| Eastern Phoebe | | | | | | | | | | | | |
| Say's Phoebe | | | | | | | | | | | | |
| phoebe sp. | | | | | | | | | | | | |
| Vermilion Flycatcher | | | | | | | | | | | | |
| Ash-throated Flycatcher | | | | | | | | | | | | |
| Tropical Kingbird | | | | | | | | | | | | |
| Cassin's Kingbird | | | | | | | | | | | | |
| Western Kingbird | | | | | | | | | | | | |
| Cassin's/Western Kingbird | | | | | | | | | | | | |
| Eastern Kingbird | | | | | | | | | | | | |
| Scissor-tailed Flycatcher | | | | | | | | | | | | |
| flycatcher sp. (Tyrannidae sp.) | | | | | | | | | | | | |
| Loggerhead Shrike | | | | | | | | | | | | |
| Northern Shrike | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loggerhead/Northern Shrike | | | | | | | | | | | | |
| shrike sp. | | | | | | | | | | | | |
| Gray Vireo | | | | | | | | | | | | |


Yellow-throated Vireo
Cassin's Vireo
Cassin's/Blue-headed Vireo
Plumbeous Vireo
Cassin's/Plumbeous Vireo
solitary vireo sp.
Warbling Vireo
Red-eyed Vireo
vireo sp.
Canada Jay
Pinyon Jay
Steller's Jay
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Woodhouse's Scrub-Jay
Black-billed Magpie
Clark's Nutcracker
American Crow
Common Raven
raven sp.
Horned Lark
Northern Rough-winged Swallow
Purple Martin
Tree Swallow
Violet-green Swallow
Bank Swallow
Barn Swallow

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cliff Swallow | | | | | | | | | | | | |
| swallow sp. | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Black-capped Chickadee | | | | | | | | | | | | |
| Mountain Chickadee | | | | | | | | | | | | |
| Black-capped/Mountain Chickadee | | | | | | | | | | | | |
| chickadee sp. | | | | | | | | | | | | |
| Juniper Titmouse | | | | | | | | | | | | |
| Bushtit | | | | | | | | | | | | |
| Red-breasted Nuthatch | | | | | | | | | | | | |
| White-breasted Nuthatch | | | | | | | | | | | | |
| Pygmy Nuthatch | | | | | | | | | | | | |
| nuthatch sp. | | | | | | | | | | | | |
| Brown Creeper | | | | | | | | | | | | |
| Rock Wren | | | | | | | | | | | | |
| Canyon Wren | | | | | | | | | | | | |
| House Wren | | | | | | | | | | | | |
| Pacific Wren | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Marsh Wren | | | | | | | | | | | | |
| Bewick's Wren | | | | | | | | | | | | |
| wren sp. | | | | | | | | | | | | |
| Blue-gray Gnatcatcher | | | | | | | | | | | | |
| American Dipper | | | | | | | | | | | | |
| Golden-crowned Kinglet | | | | | | | | | | | | |
| Ruby-crowned Kinglet | | | | | | | | | | | | |

Eastern Bluebird
Western Bluebird
Mountain Bluebird
bluebird sp.
Townsend's Solitaire
Swainson's Thrush
Hermit Thrush
Catharus sp.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

American Robin
Gray Catbird
Brown Thrasher
Sage Thrasher
Northern Mockingbird
European Starling
American Pipit
Bohemian Waxwing
Cedar Waxwing
Bohemian/Cedar Waxwing
Evening Grosbeak
Pine Grosbeak
Gray-crowned Rosy-Finch
Black Rosy-Finch
Brown-capped Rosy-Finch

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

rosy-finch sp.


House Finch
Purple Finch
Cassin's Finch
Haemorhous sp.
Common Redpoll
Red Crossbill
White-winged Crossbill
Pine Siskin
Lesser Goldfinch
American Goldfinch
Spinus sp. (goldfinch sp.)
finch sp.
Cassin's Sparrow
Grasshopper Sparrow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Chipping Sparrow
Clay-colored Sparrow
Brewer's Sparrow
Spizella sp.
Black-throated Sparrow
Lark Sparrow
Lark Bunting
American Tree Sparrow
Spizella sp./American Tree Sparrow
Fox Sparrow
Dark-eyed Junco

White-crowned Sparrow

Golden-crowned Sparrow

Harris's Sparrow

White-throated Sparrow

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Sagebrush Sparrow

Vesper Sparrow

Savannah Sparrow

Song Sparrow

Lincoln's Sparrow

Swamp Sparrow

Green-tailed Towhee

Spotted Towhee

Spotted/Eastern Towhee (Rufous-sided Towhee)

towhee sp.

sparrow sp.

Yellow-breasted Chat

Yellow-headed Blackbird

Western Meadowlark

Orchard Oriole

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Hooded Oriole

Bullock's Oriole

Baltimore Oriole

Scott's Oriole

Red-winged Blackbird

Brown-headed Cowbird
Brewer's Blackbird
Rusty/Brewer's Blackbird
Common Grackle
Great-tailed Grackle
blackbird sp.
Ovenbird
Northern Waterthrush
Black-and-white Warbler
Orange-crowned Warbler

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Nashville Warbler
Virginia's Warbler
MacGillivray's Warbler
Common Yellowthroat
American Redstart
Blackburnian Warbler
Yellow Warbler
Blackpoll Warbler
Palm Warbler
Yellow-rumped Warbler
Grace's Warbler
Black-throated Gray Warbler
Townsend's Warbler
Wilson's Warbler
Painted Redstart


**KEY:** | = insufficient data | = rare to widespread

Download Histogram Data

# Attachment G – Avian Knowledge Network Species Report

# Avian Knowledge Network



## About Your Species Report

### How Do I Print/Save My Report?

You may print a pdf version of your migratory bird report by selecting the pdf icon on the menu bar above your report (next to the show effort toggle button).

### How is My Bird List Generated?

Bird lists and abundance and presence levels associated with each bird are generated using raw observations data in the Avian Knowledge Network. Review the current l of datasets being used to generate your bird list and abundance and presence lev Birds that are included on your bird list have been observed within the 10km grid cel your project area overlaps within the past 10 years (for offshore areas there may be more than 10 years of data being referenced to generate lists due to the availability of less data currently in these areas).

### How Is Abundance Calculated and What Does It Tell Me?

Each blue bar represents the bird's abundance score during a particular week of the year (A year is represented as 12 4-week months). A taller bar represents a higher abundance score. The survey effort (see below) can be used to establish a level of confidence in the abundance score. One can have higher confidence in the abundance score if the corresponding survey effort is also high.

How is the abundance score calculated? It is done in 2 steps:

1. The abundance for each week is estimated as the total sum of birds detected, divided by the total number of survey events for that week. For example, if in week 12 a total of 45 Spotted Towhees were detected in 5 survey events, the abundance is then 9 birds/survey event.

2. The abundances across all weeks are smoothed to fill gaps from poorly surveyed weeks amidst weeks with good sampling. The resulting smoothed abundances are binned so that all possible values fall in bins of log-base-2: 0, 1-2 (= 2^1, so the graph bar takes value 1), 3-4 (= 2^2, so bar = 2), 5-8 (bar = 3), 9-16 (bar = 4), and so on. Any weeks with abundances > 1024 (i.e., > bar = 10) are assigned value 11. These values from 0 to 11 represent the abundance scores for the species.

Thus, note that the abundance score is really an index of abundance and should not be taken to mean the absolute abundance of the species that week. See “Proper Interpretation and Use of This Report” below to understand how best to use this abundance score for decision-making.

**How Is Relative Probability of Presence Calculated and What Does It Tell Me?**
Each light green bar represents the bird’s relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher relative probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the relative probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year.

The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.

3. The relative probability of presence calculated in the previous step undergoes a statistical smoothing to fill gaps from poorly surveyed weeks amidst weeks with good sampling. We then rescale the resulting smoothed relative probabilities so that all possible values fall between 0 and 10, inclusive. This is the relative probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

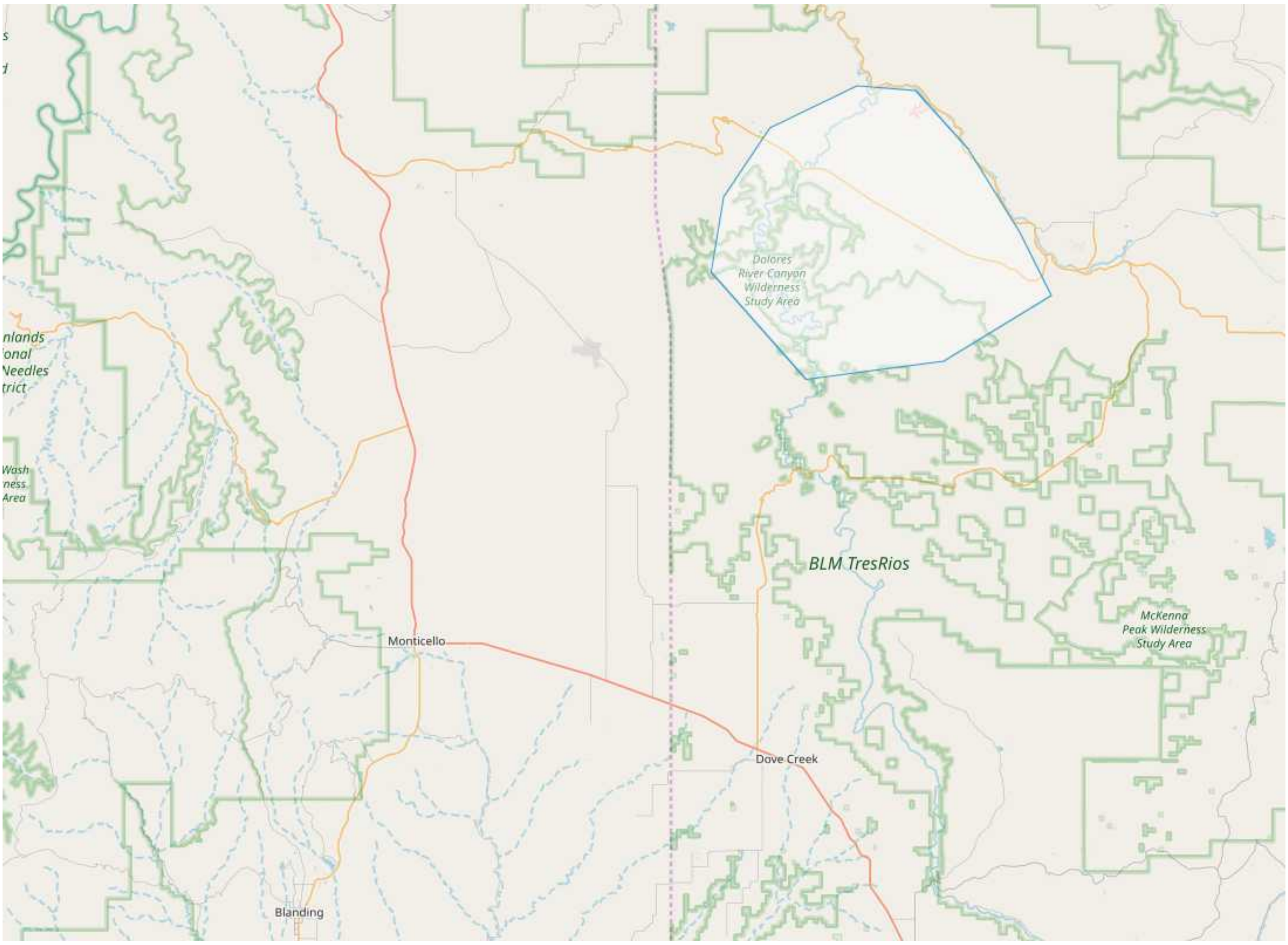
**What is Meant by Survey Effort?**

Vertical dark blue lines superimposed on probability of presence bars indicate the number of surveys performed for that species in your selected area. The number of surveys is expressed as a range, for example, 33 to 64 surveys. Ranges follow a Log-base-2 scale: 0, 1-2 (2^1 =”event count” of 1), 3-4 (2^2 =”event count” of 2), 5-8 (2^3 =”event count” of 3), 9-16 (2^4 = “event count” of 4), and so on. The last bin (bars of “event count” value 10) represents number of survey events > 1024 (2^10).

**Proper Interpretation and Use of This Report**

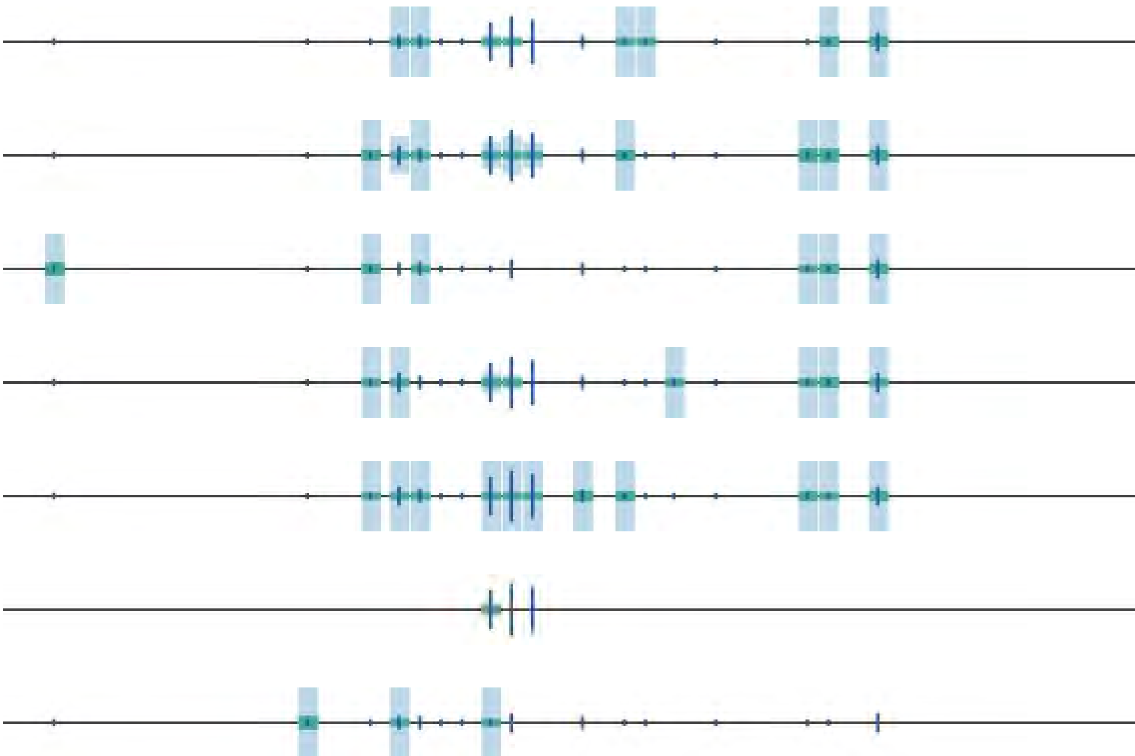
Please be aware this report provides the “relative probability of presence” and “relative abundance” of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint and not exact probabilities or abundances. Thus, the bar graphs are designed to depict how much more (or less) relatively common/abundant a species may be relative to other locations and/or times of the year. Results should not be used as proper probabilities of presence or estimates of abundance for a particular location. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the “no data” indicator (lack of a survey effort bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low or non-existent survey effort bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds have the potential to be in your project area and when they might be there. The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement measures to avoid or minimize potential impacts from your project activities, should presence be confirmed.

# Species Report




Presence Abundance Effort

Species / Scientific Name | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec



American Coot
*Fulica americana*

American Crow
*Corvus brachyrhynchos*

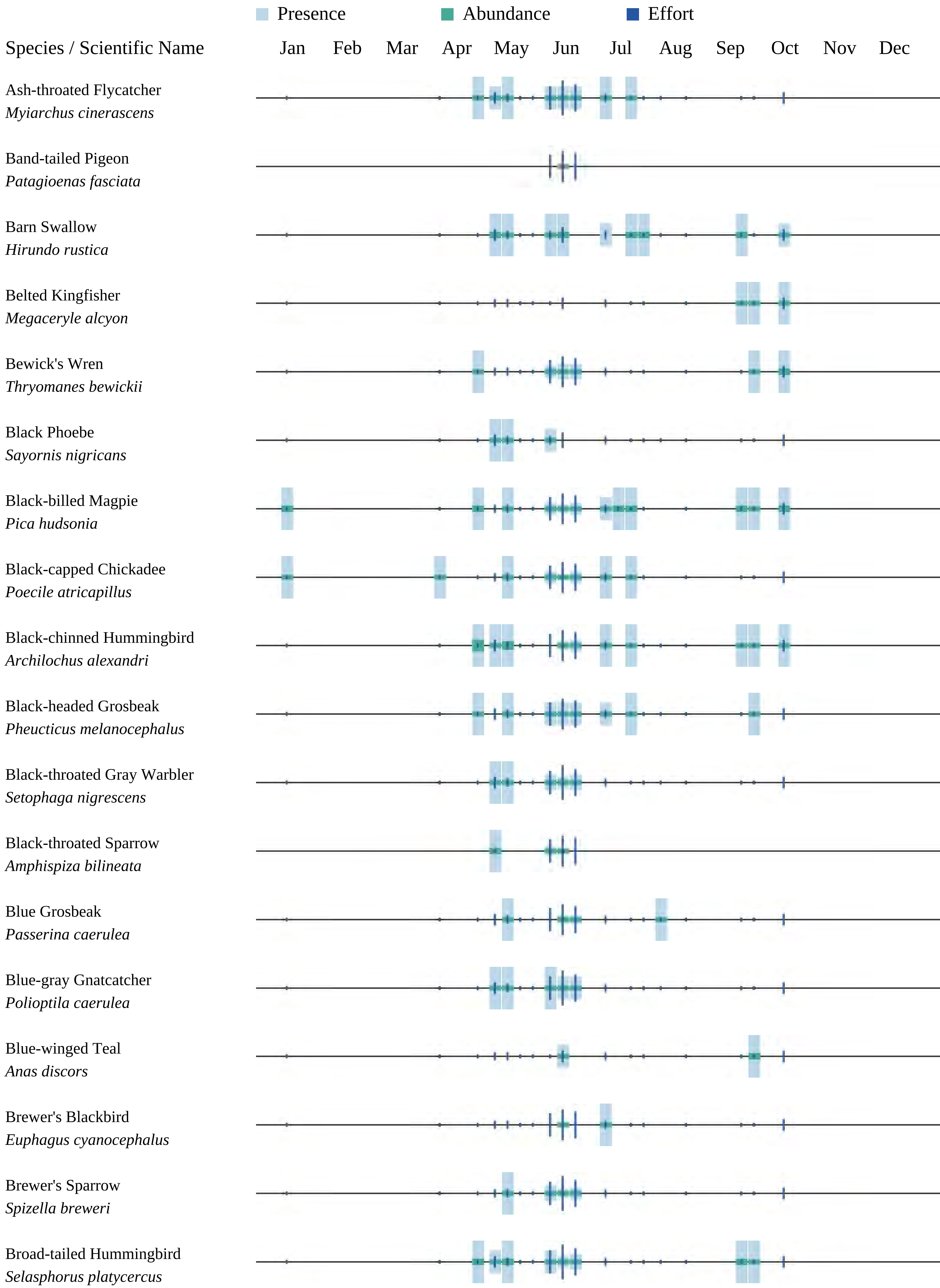
American Goldfinch
*Spinus tristis*

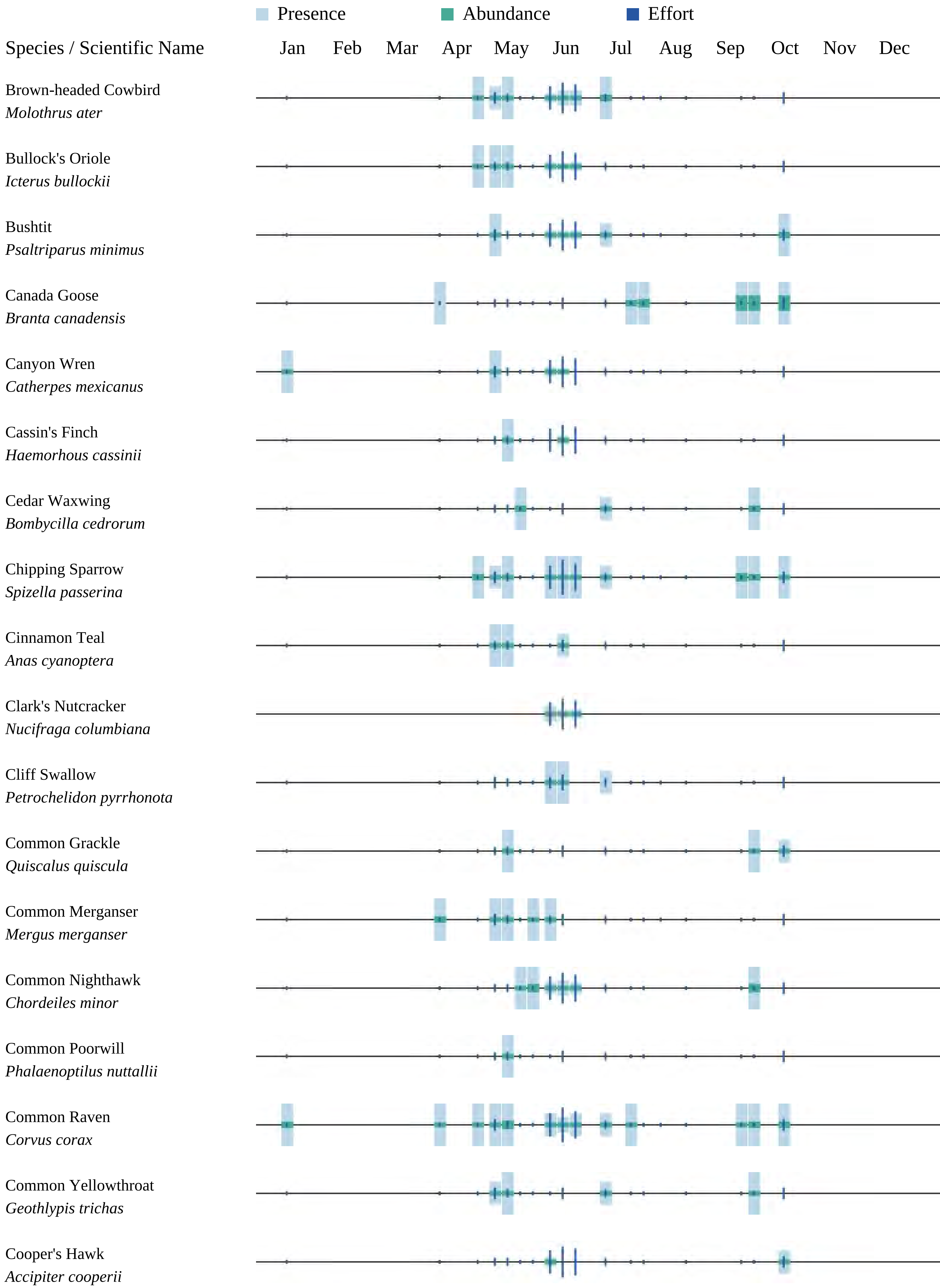
American Kestrel
*Falco sparverius*

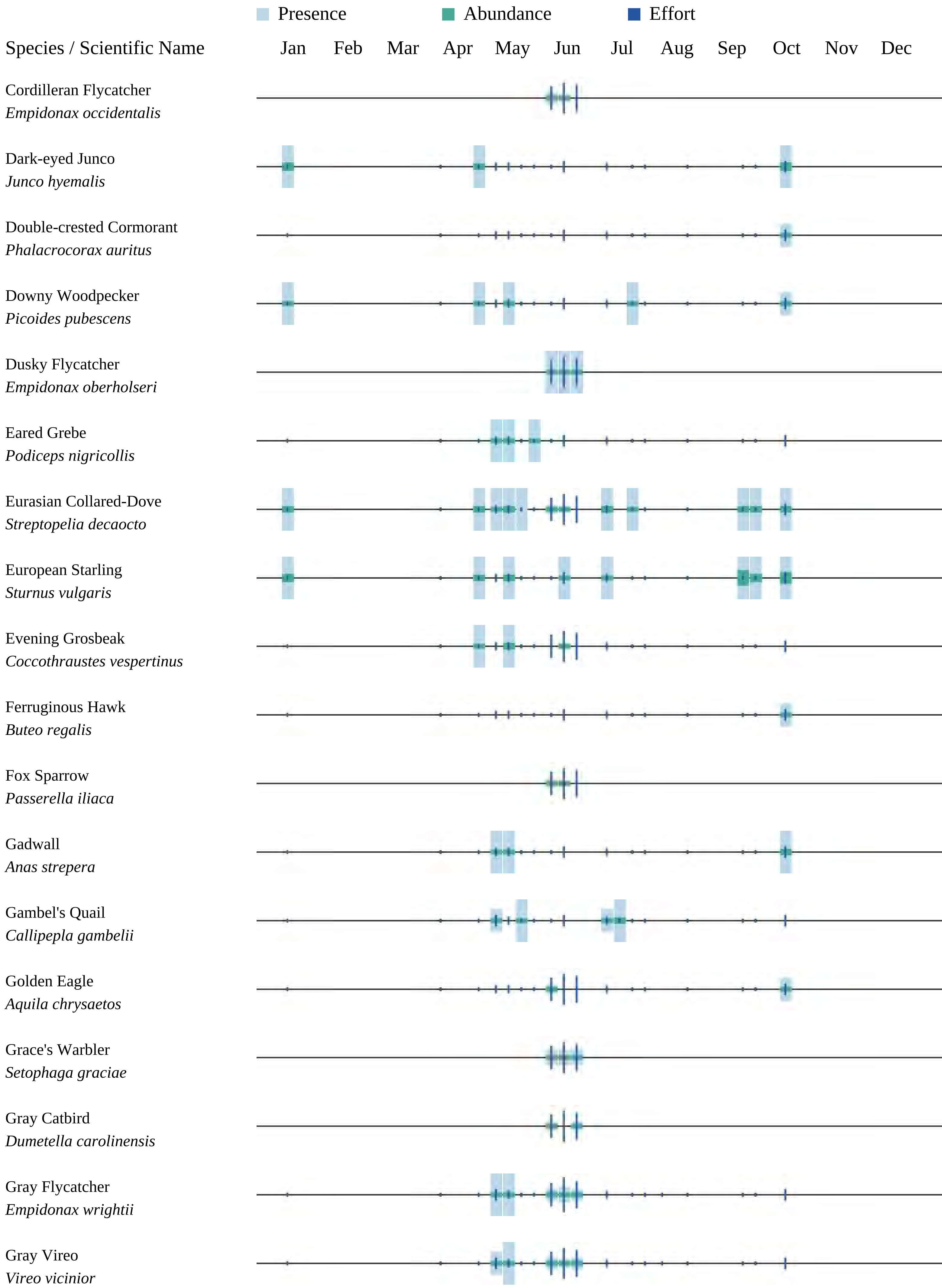
American Robin
*Turdus migratorius*

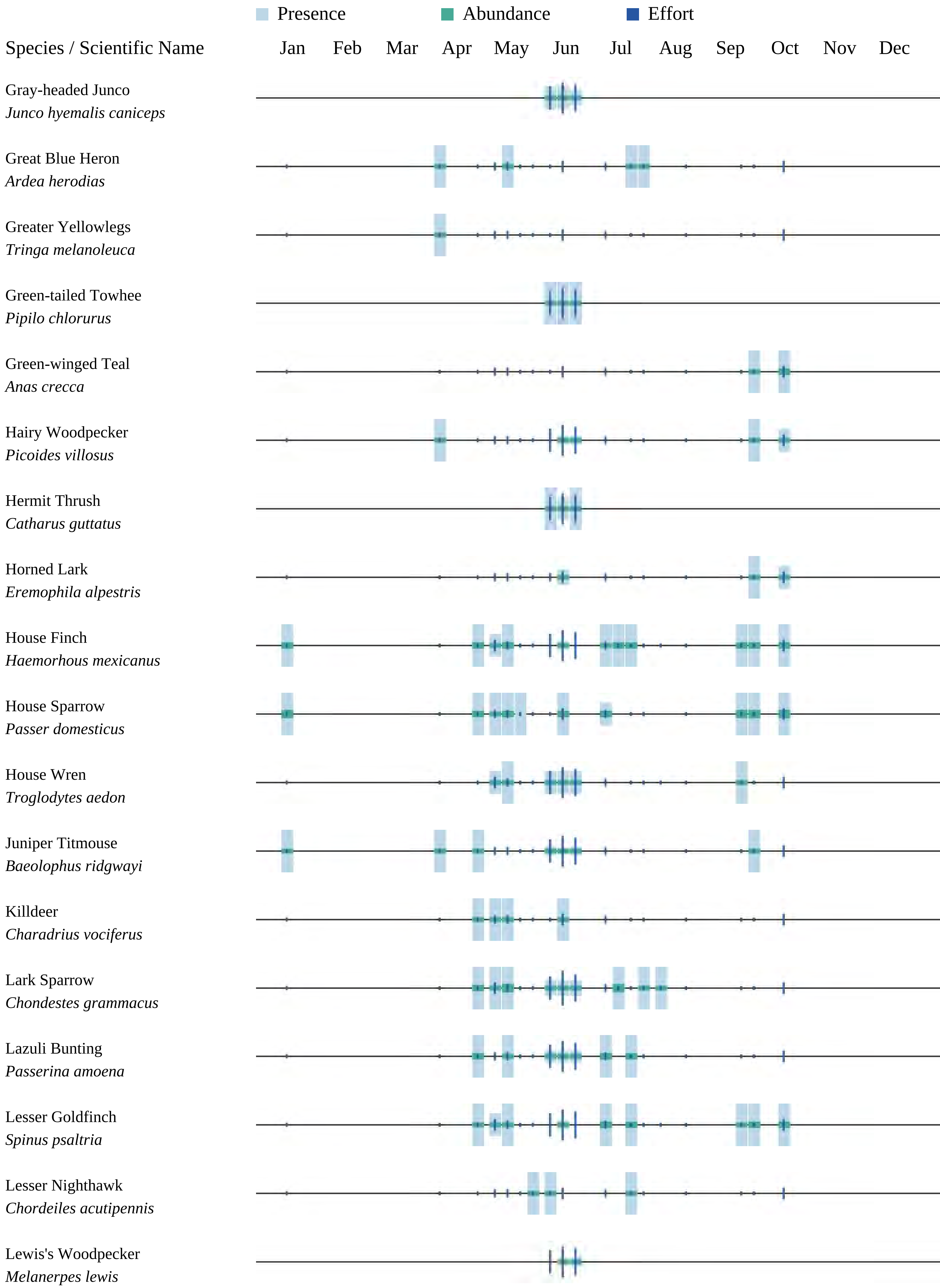
American Three-toed Woodpecker
*Picoides dorsalis*

American Wigeon
*Anas americana*

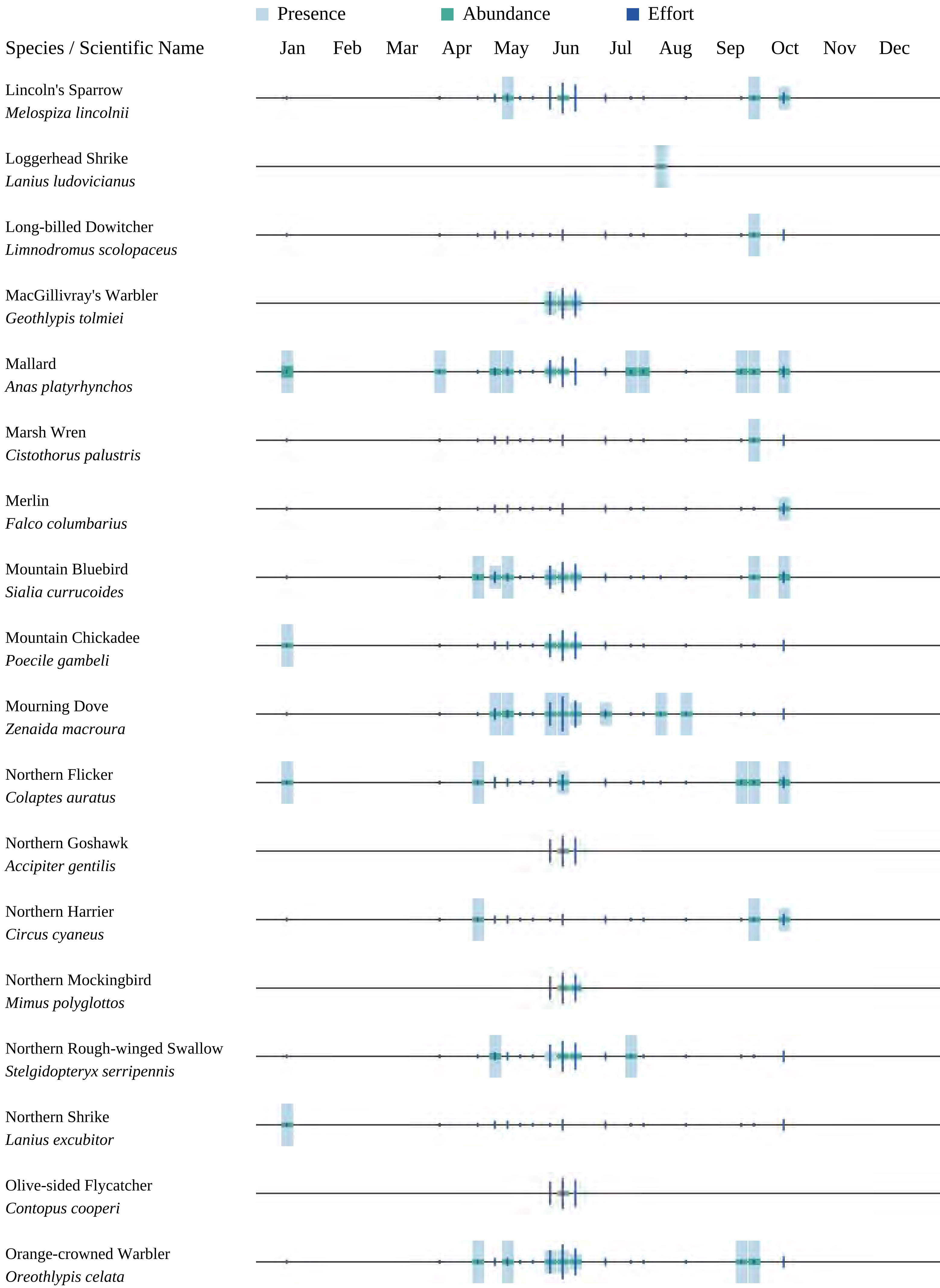

Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Ash-throated Flycatcher
Myiarchus cinerascens
Band-tailed Pigeon
Patagioenas fasciata
Barn Swallow
Hirundo rustica
Belted Kingfisher
Megaceryle alcyon
Bewick's Wren
Thryomanes bewickii
Black Phoebe
Sayornis nigricans
Black-billed Magpie
Pica hudsonia
Black-capped Chickadee
Poecile atricapillus
Black-chinned Hummingbird
Archilochus alexandri
Black-headed Grosbeak
Pheucticus melanocephalus
Black-throated Gray Warbler
Setophaga nigrescens
Black-throated Sparrow
Amphispiza bilineata
Blue Grosbeak
Passerina caerulea
Blue-gray Gnatcatcher
Polioptila caerulea
Blue-winged Teal
Anas discors
Brewer's Blackbird
Euphagus cyanocephalus
Brewer's Sparrow
Spizella breweri
Broad-tailed Hummingbird
Selasphorus platycercus

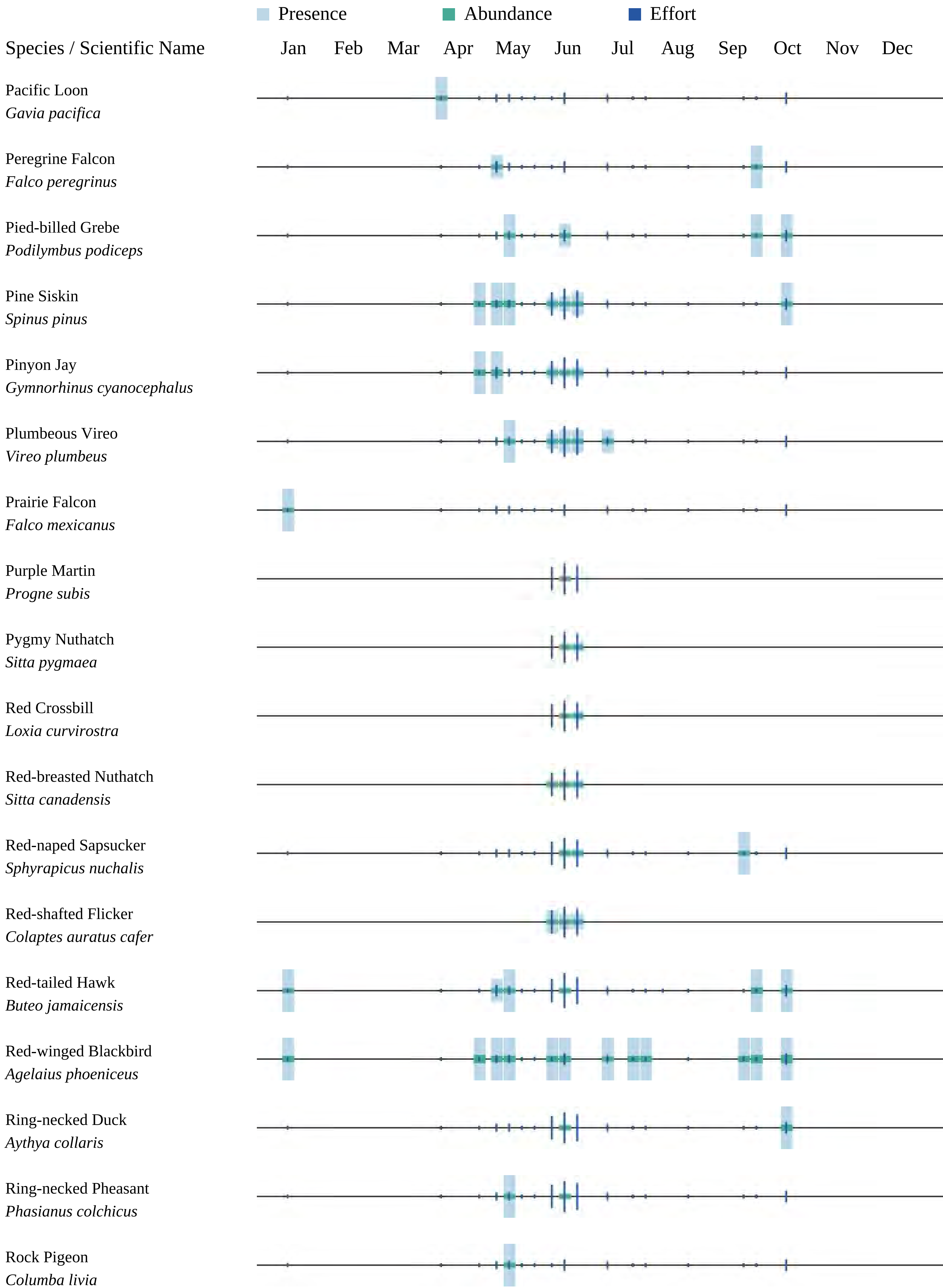

Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Brown-headed Cowbird
*Molothrus ater*
Bullock's Oriole
*Icterus bullockii*
Bushtit
*Psaltriparus minimus*
Canada Goose
*Branta canadensis*
Canyon Wren
*Catherpes mexicanus*
Cassin's Finch
*Haemorhous cassinii*
Cedar Waxwing
*Bombycilla cedrorum*
Chipping Sparrow
*Spizella passerina*
Cinnamon Teal
*Anas cyanoptera*
Clark's Nutcracker
*Nucifraga columbiana*
Cliff Swallow
*Petrochelidon pyrrhonota*
Common Grackle
*Quiscalus quiscula*
Common Merganser
*Mergus merganser*
Common Nighthawk
*Chordeiles minor*
Common Poorwill
*Phalaenoptilus nuttallii*
Common Raven
*Corvus corax*
Common Yellowthroat
*Geothlypis trichas*
Cooper's Hawk
*Accipiter cooperii*

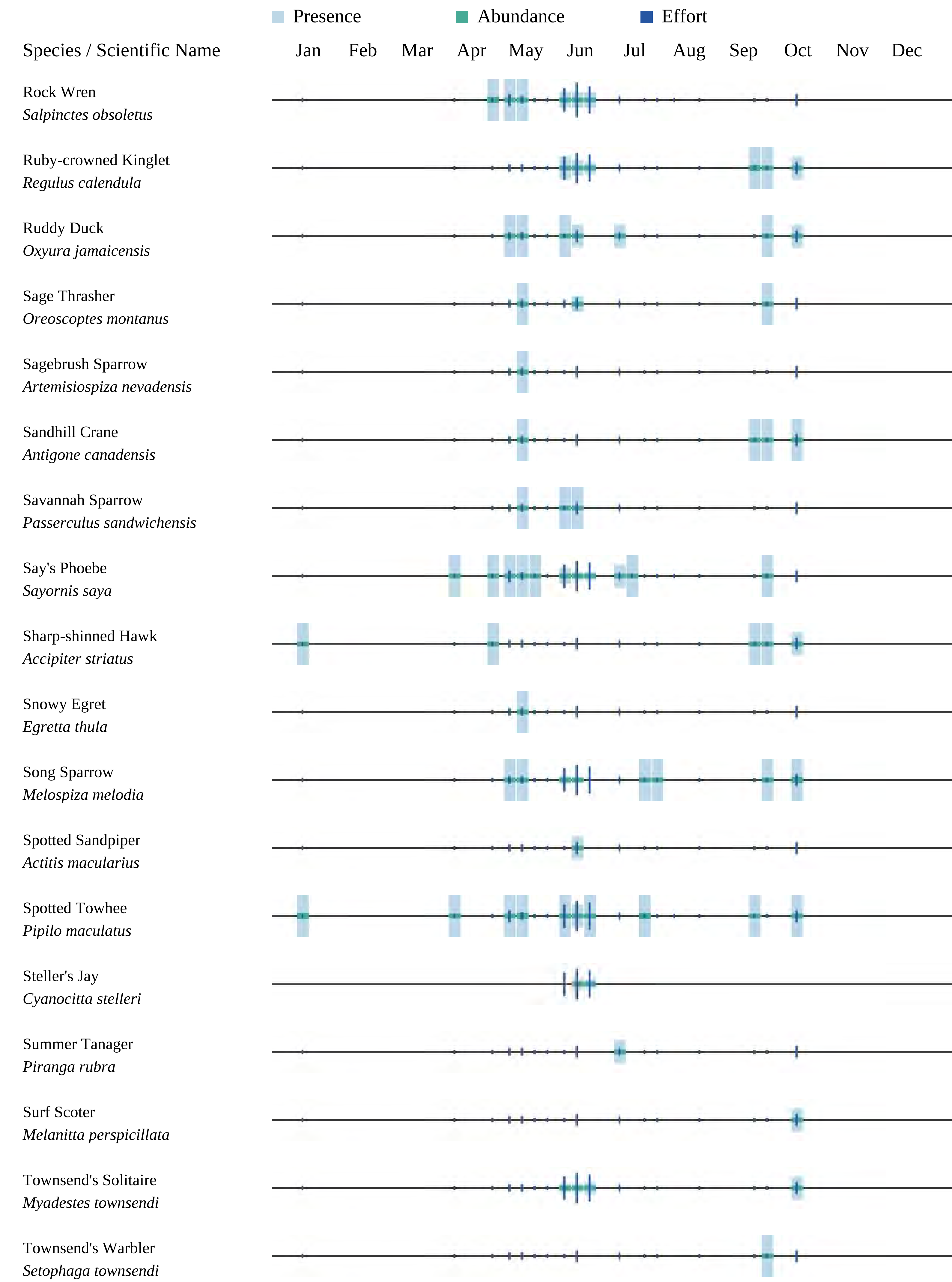

Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Cordilleran Flycatcher
Empidonax occidentalis
Dark-eyed Junco
Junco hyemalis
Double-crested Cormorant
Phalacrocorax auritus
Downy Woodpecker
Picoides pubescens
Dusky Flycatcher
Empidonax oberholseri
Eared Grebe
Podiceps nigricollis
Eurasian Collared-Dove
Streptopelia decaocto
European Starling
Sturnus vulgaris
Evening Grosbeak
Coccothraustes vespertinus
Ferruginous Hawk
Buteo regalis
Fox Sparrow
Passerella iliaca
Gadwall
Anas strepera
Gambel's Quail
Callipepla gambelii
Golden Eagle
Aquila chrysaetos
Grace's Warbler
Setophaga graciae
Gray Catbird
Dumetella carolinensis
Gray Flycatcher
Empidonax wrightii
Gray Vireo
Vireo vicinior

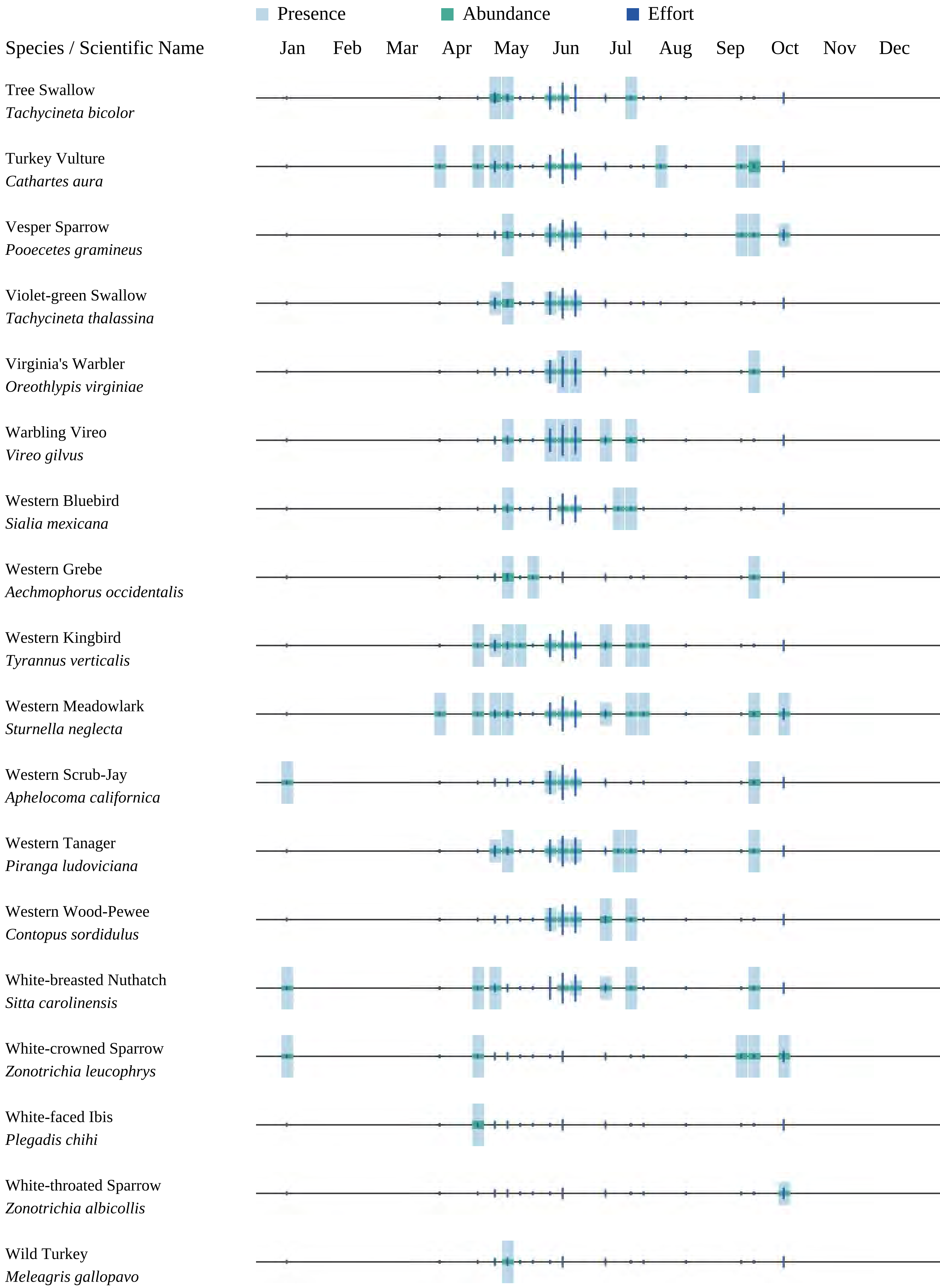


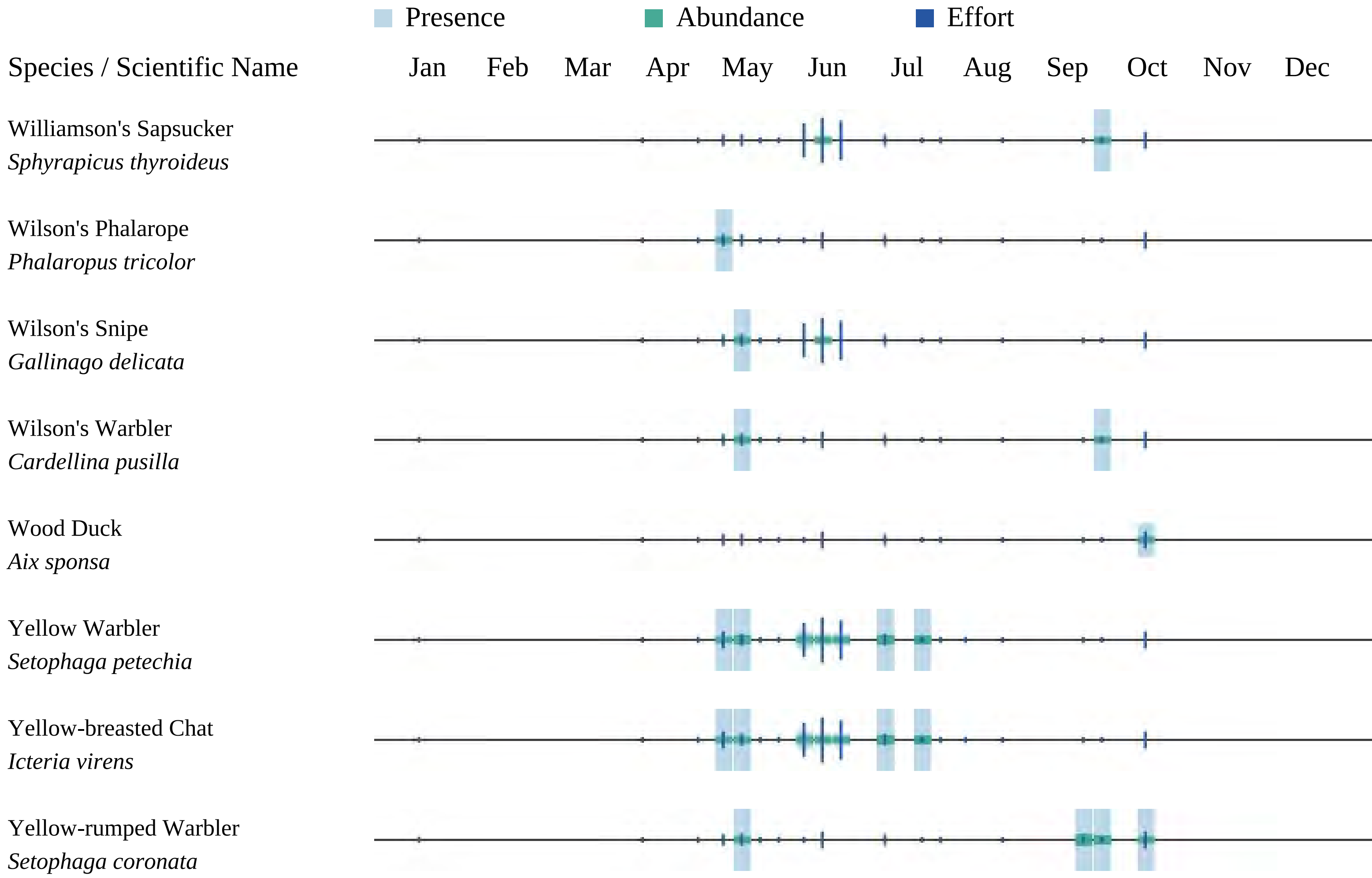
Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Gray-headed Junco
*Junco hyemalis caniceps*
Great Blue Heron
*Ardea herodias*
Greater Yellowlegs
*Tringa melanoleuca*
Green-tailed Towhee
*Pipilo chlorurus*
Green-winged Teal
*Anas crecca*
Hairy Woodpecker
*Picoides villosus*
Hermit Thrush
*Catharus guttatus*
Horned Lark
*Eremophila alpestris*
House Finch
*Haemorhous mexicanus*
House Sparrow
*Passer domesticus*
House Wren
*Troglodytes aedon*
Juniper Titmouse
*Baeolophus ridgwayi*
Killdeer
*Charadrius vociferus*
Lark Sparrow
*Chondestes grammacus*
Lazuli Bunting
*Passerina amoena*
Lesser Goldfinch
*Spinus psaltria*
Lesser Nighthawk
*Chordeiles acutipennis*
Lewis's Woodpecker
*Melanerpes lewis*


Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lincoln's Sparrow
Melospiza lincolnii
Loggerhead Shrike
Lanius ludovicianus
Long-billed Dowitcher
Limnodromus scolopaceus
MacGillivray's Warbler
Geothlypis tolmiei
Mallard
Anas platyrhynchos
Marsh Wren
Cistothorus palustris
Merlin
Falco columbarius
Mountain Bluebird
Sialia currucoides
Mountain Chickadee
Poecile gambeli
Mourning Dove
Zenaida macroura
Northern Flicker
Colaptes auratus
Northern Goshawk
Accipiter gentilis
Northern Harrier
Circus cyaneus
Northern Mockingbird
Mimus polyglottos
Northern Rough-winged Swallow
Stelgidopteryx serripennis
Northern Shrike
Lanius excubitor
Olive-sided Flycatcher
Contopus cooperi
Orange-crowned Warbler
Oreothlypis celata


Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Pacific Loon
Gavia pacifica
Peregrine Falcon
Falco peregrinus
Pied-billed Grebe
Podilymbus podiceps
Pine Siskin
Spinus pinus
Pinyon Jay
Gymnorhinus cyanocephalus
Plumbeous Vireo
Vireo plumbeus
Prairie Falcon
Falco mexicanus
Purple Martin
Progne subis
Pygmy Nuthatch
Sitta pygmaea
Red Crossbill
Loxia curvirostra
Red-breasted Nuthatch
Sitta canadensis
Red-naped Sapsucker
Sphyrapicus nuchalis
Red-shafted Flicker
Colaptes auratus cafer
Red-tailed Hawk
Buteo jamaicensis
Red-winged Blackbird
Agelaius phoeniceus
Ring-necked Duck
Aythya collaris
Ring-necked Pheasant
Phasianus colchicus
Rock Pigeon
Columba livia


Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Rock Wren
Salpinctes obsoletus
Ruby-crowned Kinglet
Regulus calendula
Ruddy Duck
Oxyura jamaicensis
Sage Thrasher
Oreoscoptes montanus
Sagebrush Sparrow
Artemisiospiza nevadensis
Sandhill Crane
Antigone canadensis
Savannah Sparrow
Passerculus sandwichensis
Say's Phoebe
Sayornis saya
Sharp-shinned Hawk
Accipiter striatus
Snowy Egret
Egretta thula
Song Sparrow
Melospiza melodia
Spotted Sandpiper
Actitis macularius
Spotted Towhee
Pipilo maculatus
Steller's Jay
Cyanocitta stelleri
Summer Tanager
Piranga rubra
Surf Scoter
Melanitta perspicillata
Townsend's Solitaire
Myadestes townsendi
Townsend's Warbler
Setophaga townsendi


Presence
Abundance
Effort
Species / Scientific Name
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Tree Swallow
Tachycineta bicolor
Turkey Vulture
Cathartes aura
Vesper Sparrow
Pooecetes gramineus
Violet-green Swallow
Tachycineta thalassina
Virginia's Warbler
Oreothlypis virginiae
Warbling Vireo
Vireo gilvus
Western Bluebird
Sialia mexicana
Western Grebe
Aechmophorus occidentalis
Western Kingbird
Tyrannus verticalis
Western Meadowlark
Sturnella neglecta
Western Scrub-Jay
Aphelocoma californica
Western Tanager
Piranga ludoviciana
Western Wood-Pewee
Contopus sordidulus
White-breasted Nuthatch
Sitta carolinensis
White-crowned Sparrow
Zonotrichia leucophrys
White-faced Ibis
Plegadis chihi
White-throated Sparrow
Zonotrichia albicollis
Wild Turkey
Meleagris gallopavo




Information attained from Avian Knowledge Network (http://avianknowledge.net/index.php/phenology-tool/), created April 2019.

# Appendix J

## Predictive Ecological Risk Assessment

# FINAL

# PREDICTIVE ECOLOGICAL RISK ASSESSMENT
# PROPOSED SOLAR EVAPORATION POND SYSTEM
# PARADOX VALLEY UNIT, COLORADO

**Submitted to:**
**Wastren Advantage, Inc.**
**1571 Shyville Road**
**Piketon, Ohio 45661**

**Submitted by:**
**Amec Foster Wheeler Environment & Infrastructure, Inc.**
**Phoenix, Arizona**

**August 2016**

**Amec Foster Wheeler Project No. 1655500023**

29 August 2016

Dave Sablosky
Wastren Advantage, Inc.
1571 Shyville Road
Piketon, Ohio 45661

**Re: Final Report for the Paradox Valley Unit Ecological Risk Assessment Study**

Dear Dave:

The report included here satisfies the deliverable for the Paradox Valley Unit Evaporation Ponds Study 4: Ecological Risk Assessment Final Report. We look forward to discussion with Wastren Advantage and the United States Bureau of Reclamation about this report.

If you have any questions or concerns regarding this report, please contact Carla Scheidlinger at 858-300-4311 or by email at carla.scheidlinger@amecfw.com.

Respectfully submitted,

**Amec Foster Wheeler Environment & Infrastructure, Inc.**

Carla Scheidlinger
Project Manager

# Executive Summary

The Bureau of Reclamation's (Reclamation) Paradox Valley Unit (PVU) is a component of the Colorado River Basin Salinity Control Program, a multi-works program to control the salinity of Colorado River water delivered to users in the United States and Mexico. The PVU currently intercepts 200 gallons per minute (gpm) of 260,000 milligrams per liter (mg/L) brine and diverts it to a 16,000' deep injection well for disposal. The injection rate has been curtailed during the 20 year life of the well due mainly to induced seismic activity associated with the injection process. At the current rate, Reclamation prevents approximately 100,000 tons per year from entering the Colorado River system. The current collection well field is capable of producing 400 gpm. However salinity control benefits may decrease when pumping in excess of 300 gpm. Therefore, for purposes of this study, the goal is to control up to 170,000 tons per year, or 300 gpm. Due to current and future limitations of the injection well, and long term salinity control considerations at Paradox, Reclamation is currently evaluating alternative methods of brine disposal of this produced brine. One of the long-term strategies being considered for brine disposal is diverting the brine to an evaporation pond or series of ponds.

An Environmental Impact Statement (EIS) is currently being prepared under the auspices of the National Environmental Policy Act (NEPA) to evaluate alternative methods for disposing of the pumped brine. This PERA evaluates the potential ecological consequences of the implementation of the evaporation pond alternative. It follows the framework for conducting ecological risk assessments (ERAs) as established by the U.S. Environmental Protection Agency (USEPA) (1998). This framework divides the ERA process into three phases:

1. Problem Formulation
2. Analysis
3. Risk Characterization

Samples of the pumped groundwater collected in March, 2016, had total dissolved solid (TDS) content of approximately 28% (eight times more saline than seawater). Of the major cations, sodium comprises approximately 10% of the brine followed by potassium (0.53%), magnesium (0.20%), and calcium (0.17%). Among the major anions, chloride comprises 17% of the brine followed by sulfate (0.70%). All others (bromide, fluoride, nitrate, nitrite, and orthophosphate) are less than 0.02%. Sodium and chloride comprise approximately 97% of the TDS in the pumped groundwater. Among the lesser metals (referred to "trace elements"), strontium showed the highest concentration at about 32 mg/L, followed by boron (11 mg/L), silicon (2.7 mg/L), manganese (0.59 mg/L), lithium (0.39 mg/L), bismuth (0.049 mg/L), and barium (0.037 mg/L). All other metals were less than their corresponding method detection limit (MDL).

Three sites are currently being considered as locations for the solar evaporation ponds (Amec FW, 2016a):

- Paradox NW Site—Located approximately 2.5 miles northwest of the Dolores River at an elevation of about 5,100 feet above mean sea level (amsl). This site is approximately 36 road miles from the Broad Canyon Landfill, which may be used for the disposal of solid salts.

- BLM Site—Located approximately 7 miles southeast of the Dolores River at an elevation of about 5,400 feet amsl. This site is approximately 25 road miles from the Broad Canyon Landfill, which may be used for the disposal of solid salts.

- Landfill Site—This site is adjacent to the Broad Canyon Landfill at an elevation of about 6,200 feet amsl. This site would require minimal hauling of solid salts, but over 20 miles of pipeline to bring the well brine to the ponds.

For each of these three primary sites being considered, a nearby site has been identified as an alternative. These are the Paradox SW Site, Central Site, and Hamilton Canyon Site, respectively.

It is estimated that the evaporation pond system would require approximately 350 to 400 acres of surface area that will need to be converted from its current use (rangeland/wildlife habitat) to evaporation pond, salt storage/disposal, and supporting facility uses. Descriptions of the current habitat conditions at each of the three proposed sites are presented. No populations of sensitive species are anticipated to be affected by the construction of the facility provided that the construction is conducted within the normal guidelines for environmental protection.

The proposed evaporation pond system will entail a series of four pond types. From top to bottom these are:

- Surge Pond (approximately 20 acres)
- Concentrator Pond(s) (approximately 110 acres)
- Crystallizer Ponds (3 to 5 ponds, totaling approximately 205 acres)
- Bittern Pond (approximately 24 acres for concentration and an additional 3 acres for storage)

Because of the very high salinity of the water that will be retained in these ponds, they will present a potentially significant hazard to wildlife that may attempt to use them for drinking, feeding, or resting. These hazards include the toxic effects from ingestion of the salts and trace elements in the water; osmotic imbalances from consuming or resting on the water; and entrapment, waterlogging, and eventual mortality due to salt encrustation. Pond design (particularly bank steepness) may also present a hazard to waterfowl from entrapment. The storage, transport, and final disposal of salt and other waste material may pose hazards to wildlife with regard to ingestion of salt or runoff water, and with regard to increased possibility of road kills along the salt-transport trucking routes.

Because the high levels of hydrogen sulfide ($H_2S$) in the brine pose a potential human health hazard, Amec FW recommends that the brine be treated with sodium hypochlorite to convert $H_2S$ to less toxic forms, followed by treatment with reducing agents to remove excess chlorine and lime to increase pH to neutrality (Amec FW, 2016b). These treatments are not expected to significantly change the brine chemistry with respect to the overall toxicity. The conversion of $H_2S$ is expected to be essentially complete, with essentially no residual $H_2S$ gas being released over the surge pond.

The purpose of the PERA was to qualitatively and quantitatively evaluate the potential for adverse effects to the ecological resources of the Paradox Valley as well as the potential severity of those effects if the evaporation pond alternative is carried out for the continued operation of the PVU. The very high salinity of the waters in the evaporation pond system presents the most significant potential hazard to wildlife of all classes, but particularly to waterfowl. The hazards are from both physical and toxicological effects on the organisms that may contact or consume the water. For the quantitative evaluation of toxicological risk from salt ingestion, five surrogate species chosen to represent the terrestrial mammals and aquatic birds are as follows:

- Eared grebe (*Podiceps nigricollis*), representing waterfowl with small body size
- Northern shoveler (*Anas clypeata*), representing waterfowl with medium body size
- Canada Goose (*Branta canadensis*), representing waterfowl with large body size
- Deer Mouse (*Peromyscus maniculatus*), representing small, upland mammals
- Black-throated Sparrow (*Amphispiza bilineata*), representing upland songbirds (passerines)
- Red-tailed Hawk (*Buteo jamaicensis*), representing carnivorous and scavenging birds

The potential risk to these receptors from the ingestion of water and/or food (in the case of the red-tailed hawk) from the evaporation ponds was evaluated based on hazard quotients (HQs) and hazard indices (HIs). Constituents of potential ecological concern (COPECs) included major salt cations (sodium, potassium, magnesium, and calcium) and detected trace elements (aluminum, barium, bismuth, boron, lithium, manganese, and strontium). Potential water and food ingestion pathways for these COPECs were modeled to estimate daily doses of each of the COPECs for each of the selected representative receptor species. These exposure levels were compared to toxicity reference values (TRVs) at two levels of toxic response. Highly conservative TRVs (based on chronic no-observed-adverse-effect levels [NOAELs]) were used to screen the COPECs and eliminate those that are unlikely to contribute to significant toxicological risk. Based on the HQs and HIs from this screening, all of the trace elements were found to be of negligible risk to wildlife and were not evaluated further.

In the second level of risk evaluation, the estimated doses were compared to acute median lethal dose ($LD_{50}$) levels to determine whether any of the remaining COPECs poses an acute risk to wildlife receptors based on short-term (less than one day) ingestion. Sodium was found to be potentially acutely toxic to all receptors throughout the evaporation pond system from water consumption. Frequent or habitual predation or scavenging by birds around the margins of the ponds also has the potential to result in sodium toxicosis. Potassium is also at toxic levels for mammals, but could not be evaluated for birds due to insufficient avian-specific toxicity data to develop a TRV. Magnesium did not show HQs greater than 1 for the input water (i.e., the water in the surge ponds and the upper end of the concentrator pond), but will likely be at acutely toxic levels for birds and mammals within the crystallizers, and may be the primary toxin in bittern. Calcium is not a risk concern due to low toxicity and the fact that most calcium is expected to precipitate out of the brine before it reaches the crystallizer pond(s).

Other potential sources of risk to waterfowl may result from direct contact with hypersaline water and include osmotic water loss and salt encrustation. Osmotic water loss from exposed areas of skin (e.g., feet and cloaca) can lead to severe dehydration and possible death in waterfowl that remain in contact with the water for extended periods (to 36 hours). Salt encrustation and feather disruption are physical hazards that can occur when the water is at or above the saturation point for some salts. For waterfowl, salt encrustation can lead to hypothermia, waterlogging, and drowning. In this pond system, salt encrustation would likely be at the lower end of the concentrator pond(s) and throughout the crystallizer ponds and bittern pond.

The predicted potential for risk to these receptors is based on conservative assumptions of contact with and ingestion of saline water. The actual risk to these receptors will largely be determined by behavioral responses to the water. Most species are expected to show an aversion to prolonged contact or consumption of the saline and hypersaline waters (Dein et al. 1997). Anecdotal evidence indicates that bats avoid saline water as drinking sources. For waterfowl, the ability to escape from the saline pond will be critical to their survival. However, their ability to escape by flight can be limited by the toxic effects of salt consumption, dehydration, hypothermia, and/or the excess weight from salt encrustation or waterlogging. If near the shoreline, walking out of the pond can be crucial; however, this may not be possible if the banks are too steep. Reaching fresh water after exposure leaving the saline pond can quickly reverse the effects of salt exposure, but this may not always be possible or successful, resulting in mortality in and around the banks of the saline pond.

Risk of this adverse effect can be reduced the implementation of one or more mitigation methods. Several of these are described in the PERA report. These include both active and passive methods, including barriers (netting and wires), hazing of various types, and providing alternative habitat. These various potential methods are then discussed with regard to their applicability to the proposed PVU facility within the context of an adaptive management system.

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## Acronyms and Abbreviations

| | |
|---|---|
| % | percent |
| ac ft | acre feet |
| Amec FW | Amec Foster Wheeler, Inc. |
| BCC | birds of conservation concern |
| BGEPA | Bald and Golden Eagle Protection Act |
| BLM | United States Bureau of Land Management |
| CDOT | Colorado Department of Transportation |
| COPEC | constituent of potential ecological concern |
| CPW | Colorado Parks and Wildlife |
| CRBSCP | Colorado River Basin Salinity Control Program |
| CSM | Conceptual Site Model |
| CSU | Colorado State University |
| EIS | Environmental Impact Statement |
| EPC | exposure point concentration |
| ERA | ecological risk assessment |
| ESA | Endangered Species Act |
| fl oz | (U.S.) fluid ounce |
| FWCA | Fish and Wildlife Coordination Act |
| gpm | gallons per minute |
| HI | hazard index |
| HQ | hazard quotient |
| $H_2S$ | hydrogen sulfide |
| IPaC | Information for Planning and Conservation |
| $LC_{50}$ | median lethal concentration |
| $LD_{50}$ | median lethal dose |
| LOAEL | lowest-observed-adverse-effect level |
| MDL | method detection limit |
| mg/kg-day | milligrams per kilogram (body weight) per day |
| mg/L | milligrams per liter |
| mL | milliliter |
| MBTA | Migratory Bird Treaty Act |

| | |
|---|---|
| NaCl | sodium chloride |
| NEPA | National Environmental Policy Act |
| NOAEL | no-observed-adverse-effect level |
| PERA | Predictive Ecological Risk Assessment |
| ppm | parts per million |
| PVU | Paradox Valley Unit |
| QC | quality control |
| Reclamation | United States Bureau of Reclamation |
| RL | reporting limit |
| SWReGAP | Southwest Regional Gap Analysis Project |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| TRV | toxicity reference value |
| TSS | total suspended solids |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |

# PREDICTIVE ECOLOGICAL RISK ASSESSMENT
# PROPOSED SOLAR EVAPORATION POND SYSTEM
# PARADOX VALLEY UNIT, COLORADO

## 1.0 INTRODUCTION

The Bureau of Reclamation's (Reclamation) Paradox Valley Unit (PVU) is a component of the Colorado River Basin Salinity Control Program, a multi-works program to control the salinity of Colorado River water delivered to users in the United States and Mexico. The PVU currently intercepts 200 gallons per minute (gpm) of 260,000 milligrams per liter (mg/L) brine and diverts it to a 16,000' deep injection well for disposal. The injection rate has been curtailed during the 20 year life of the well due mainly to induced seismic activity associated with the injection process. At the current rate, Reclamation prevents approximately 100,000 tons per year from entering the Colorado River system. The current collection well field is capable of producing 400 gpm. However salinity control benefits may decrease when pumping in excess of 300 gpm. Therefore, for purposes of this study, the goal is to control up to 170,000 tons per year, or 300 gpm. Due to current and future limitations of the injection well, and long term salinity control considerations at Paradox, Reclamation is currently evaluating alternative methods of brine disposal of this produced brine. One of the long-term strategies being considered for brine disposal is diverting the brine to an evaporation pond or series of ponds.

This report presents the results of a predictive ecological risk assessment (PERA) performed by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) that evaluates the potential ecological consequences of the implementation of the evaporation pond alternative. It follows the United States Environmental Protection Agency (USEPA) framework for conducting ecological risk assessments (ERAs) (USEPA 1998). This framework divides the ERA process into three phases:

1. Problem Formulation
2. Analysis
3. Risk Characterization

These three phases are presented in Sections 2 through 4, below. Section 5 presents a summary of the PERA results and provides recommendations for methods by which the potential for risk to key receptors may be mitigated as part of an adaptive management system for the proposed solar evaporation pond facility.

# 2.0 PROBLEM FORMULATION

Problem formulation provides the foundation for the ecological risk assessment. The nature of the problem is established and described, and the objectives for the risk assessment are defined. In addition to describing the history and natural setting of the proposed project, the Problem Formulation develops conceptual site models (CSMs) that show the links or "pathways" by which the environmental conditions created by the evaporation pond system can lead to exposure of organisms in the environment (ecological "receptors") to conditions with the potential to adversely affect the organisms ability to survive, grow, and/or reproduce (generally referred to as "stressors"). The Problem Formulation also establishes Assessment and Measurement Endpoints that explicitly define the resource management objectives of the ERA and the method by which those objectives will be evaluated in the ERA.

## 2.1 Project Background

The following sections provide the details of the project history and a description of the proposed evaporation pond system. It also presents the goals and objectives of this PERA and the regulatory requirements underlying it.

### 2.1.1 Project Location and History

The PVU is located along Highway 90 near Bedrock, Colorado, about 10 miles east of the Colorado-Utah state line (Figure 2-1). The PVU was put on line in 1996 to lower the elevation of the saline aquifer by pumping, thereby reducing its discharge to the Dolores River, and subsequently the Colorado River. As indicated in Section 1.0, the goal of the PVU is to pump approximately 300 gpm from the aquifer, thereby preventing approximately 170,000 tons of salt per year from entering the Colorado River system. However, due to limitations in the disposal method for this brine (deep well injection), the PVU currently pumps 200 gpm of groundwater from the well field near the Dolores River, preventing approximately 100,000 tons of salt per year from entering the Colorado River drainage. Therefore, alternative methods for long-term disposal of brine are being evaluated. One of the alternative strategies being considered is diverting the brine to a surface evaporation pond system by which the water will be removed from the brine through natural evaporation and the remaining solids would be either sold (if marketable) or placed in a permanent disposal facility.

As part of the selection process, an Environmental Impact Statement (EIS) is being prepared under the auspices of the National Environmental Policy Act (NEPA) to evaluate alternatives for controlling salt at Paradox. Evaporation ponds are one of the alternatives being evaluated. It is estimated that the evaporation pond system would require approximately 350 to 400 acres of surface area in the valley. Because of the very high salinity of the water that will be retained in these ponds, they will present a potentially significant hazard to wildlife that may attempt to use them for drinking, feeding, or resting. These hazards include the toxic effects from ingestion of the salts and trace elements in the water; osmotic imbalances from consuming or resting on the water;

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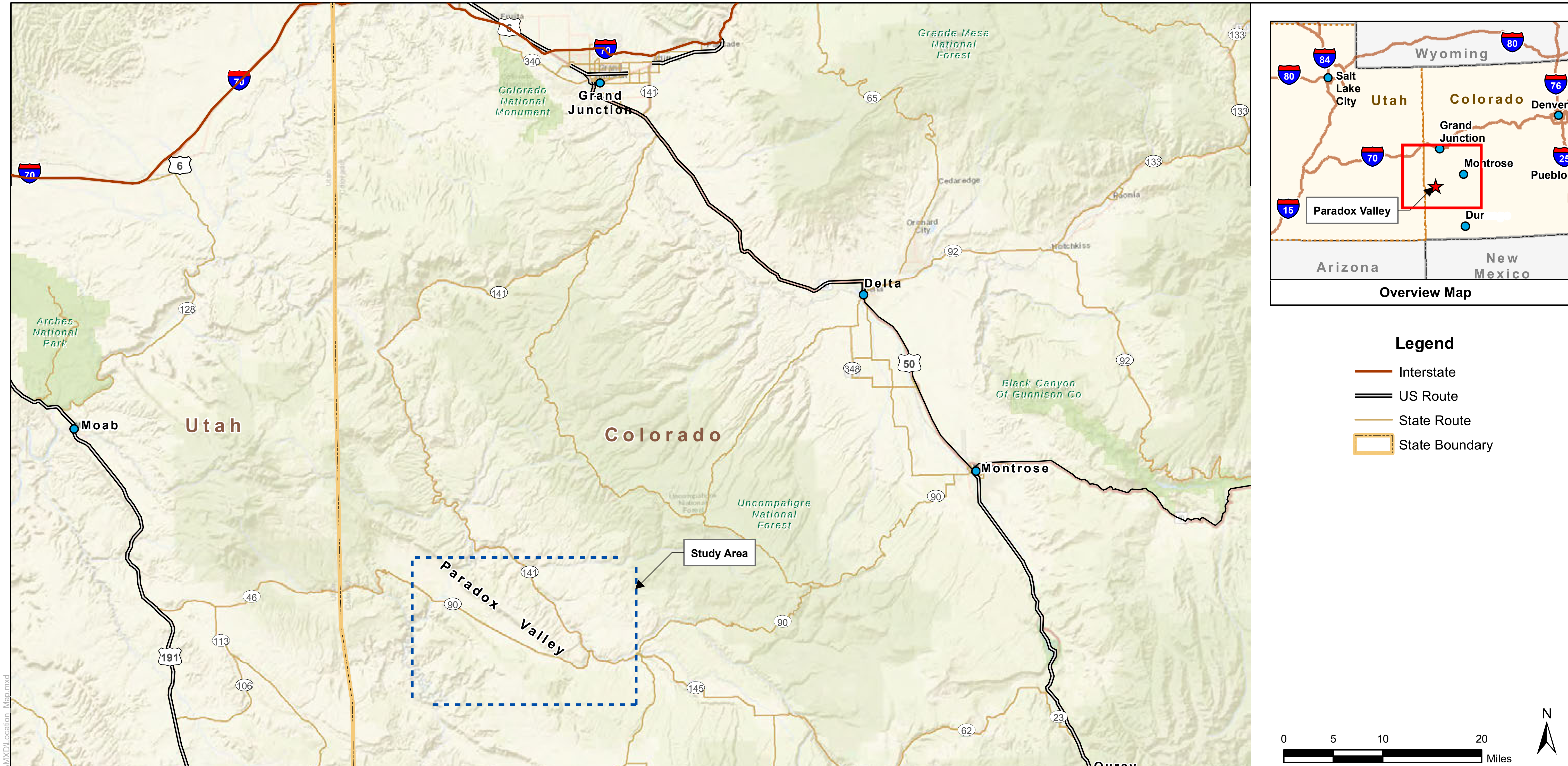


PVU Evaporation Ponds
Predictive Ecological Risk Assessment

**General Location Map**

FIGURE 2-1

Job No.: 1655500023
PM: TF
Date: 5/12/2016
Scale: 1"= 10 miles

The map shown here has been created with all due and reasonable care and is strictly for use with Amec Foster Wheeler Project Number 1655500023. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Amec Foster Wheeler assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

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and entrapment, waterlogging, and eventual mortality due to salt encrustation. The purpose of this PERA is to qualitatively and quantitatively evaluate the potential for adverse effects to the ecological resources of the Paradox Valley as well as the potential severity of those effects if the evaporation pond alternative is carried out for the continued operation of the PVU.

### 2.1.2 Proposed Evaporation Pond System

The proposed evaporation pond system will entail a series of four pond types. From top to bottom these are:

- Surge Pond
- Concentrator Pond(s)
- Crystallizer Ponds
- Bittern Pond

The surge pond will receive the brine by pipeline from the brine collection wells near the Dolores River at a rate of about 300 gpm. Because there are approximately four months of the year (October through January) during which precipitation exceeds evaporation, the surge pond will act as a reservoir for the incoming brine during this time period. The capacity of the surge pond will be approximately 180 acre-feet (ac-ft). When the net evaporation rate becomes positive (in February), the water from the surge pond will be discharged into the concentrator pond at a rate of 200 to 500 gpm, either by gravity or pumping.

The function of the concentrator pond is to evaporate the well brine to the point where sodium chloride (NaCl), the principal salt in the well brine, begins to reach saturation and starts to precipitate. To accomplish this, the concentrator pond will be designed to be shallow with a large surface area. To accommodate the pumping rate, the surface area of this pond will be approximately 110 acres. The normal working depth will be approximately 18 to 24 inches. (The capacity of the concentrator pond will be approximately the same as surge pond, but with greater surface area and less depth.) The concentrator pond may be divided into a series of smaller ponds or contain interior diversion levees to force the brine to flow through a circuitous path from the inlet to the outlet so that the inflow does not create a direct-line flow to the outlet. The flow through the pond(s) will be assisted by the slight gradient of about 1% from the inlet to the outlet. The concentrated brine will then be transferred to the crystallizer pond(s) at a rate varying from 110-300 gpm depending on the month.

In the crystallizer ponds, the bulk of the NaCl is precipitated out of the brine as crystalline salt. The system will be composed of three to five separate ponds (ideally four) with a total surface area of approximately 205 acres and a normal working depth of approximately 18 to 24 inches. Each pond will be fed in parallel from the concentrator by means of a distribution pipe or ditch. Crystallization will occur between February and September with about 4 to 5 inches of NaCl precipitating out of the brine each year. During the October through January timeframe, the salt in the crystallizers will be harvested. This will be done by draining one crystallizer pond into an adjacent one then mechanically removing the salt before refilling with brine. Harvesting may occur every other year in a particular pond.

Bittern refers to a heavy brine that develops in the crystallizers that is rich with magnesium and does not easily evaporate. If left in the crystallizers, bittern will reduce the efficiency of the pond and produce moisture-laden (“slushy”) crystals that are more difficult to harvest. Two ponds will be associated with the management of bittern. A concentrator pond (approximately 24 acres) will allow further evaporation from the bittern, reducing the volume by about one half each year. A 3-acre pond will then be used for the storage of the remaining bittern.

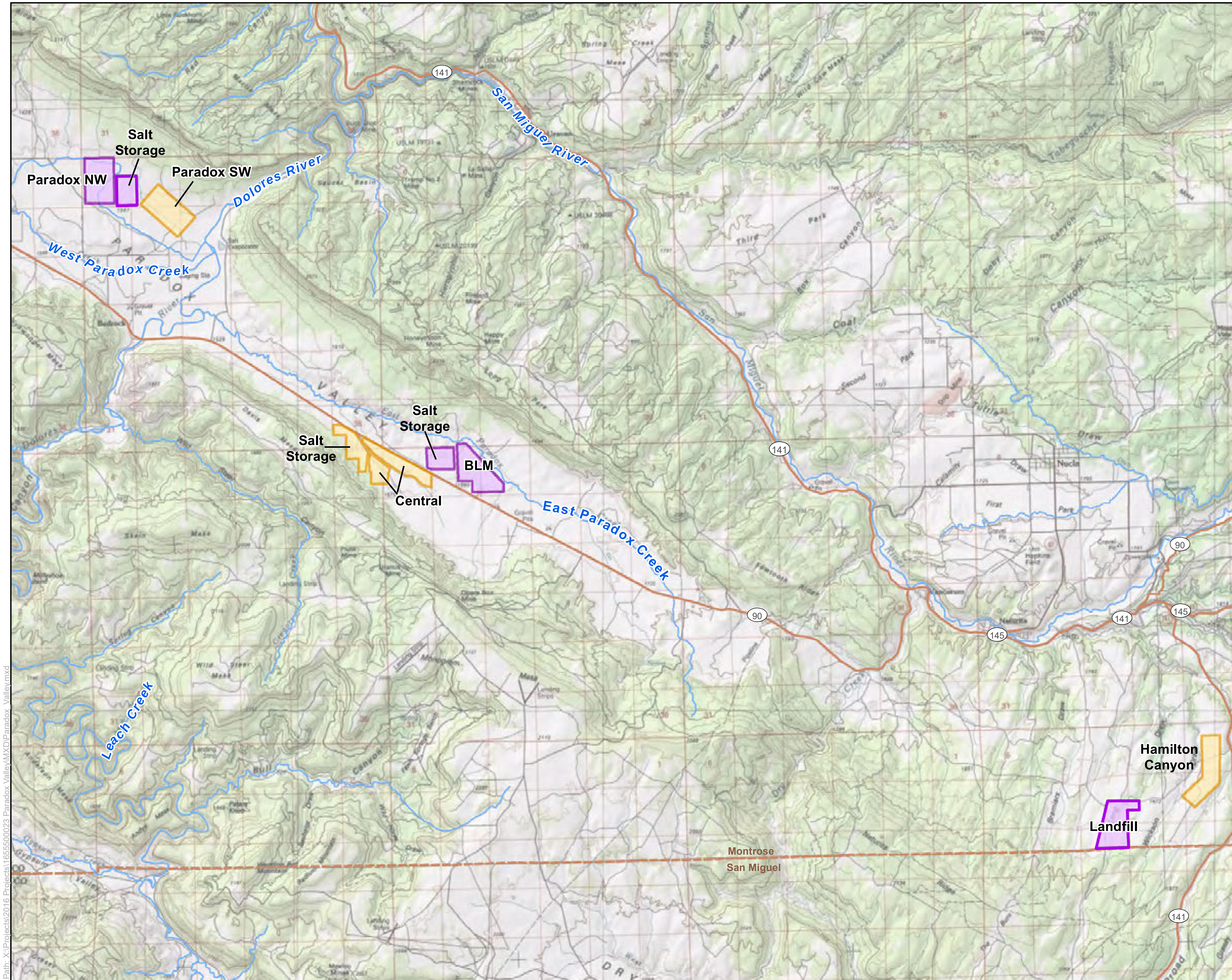
It is expected that approximately 171,000 tons of salt will be produced each year in this system (Amec FW, 2016c). The salt could be disposed of by making it available for use as road salt. However, because the yearly rate of salt production will be continuous, but the demand for road salt will probably fluctuate, it is likely that there will need to be a storage facility for the disposal of excess salt. The Broad Canyon Landfill at the south end of the Paradox Valley is a potential location for a storage facility; however, unless the ponds are sited near this existing landfill, the cost of transporting the salt (by truck) may be prohibitive. Therefore, the development and operation of an independent storage facility adjacent to the pond site will likely be the preferred option (Amec FW, 2016c).

### 2.1.3 Potential Solar Evaporation Pond Sites

Three sites are currently being considered as locations for the solar evaporation ponds (Figure 2-2). These are:

- Paradox NW Site—Located approximately 2.5 miles northwest of the Dolores River at an elevation of about 5,100 feet above mean sea level (amsl). This site is approximately 36 road miles from the Broad Canyon Landfill, which may be used for the disposal of solid salts.
- BLM Site—Located approximately 7 miles southeast of the Dolores River at an elevation of about 5,400 feet amsl. This site is approximately 25 road miles from the Broad Canyon Landfill, which may be used for the disposal of solid salts.
- Landfill Site—This site is adjacent to the Broad Canyon Landfill at an elevation of about 6,200 feet amsl. This site would require minimal hauling of solid salts, but over 20 miles of pipeline to bring the well brine to the ponds.

For each of these three primary sites being considered, a nearby site has been identified as an alternative. These are the Paradox SW Site, Central Site, and Hamilton Canyon Site, respectively (Figure 2-2). The alternative sites are similar in setting, but differ in land ownership, which may facilitate acquisition.





**Area of Detail**

## Legend

- Proposed Solar Evaporation Pond Site
- Alternative Site
- Stream
- County Line

0 1 2 4 Miles

N

PVU Evaporation Ponds
Predictive Ecological Risk Assessment

**Locations of the Three Proposed Solar Evaporation Pond Sites**
**Paradox Valley Unit, Colorado**

FIGURE **2-2**

| | |
|---|---|
| Job No.: | 1655500023 |
| PM: | TF |
| Date: | 7/27/2016 |
| Scale: | 1"= 2 Miles |



amec foster wheeler

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### 2.1.4 Purpose and Objectives of the PERA

The purpose of this PERA is to quantitatively and qualitatively evaluate the potential for adverse effects to ecological resources in the Paradox Valley that would be incurred by the selection of the solar evaporation pond alternative as the means to dispose of saline groundwater pumped from the western side of the valley to reduce the salinity of the Dolores River and its downstream receiving waters (the Colorado River). The object is to present to decision-makers and stakeholders sufficient and scientifically-defensible information on the potential ecological risks associated with this alternative so that a clear and environmentally sound comparison between alternatives can be made.

### 2.1.5 Regulatory Requirements

The PERA provides information on the potential for adverse effects on ecological resources of the Paradox Valley, including the loss or modification of habitat and direct injury or death of wildlife that are exposed to the brines and salts associated with the proposed solar evaporation pond system. The following federal and state laws are applicable to these potential environmental impacts.

**Endangered Species Act (ESA) of 1973** (16 U.S.C. 1531 – 1544) authorizes the U.S. Fish and Wildlife Service (USFWS) to list species (or recognized subspecific taxonomic entities) of plants and animals as threatened or endangered over all or a significant portion of its range and to designate areas of critical habitat necessary for the continued existence of that species or subspecies. Under this act, it is unlawful to “take” any listed threatened or endangered species. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect an individual of that species, or to attempt to engage in any such conduct. Under Section 7 of the ESA, federal agencies that are undertaking any action that may result in take of a listed species or modify designated critical habitat are required to consult with the USFWS to ensure that the action does not further jeopardize the continued existence of the species.

**Migratory Bird Treaty Act (MBTA) of 1918** (16 U.S.C. 703 – 712) provides legal protection to over 800 native bird species of the United States from unlawful pursuit, hunting, taking, capture, killing, or selling (alive or dead, or parts thereof). Specifically, Section 703 of the MBTA states that, “Unless and except as permitted by regulations made as hereinafter provided in this subchapter, it shall be unlawful at any time, by any means or in any manner, to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export, any migratory bird, any part, nest, or egg of any such bird, or any product, whether or not manufactured, which consists, or is composed in whole or part, of any such bird or any part, nest, or egg thereof...”

Section 704 of the MBTA, establishes the process by which exceptions to the act are allowed as follows:

> Subject to the provisions and in order to carry out the purposes of the conventions[1], referred to in section 703 of this title, the Secretary of the Interior is authorized and directed, from time to time, having due regard to the zones of temperature and to the distribution, abundance, economic value, breeding habits, and times and lines of migratory flight of such birds, to determine when, to what extent, if at all, and by what means, it is compatible with the terms of the conventions to allow hunting, taking, capture, killing, possession, sale, purchase, shipment, transportation, carriage, or export of any such bird, or any part, nest, or egg thereof, and to adopt suitable regulations permitting and governing the same, in accordance with such determinations, which regulations shall become effective when approved by the President.

Therefore, the Secretary of the Interior (with Presidential approval) can determine when and to what extent and by what means the take of migratory birds may be allowed. These determinations are to be made based on "due regard to the zones of temperature and to the distribution, abundance, economic value, breeding habits, and times and lines of migratory flight."

**Bald and Golden Eagle Protection Act (BGEPA) of 1940** (16 U.S.C 668 – 668d) provides additional protection to bald and golden eagles from take, including their parts, nests, and eggs, as well as from molesting or disturbing the birds. Both the bald and golden eagle are listed as potentially occurring in the Paradox Valley (see Tables 2-2 and 2-4).

**Fish and Wildlife Coordination Act (FWCA) of 1934** (16 U.S.C 661 – 667e) requires agency consultation with the USFWS and state fish and wildlife management agencies for projects that will involve construction of dams, levees, impoundments, stream relocations, and water diversion structures in order to protect, develop, and improve fish and wildlife

**Colorado Nongame, Endangered, or Threatened Species Conservation Act** (CRS 33-2-101 to 33-2-108) provides legal protection from take, possession, transportation, exportation, processing, sale, or shipment of nongame wildlife deemed by the Colorado Parks and Wildlife Commission to be in need of management except as allowed by the Commission. It also allows the Commission to list species and subspecies of wildlife as threatened or endangered within the state making it unlawful to take, possess, transport, export, process, sell, or ship species or subspecies on that list.

[1] Referring to international conventions between the U.S. and Great Britain, Mexico, Japan, and Russia.

## 2.2 Site Description (Paradox Valley)

This section provides descriptions of the existing environment of the Paradox Valley, including the physical setting, geology, hydrology, and the biological environment, including threatened, endangered, and other sensitive species that occur in and near the valley.

### 2.2.1 Physical Setting

The proposed project will take place within the Paradox Valley in Montrose County, Colorado. This northwest-southeast situated linear valley is located in a transition area between the Rocky Mountains to the east and the arid Colorado Plateau to the west. The region is drained by the north-flowing Dolores River, which bisects the valley perpendicularly, leading to the name “Paradox”. East Paradox Creek and West Paradox Creek flow lengthwise through the valley from the east and west, respectively, to feed into the Dolores River near the center of the valley. Elevations within the Paradox Valley range from approximately 5,000 to 6,000 feet amsl. The valley is bounded by steep slopes on the east, west, and south sides, which give way to flat mesa-tops of 6,500 to 7,000 feet amsl in elevation. The northwestern portion of the valley is bounded by the southwestern slopes of the La Sal range, which reach over 12,000 feet amsl just 14 miles from the valley floor. Where it flows into and out of the valley, the Dolores River has eroded deep canyons, both of which are referred to as Dolores Canyon.

Two towns are located within the valley, Paradox and Bedrock. The valley is also bisected by the northwest-southeast trending State Route 90. Land ownership in the valley is mostly a patchwork of private land and Bureau of Land Management (BLM) administered land. Much of the valley is undeveloped native scrublands and grasslands; however, agricultural development is present in the valley and is mostly restricted to the areas along the Dolores River and West Paradox Creek. Other land uses in the area include livestock grazing, mining, and solar development.

### 2.2.2 Geology

The Paradox Valley was formed by a collapsed salt anticline and is the largest of many salt anticlines in the region. The movement of salt tectonics forming the anticline have increased salinity levels for this area. The Paradox Valley was formed over 150 million years during the Middle Pennsylvanian period (Chenoweth, 1987). During this period, a fault-block ridge buried beneath the region’s salt deposits deflected the deposits upwards and formed a salt dome. Groundwater entering the top of the dome dissolved underlying salt beds causing the center to collapse, leading to the formation of the Paradox Valley. The thickest deposition of salt formed in the northeastern part of the basin and was repeatedly lowered over time. The rock beds are complexly folded and brecciated making it difficult to determine the true thickness and stratigraphic relations with adjacent rocks (Baker et al., 1933).

Salt flows in the region progressed throughout the Permian, Triassic, and Jurassic time periods and ceased during the Late Cretaceous. The exposed visible outcrop of these features are mostly gypsum with various small broken pieces of grey limestone, sandstone, and black shale. The subsurface consists of thick salt alternating with anhydrite, shale, and limestone. Deep wells drilled into the salt structures revealed contorted beds of salt and gypsum extending downwards of about 15,000 feet (Baars, 2000).

The collapse of the salt anticline has left the Paradox Valley with several distinct structural units. The southeast end of the valley has a basin-like downwarp known as the Coke Oven syncline. This formation is likely caused by the removal of salt by pressure-induced flowage. On the southeast end of the valley, the Dry Creek anticline was caused by draping sediments over the faulted margin of the Paradox Valley anticline during its collapse. The valley axis contains many closely spaced faults on both sides of the valley and divide rocks into lengthy linear ridges that trend parallel to the axis. The central area of Paradox Valley retains a salt core (Chenoweth 1987). Carnotite deposits existing on the rim of the valley have been mined for radium, vanadium, and uranium since 1910. The east-central portion of Paradox Valley contains two important mining areas as part of the Uravan mineral belt mining region. (Chenoweth, 1987).

### 2.2.3 Hydrology

The northward-flowing Dolores River bisects the Paradox Valley in a northeasterly direction, entering and leaving it through deep and narrow canyons. The valley was given the name “Paradox” due to the Dolores River crossing it perpendicularly through the middle, rather than flowing down the length, of the valley. The Dolores River is a tributary of the Colorado River and runs most of its length in Colorado, but joins the Colorado River in eastern Utah. The headwaters of the Dolores River are in the San Juan Mountains in southwestern Colorado. It is dammed at McPhee Dam where some of its water is diverted from the reservoir for irrigation in Montezuma County. Downstream of McPhee reservoir, the Dolores River flows to the northeast through Slick Rock, Colorado, before turning to the east and bisecting the Paradox Valley. Snowmelt from the La Sal Mountains in Utah increases the Dolores River flow before it enters the Paradox Valley.

Within the Paradox Valley, the Dolores River meets East Paradox Creek (ephemeral) and West Paradox Creek before continuing its flow through to the Colorado River. Buckeye Reservoir, a 1,600 acre-foot reservoir in the upper (northwestern) part of the valley, regulates the flow of West Paradox Creek before it reaches the Dolores River. The mean annual precipitation for Paradox Valley varies from 11 to 15 inches.

The U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory shows wetlands adjacent to this section of the Dolores River. Small patches of emergent freshwater wetlands are found toward the central part of the valley and two freshwater ponds are also shown on the USFWS wetland map. Prior to the PVU, the salinity of the Dolores River increased dramatically on the east side of the valley where the river encountered the collapsed salt anticline. Before the PVU pumping operation, groundwater surfaced into the Dolores River, contributing dissolved halite and other evaporite minerals to the river (Chafin, 2003).

## 2.3 Biological Setting

The Paradox Valley provides diverse habitat for both resident and migratory wildlife species. Habitat variability is influenced by vegetation type, elevation, precipitation, topography, soil, and other factors. The Paradox Valley hosts habitats ranging from, but not limited to; grasslands, sagebrush, pinyon-juniper, riparian areas, and canyons. This diverse habitat provides foraging grounds supporting resident wildlife and acts as a migratory stopover for birds moving through this area.

### 2.3.1 Vegetation

The Paradox Valley is located within the Shale Deserts and Sedimentary Basins Ecoregion of Colorado (Chapman et. al. 2006). This arid ecoregion is characterized by level basins or valleys with low rounded hills and badlands. Sparse vegetation in the ecoregion is a result of high alkalinity in the soils. Common plants that occur in the ecoregion include greasewood (*Sarcobatus vermiculatus*), alkali sacaton (*Sporobolus airoides*), seepweed (*Suaeda* spp.), shadscale saltbush (*Atriplex confertifolia*), bud sagebrush (*Picrothamnus desertorum*), James' galleta (*Pleuraphis jamesii*), and desert trumpet (*Eriogonum inflatum*). Much of this ecoregion is used for livestock grazing or has been converted to cropland growing winter wheat, grains, and forage crops (Chapman et. al. 2006).

The US Geological Survey's (USGS) Southwest Regional Gap Analysis Project (SWReGAP; USGS 2004) was used to identify vegetation types that occur within the Paradox Valley. The SWReGAP is a land cover dataset that uses soil type, elevation, aerial imagery, and locality to model terrestrial land cover and vegetative communities. Table 2-1 describes the vegetation communities located within the Paradox Valley.

The SWReGAP also identified large tracts of agriculture and invasive grasslands and shrublands within the valley (USGS 2004). Invasive species such as Russian thistle (*Salsola* spp.), Russian knapweed (*Acroptylon repens*), field bindweed (*Convolvulus arvensis*), bull thistle (*Cirsium vulgare*), wild oats (*Avena* spp.), bromes (*Bromus* spp.), and Mediterranean grass (*Schismus* spp.) are likely established within the local native vegetation communities. Large patches of invasive grasses or forbs within the valley may be associated with areas of human disturbance, fire, or overgrazing by livestock. Portions of the Dolores River and other waterways within the valley have established dominant stands of Tamarisk (*Tamarix chinensis*) (BLM 2009).

**Table 2-1. Vegetation Communities within the Paradox Valley**

| Community | Description | Location within Valley |
|---|---|---|
| Colorado Plateau Pinyon-Juniper Shrubland | Characteristic of rocky slopes of the Colorado Plateau and western Colorado. Forms extensive, open shrublands dominated by dwarfed pinion pine (*Pinus edulis*) and one-seed juniper (*Juniperus osteosperma*). Other common species include sagebrush (*Artemisia* spp.), rabbitbrush (*Ericameria* spp.), blackbrush (*Coleogyne ramosissima*), and a variety of xeric grasses. | Ridges and mesas surrounding the valley. |
| Colorado Plateau Pinyon-Juniper Woodland | Similar to a Colorado Plateau Pinyon-Juniper Shrubland, but with taller pinion pines and junipers. Occurs on dry mountain slopes, mesas, plateaus, and ridges with rocky soils. | Ridges and mesas surrounding the valley. |
| Inter-Mountain Basins Big Sagebrush Shrubland | Common within intermountain basins in the western US. Often found in areas of deep, well-drained, non-saline, clay soils between 5,000 and 7,500 feet amsl. Typically dominated by dense stands of tall Artemisia species sometimes interspersed with one-seed juniper. Common plants include big sagebrush (*Artemisia tridentata*), rabbitbrush, winterfat (*Krascheninnikovia lanata*), and a variety of xeric grasses. | Along valley floors. |
| Inter-Mountain Basins Greasewood Flat | Found throughout the western US within intermountain basins and in the Great Plains. Typically found alongside drainages or on playas, with saline soils, a shallow water table, and an intermittent flooding regime. Common plants include greasewood, saltbush (*Atriplex* spp.), rabbitbrush, cholla (*Cylindropuntia* spp.), winterfat, and alkali sacaton (*Sporobolus airoides*). | Along valley floors in the vicinity of waterways or salt flats. |
| Inter-Mountain Basins Semi-Desert Grassland | Common in the Western US, occurring on dry plains or mesas. Often occupy xeric swales, playas, plateaus, plains, or alluvial flats with well drained soils. Common grasses include Indian ricegrass, three-awn grass (*Aristida* spp.), blue gramma, needle and thread, muhly grass (*Muhlenbergia* spp.), and James' galleta. | Along valley floors. |

**Table 2-1. Vegetation Communities within the Paradox Valley**

| Community | Description | Location within Valley |
|---|---|---|
| Inter-Mountain Basins Mixed Salt Desert Scrub | Characterized by open-canopy shrublands within saline basins, alluvial slopes, or plains, typically on saline soils. The shrublands are typically dense and dominated by various species of saltbush. Other common species include sagebrush, rabbitbush, ephedra (*Ephedra* spp.), and a variety of grasses. | Along valley floors. |
| Rocky Mountain Lower Montane Riparian Woodland and Shrubland | Common along large intermittent or perennial waterways of the Rocky Mountains and Colorado Plateau. The community can be tree or shrub dominated depending on its environment. It is dependent on a natural hydrologic regime with annual flooding. Dominant trees can include boxelder (*Acer negundo*), Rocky Mountain maple (*Acer glabrum*), gray alder (*Alnus incana*), water birch (*Betula occidentalis*) cottonwood (*Populus* spp.), and willow (*Salix* spp.). | Alongside portions of the Dolores River and tributaries within the valley floor. |

(USGS 2004)

Colorado Parks and Wildlife (CPW) and BLM, in association with The Nature Conservancy, Colorado Natural Heritage Program, and Southern Rockies Ecosystem Project, developed two Land Health Assessments of the Paradox Valley: West Paradox Land Health Assessment (BLM 2009) and East Paradox Land Health Assessment (BLM 2010). The assessments identified several areas within the valley as important for local biological conservation based on the occurrence of rare species and resource values:

- <u>Paradox Valley North</u>
  Located along the foothills in the northwestern side of the valley, north of the Dolores River. High occurrence of wildflowers and supports peregrine falcon (*Falco peregrinus*)

- <u>West Paradox Creek</u>
  Located in the upstream portions of West Paradox Creek, in the higher elevations of the La Sal Mountain foothills. High quality example of Douglas fir (*Pseudotsuga menziesii*)/redosier dogwood (*Cornus sericea*) community.

- <u>East Paradox Creek</u>
  Located southeast of the Dolores River, from East Paradox Creek to the foothills to the northwest. High quality grassland, shrubland, and pinon-juniper woodland habitats that support high biodiversity. (BLM 2009, 2010)

Local wildlife and migratory species depend on these healthy intact plant communities for habitat, food resources, and stopovers.

### 2.3.2 Fish and Wildlife

#### 2.3.2.1 Birds

Migrating birds, including waterfowl, pass through the Paradox Valley each fall and spring. Although the interpretation and definition of the four major migratory “flyways” of North America (Atlantic, Mississippi, Central, and Pacific) vary; western Colorado (including the Paradox Valley) is often considered to be on the westernmost edge of the Central Flyway. The principal route of the Central Flyway generally follows the Great Plains east of the Rocky Mountains to northeastern Mexico. A minor western route, however, follows the western slope of the Rocky Mountains of Idaho and the Great Salt Lake region of Utah, passing through western Colorado and central New Mexico, and ending in northeastern Mexico. Some migrants on this route turn west and merge with the Pacific Flyway, ending in coastal regions of western Mexico. This “western” route (potentially including the Paradox Valley) is variously defined as part of the Central Flyway, part of both the Central and Pacific Flyways, or being in neither flyway. Regardless of its formal definition with regard to the major flyways, however, this route is not a major migratory corridor for waterfowl.

Variable habitat types exist within the Paradox Valley attracting a diversity of birds. Water bodies such as the Dolores River and local man-made reservoirs could attract high numbers of waterfowl and shorebirds. Sandhill crane (*Grus canadensis*), for example, are known to nest near reservoirs within the valley (Colorado Department of Wildlife 2013). Grasslands, pinyon-juniper woodlands and sagebrush shrublands likely support migrating or breeding gray vireo (*Vireo vicinior*), black-throated sparrow (*Amphispiza bilineata*), black-throated gray warbler (*Setophaga nigrescens*), gray flycatcher (*Empidonax wrightii*), and pinyon jay (*Gymnorhinus cyanocephalus*). The riparian habitat along the Dolores River likely supports riparian obligate species such as yellow-breasted chat (*Icteria virens*) and yellow warbler (*Setophaga petechia*), and provides nesting habitat for raptors. Riparian areas could also serve as migration corridors for montane species migrating toward higher elevation forests.

In 2008, the USFWS identified a list of breeding birds of conservation concern (BCC) that, without conservation action, are likely to become candidates for federal listing under the ESA. Using the BLM’s Land Health Assessment and the USFWS’s Information for Planning and Conservation (IPaC) website (USFWS 2016), a list of BCC that could breed or winter within the Paradox Valley was developed and is listed in Table 2-2.

### Table 2-2. Birds of Conservation Concern within the Paradox Valley

| Common Name | Scientific Name | Habitat | Season |
|---|---|---|---|
| American bittern | *Botaurus lentiginosus* | Marshes | Breeding |
| Bald eagle | *Haliaeetus leucocephalus* | Riparian | Year-round |
| Bendire's thrasher | *Toxostoma bendirei* | Shrublands | Breeding |
| Black rosy-finch | *Leucosticte atrata* | Pine forests and riparian areas | Year-round |
| Brewer's sparrow | *Spizella breweri* | Shrublands | Breeding |
| Brown-capped rosy-finch | *Leucosticte australis* | Pine forests and riparian areas | Wintering |
| Burrowing owl | *Athene cunicularia* | Grasslands and agricultural fields | Breeding |
| Cassin's finch | *Haemorphus cassinii* | Pine forests and pinion woodlands | Year-round |
| Chestnut-collared longspur | *Calcarius ornatus* | Grasslands | Breeding |
| Ferruginous hawk | *Buteo regalis* | Grasslands, woodlands, and shrublands | Year-round |
| Golden eagle | *Aquila chrysaetos* | Grasslands, woodlands, and shrublands | Year-round |
| Grasshopper sparrow | *Ammodramus savannarum* | Grasslands and agricultural fields | Breeding |
| Gray vireo | *Vireo vicinior* | Shrublands and woodlands | Breeding |
| Juniper titmouse | *Baeolophus ridgwayi* | Shrublands and woodlands | Breeding |
| Long-billed curlew | *Numenius americanus* | Grasslands and agricultural fields | Breeding |
| Loggerhead shrike | *Lanius ludovicianus* | Shrublands | Year-round |
| Lucy's warbler | *Oreothlypis luciae* | Riparian | Breeding |
| Mountain plover | *Charadrius montanus* | Grasslands and agricultural fields | Breeding |
| Peregrine falcon | *Falco peregrinus* | Grasslands, woodlands, and shrublands | Breeding |
| Pinyon jay | *Gymnorhinus cyanocephalus* | Shrublands and woodlands | Breeding |
| Prairie falcon | *Falco mexicanus* | Grasslands, woodlands, and shrublands | Year-round |
| Sage thrasher | *Oreoscoptes montanus* | Shrublands | Breeding |
| Short-eared owl | *Asio flammeus* | Grasslands | Wintering |
| Snowy plover | *Charadrius nivosus* | Alkali flats | Breeding |
| Swainson's hawk | *Buteo swainsoni* | Grasslands, woodlands, and shrublands | Breeding |
| Veery | *Catharus fuscescens* | Riparian areas | Breeding |
| Virginia's warbler | *Oreothlypis virginiae* | Riparian areas | Breeding |
| Western grebe | *Aechmophorus occidentalis* | Waterbodies and marshes | Breeding |
| Willow flycatcher | *Empidonax traillii* | Riparian areas | Breeding |

(BLM 2009; USFWS 2016)

The Paradox Valley supports a variety of special status bird species listed by both the BLM and the USFWS. Ferruginous hawk (*Buteo regalis;* BLM Sensitive), northern goshawk (*Accipter gentilis;* BLM Sensitive), peregrine falcon (*Falco peregrinus;* BLM Sensitive), and bald eagle *(Haliaeetus leucocephalus;* Bald and Golden Eagle Act*)* are all known to nest or forage within the Paradox Valley, particularly along the Dolores River (BLM 2009).

The Dolores River and surrounding tributaries potentially provide habitat for nesting and foraging yellow-billed cuckoo (*Coccyzus americanus;* USFWS Threatened [Western Distinct Population Segment]) and southwestern willow flycatcher (*Empidonax traillii extimus; USFWS Endangered*). Neither of these species has been detected within the Paradox Valley recently; however both have been found in similar riparian habitats elsewhere in western Colorado (BLM 2009). Southwestern willow flycatchers are thought to be extirpated from the region, although other subspecies of willow flycatcher may exist (BLM 2009). Similarly, Gunnison sage grouse (*Centrocercus minimus; USFWS Threatened)* has suitable habitat within the valley, but is not known to occur (BLM 2009).

#### 2.3.2.2 Mammals

The Paradox Valley is expected to contain a high number of mammal species both characteristic of the Colorado Plateau portion of the Great Basin Desert to the west and the Rocky Mountains to the east. Large grazing ungulate species in the valley include elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocarpa americana*), and feral horses (*Equus caballus*). Bighorn sheep *(Ovis canadensis)* are less common but a small herd has been known to utilize areas along the Dolores River (BLM 2009). Large carnivores such as coyote (*Canis latrans*), cougar *(Puma concolor),* and bobcat (*Lynx rufus*) are also prominent in the valley. Black bear *(Ursus americanus*) occur in the higher elevations of the valley and in the nearby mountains. Canada lynx *(Lynx canadensis)* were released into western Colorado as part of a reintroduction program in 2005 and although they are adapted to higher altitude forests and riparian areas there is a possibility for migrating or dispersing individuals to travel through Paradox Valley (BLM 2009). Additionally, a successful river otter population has been reintroduced to the Dolores River, which is monitored by the CPW (BLM 2009).

Small mammals of all types are likely to occur all year, such as long-tailed weasel (*Mustela frenata*), Ord's kangaroo rat (*Dipodomys ordii*), least chipmunk (*Tamias minimus*), Hopi chipmunk (*Tamias umbrinus*), and valley pocket gopher (*Thomomys bottae*) (West Water 2009).

Gunnison's prairie dogs (*Cynomys gunnisoni*), which have been petitioned for federal special status listing, are known to inhabit portions of the Paradox Valley. Often associated with prairie dog complexes in the western US are the federally endangered black-footed ferret (*Mustela nigripes*). There is currently no known ferret population in the Montrose County (BLM 2009); however, suitable habitat and healthy Gunnison's prairie dog populations could potentially sustain black-footed ferrets if their range were to expand or reintroductions were to occur.

The Paradox Valley serves as a roosting, foraging, and drinking site for a variety of bat species. Mist-netting and acoustic surveys were conducted in 2008 to determine the presence of bat species occurring in the Paradox Valley area. The study reported 14 species of bats occurring in the area. The study also reported that the Paradox Valley experienced significantly more bat activity than nearby study sites. Bats known to occur within the Paradox Valley include big brown bat (*Eptesicus fuscus*), big free-tailed bat (*Nyctinomops macrotis*), Brazilian free-tailed bat (*Tadarida brasiliensis*), California myotis (*Myotis californicus*), fringed myotis (*Myotis thysanodes*), little brown myotis (*Myotis lucifugus*), long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), silvered-haired bat (*Lasionycteris noctivagans*), spotted bat (*Euderma maculatum*), Townsend's big-eared bat (*Corynorhinus townsendii*), western pipistrelle (*Pipistrellus hesperus*), western small-footed myotis (*Myotis ciliolabrum*), and Yuma myotis (*Myotis* yumanensis) (Hayes et. al. 2008).

#### 2.3.2.3 Reptiles and Amphibians

The shrubby, arid landscape of the Paradox Valley likely supports many species of lizard and snake. Surveys conducted in a portion of the valley by WestWater Engineering in 2009 found western [tiger] whiptail (*Aspidoscelis tigris*), common collard lizard (*Crotaphytus collaris*), and sagebrush lizard (*Sceloporus graciosus*) (WestWater Engineering 2009). Other species known to inhabit the valley include longnose leopard lizard (*Gambelia wislizenii*), eastern fence lizard (*Sceloporus undulatus*), eastern racer (*Coluber constrictor*), corn snake (*Elaphe guttata*), night snake (*Hypsiglena torquata*), milk snake (*Lampropeltis triangulum*), striped whipsnake (*Masticophis taeniatus*), bullsnake (*Pituophis catenifer*), garter snake (*Thamnophis* spp.), and prairie rattlesnake (*Crotalus viridis*) (Colorado Herpetological Society 2016).

Additionally, a variety of amphibian species inhabit the valley along the Dolores River and in other moist or seasonally wet areas (stock ponds, grassy yards, irrigation ditches, evaporation ponds, etc.). Northern leopard frogs (*Lithobates pipiens*), canyon treefrogs (*Hyla arenicolor*), Great Basin spadefoot toads (*Spea intermontana*), and Woodhouse's toads (*Anaxyrus woodhousii*) are expected to be common in the area (BLM 2009).

Similar to other types of animals, the presence of healthy populations of reptiles and amphibians is highly dependent on prey availability. Within the Paradox Valley, the highest area of reptile and amphibian diversity is anticipated to be in the vicinity of the Dolores River and its tributaries, due to the variety of terrestrial and aquatic prey items.

#### 2.3.2.4 Fish

Fish are present within the Paradox Valley, particularly within the Dolores River and its tributaries, although some species may persist in small man-made reservoirs. The Dolores River watershed within the Paradox Valley is typically warm during summer months, highly seasonal in flow volume, high in salinity, and often murky or silty. As a result, this portion of the Dolores River watershed is considered a poor fishery with low biodiversity. More suitable native fish habitat can be found upstream within the Dolores River Canyon Wilderness Study Area (BLM 2009, Fort Lewis College 2014). Native fish such as roundtail chub (*Gila robusta*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus jarrovii*), along with non-native channel catfish (*Ictalurus punctatus*) and common carp (*Cyprinus* carpio), are present within the watershed and are expected within the valley (Fort Lewis College 2014). While present within the headwaters of the watershed, the BLM Sensitive Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) is unlikely to be found in warm waters of the Paradox Valley. Bonytail chub (*Gila elegans; USFWS Endangered*) may be present within the watershed, but has not been recorded (BLM 2009).

### 2.3.3 Special Status Species

The potential for ESA listed species to occur within the project area is evaluated in Table 2-3. This table includes a list of eight federally endangered and threatened species which may occur within one or more US Geological Survey 7.5 minute quadrangle for which the Paradox Valley intersect, as generated by the USFWS's IPaC system. Occurrence determinations in this table are directly based on the findings of the BLM's 2009 Land Health Assessment, unless cited otherwise. No designated critical habitat was identified within the valley.

In addition to species protected under the ESA, the BLM maintains a list of sensitive species, which warrant protection on land administered by the agency. Table 2-4 presents BLM sensitive species that could potentially occur within the Paradox Valley. This table was developed by comparing the list of BLM species known to occur within the BLM's Uncompahgre Field Office (BLM 2015) with the findings of the West Paradox Land Health Assessment. Table 4 only represents species that the BLM's Land Health Assessment determined "may occur" within the Paradox Valley.

### Table 2-3. Potential ESA Listed Species within Paradox Valley

| Common Name | Scientific Name | Status | Habitat Description | Potential to Occur in Paradox Valley |
|---|---|---|---|---|
| Bonytail chub | *Gila elegans* | E | Warm backwaters with rocky or muddy bottoms and flowing pools within the Colorado River and its tributaries. | May occur. Has not been confirmed in Dolores River, but the river is suitable habitat for the species (Kowalski et. al. 2010). Extensive surveys have not taken place in the Paradox Valley. |
| Colorado Pikeminnow | *Ptychocheilus lucius* | E | Warm waters with deep pools, eddies, and runs within the Colorado River and its tributaries. | Unlikely to occur. The species is not known to occur within Montrose County or the Dolores River watershed. |
| Humpback Chub | *Gila cypha* | E | Warm waters with seasonal fluctuations in flow, turbid mainstreams, and calm eddies within the Colorado River and its tributaries. | Unlikely to occur. The species is not known to occur within Montrose County or the Dolores River watershed. |
| Razorback Sucker | *Xyrauchen texanus* | E | Eddies, backwaters, and slow run, sandy riverine areas, and oxbow lakes throughout the larger rivers of the Colorado River and its tributaries. | Unlikely to occur. The species is not known to occur within Montrose County or the Dolores River watershed. |
| Greenback Cutthroat Trout | *Oncorhynchus clarki stomias* | T | Cold, high elevation streams and lakes. | Does not occur. Suitable high elevation habitat is not located within the Paradox Valley or any of its stream systems. |

**Table 2-3. Potential ESA Listed Species within Paradox Valley**

| Common Name | Scientific Name | Status | Habitat Description | Potential to Occur in Paradox Valley |
|---|---|---|---|---|
| Mexican Spotted Owl | *Strix occidentalis lucida* | T | Canyons of dense forests and typically older forests of mixed conifer or ponderosa pine/gamble oak type. | Unlikely to occur. Potential habitat is located in the nearby La Sal Mountains; however, the only confirmed Mexican spotted owls in Colorado are in the far southwestern corner of the state. |
| Western Yellow-billed Cuckoo | *Coccyzus americanus* | T | Tall cottonwood and willow riparian woodlands and gallery forests, often with dense undergrowth. | May occur. While not yet detected in the Paradox Valley, suitable habitat exists and the species is known to occupy similar habitat in western Colorado. |
| Gunnison Sage Grouse | *Centrocercus minimus* | T | Sagebrush communities with diverse grass and forbs and nearby riparian areas. | Unlikely to occur. “Occupied critical habitat” occurs at higher elevations southwest of the Paradox Valley, but no critical habitat is located within the Valley or at any locations potentially affected by the evaporation pond operations. |

**Table 2-4. BLM Sensitive Species that May Occur within Paradox Valley**

| Common Name | Scientific Name | Habitat Description |
|---|---|---|
| Roundtail chub | *Gila robusta* | Pools and eddies of medium sized streams or rivers in the Colorado River watershed. |
| Bluehead sucker | *Catostomus discobolus* | Medium to large streams and rivers of the Colorado River watershed. |
| Flannelmouth sucker | *Catostomus latipinnis* | Medium to large streams and rivers of the Colorado River watershed. |
| Bighorn sheep | *Ovis canadensis* | Alpine meadows, mountainous slopes, and foothills, typically with rocky terrain. |
| White-tailed prairie dog | *Cynomys leucurus* | Grasslands, prairies, and shrublands, of Colorado, Utah, and Wyoming. |
| Gunnison’s prairie dog | *Cynomys gunnisoni* | Grasslands, prairies, and shrublands, of Colorado, Utah, and New Mexico. |
| Allen’s big-eared bat | *Idionycteris phyllotis* | Cliffs, caves, or rock outcroppings in the vicinity of pinion-juniper woodlands. |
| Spotted bat | *Euderma maculatum* | Cliffs, caves, or rock outcroppings in the vicinity of open deserts, shrublands, and grasslands. |
| Townsend’s big-eared bat | *Corynorhinus townsendii* | Cliffs, caves, or rock outcroppings in the vicinity of deserts, woodlands, pine forests, or shrublands. |
| Fringed myotis | *Myotis thysanodes* | Cliffs, caves, or rock outcroppings in the vicinity of deserts, woodlands, pine forests, or shrublands. |
| Bald eagle | *Haliaeetus leucocephalus* | Riparian vegetation with large trees for roosting and a nearby water source for foraging. |
| Golden eagle | *Aquila chrysaetos* | High mountains, canyons, cliffs, or bluffs for roosting with nearby open land for foraging. |

**Table 2-4. BLM Sensitive Species that May Occur within Paradox Valley**

| Common Name | Scientific Name | Habitat Description |
|---|---|---|
| American peregrine falcon | *Falco peregrines anatum* | Cliffs, bluffs, or tall structures for roosting with nearby open land for foraging. |
| Ferruginous hawk | *Buteo regalis* | Open country such as grasslands, shrublands, or desert largely devoid of large trees. |
| Burrowing owl | *Athene cunicularia* | Grasslands, deserts, or agricultural fields with open visibility, prey abundance, and the presence of burrowing mammals (i.e. prairie dogs). |
| Brewer's sparrow | *Spizella berweri* | Sagebrush shrublands or pinion-juniper woodlands with large open patches. |
| Longnose leopard lizard | *Gambelia wislizenii* | Arid grasslands, deserts, or shrublands with flat ground and sparse vegetation. |
| Midget faded rattlesnake | *Crotalus viridis concolor* | Arid grasslands, deserts, or shrublands with sparse vegetation, within the Colorado and Green River basins. |
| Northern leopard frog | *Lithobates pipiens* | Permanent waterbodies such as streams, marshes, or ponds, with abundant wetland vegetation. |
| Canyon treefrog | *Hyla arenicolor* | Arid or semiarid rocky habitats, typically near a permanent water source. |
| Naturita milkvetch | *Astragalus naturitenis* | Sandstone outcrops in pinion-juniper woodlands. |
| San Rafael milkvetch | *Astragalus rafaelensis* | Clay, silty, or sandy soils under cliffs or near washes. |
| Sandstone milkvetch | *Astragalus sesquiflorus* | Sandstone outcroppings, under cliffs, or near washes in pinion-juniper woodlands. |
| Paradox Valley (Payson's) lupine | *Lupinus crassus* | Chinle formation shales in pinion-juniper woodlands. Endemic to the Paradox Valley region. |
| Paradox (Aromatic Indian) breadroot | *Pediomelum aromaticum* | Sandy soils or adobe hills within pinion-juniper woodlands. |

## 2.4 Chemical Characterization of Brine and Salt By-products

Two duplicate samples of Paradox Valley groundwater (referred to as “brine”) were collected from the injection well inflow pipe on March 10, 2016. Each of these field duplicate samples was then split for separate quality control (QC) analysis. These samples were submitted to ALS Environmental in Fort Collins, Colorado, for analysis of the following:

- Metals, including mercury
- Major anions (chloride, bromide, fluoride, sulfate, nitrate, nitrite, and orthophosphate)
- Methane
- Ammonia
- Total phosphate
- Alkalinity (as $CaCO_3$)
- Total organic carbon (TOC)
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- pH
- Specific conductivity

The results of these analyses are presented in Table 2-5. These data are used in this PERA to characterize the brine as it will enter the surge pond. As described in Appendix A, the reporting limits (RLs) for these analyses were determined to be protective of the ecological receptors (i.e., wildlife) that may be exposed to the brine. It should be noted that the TDS measurements from the two duplicate samples (85% and 58%[2]) do not correspond well with each other and are much higher than the TDS predicted by the sums of the measured constituents (approximately 28%). Further, these values exceed the saturation level of sodium chloride of 36% (in one case, more than double). For this reason, the measured TDS values are considered anomalous and are not used directly in this PERA.

Sodium and chloride dominate the salt content of the brine, comprising approximately 97% of the dissolved cations and anions in the well water. Of the major cations, sodium comprises approximately 10% of the brine followed by potassium (0.53%), magnesium (0.20%), and calcium (0.17%). Among the major anions, chloride comprises 17% of the brine followed by sulfate (0.70%). All others (bromide, fluoride, nitrate, nitrite, and orthophosphate) are less than 0.02%.

Among the lesser metals (referred to “trace elements”), strontium showed the highest concentration at about 32 mg/L, followed by boron (11 mg/L), silicon (2.7 mg/L), manganese (0.59 mg/L), lithium (0.39 mg/L), bismuth (0.049 mg/L), and barium (0.037 mg/L). All other metals were less than their corresponding method detection limit (MDL) (Table 2-5).

[2] Percentages are based on the proportion of the brine as weight per volume, where 1% = 10,000 mg/L.

**Table 2-5**
**Analytical Results from Well Brine Samples Used in the Predictive Ecological Risk Assessment**

| Analyte | Sample Concentrations[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PVUBIF 16031001 | | | | PVUBIF 16031002 | | | |
| | Primary Analysis (1603232-3) | | Duplicate Analysis (1603232-6) | | Primary Analysis (1603232-4) | | Duplicate Analysis (1603232-7) | |
| **Major Salt Cations** | | | | | | | | |
| Sodium | 100,000 | | 110,000 | | 94,000 | | 110,000 | |
| Potassium | 5,300 | | 5,300 | | 5,400 | | 5,400 | |
| Magnesium | 1,900 | | 1,900 | | 2,000 | | 2,000 | |
| Calcium | 1,700 | | -- | | 1,700 | | 1,700 | |
| **Anions** | | | | | | | | |
| Chloride | 170,000 | | -- | | 170,000 | | -- | |
| Bromide | 86 | | -- | | 83 | J | -- | |
| Fluoride | 0.05 | U | -- | | 0.05 | U | -- | |
| Sulfate | 7,100 | | -- | | 6,800 | | -- | |
| Bicarbonate (as CaCO3) | 200 | | -- | | 200 | | -- | |
| Carbonate (as CaCO3) | 20 | U | -- | | 20 | U | -- | |
| Nitrate (as N) | 0.1 | U | -- | | 0.1 | U | -- | |
| Nitrite (as N) | 0.05 | U | -- | | 0.05 | U | -- | |
| Orthophosphate (as P) | 0.25 | U | -- | | 0.25 | U | -- | |
| **Trace Elements** | | | | | | | | |
| Aluminum | 5.0 | U | 3.4 | | 5.0 | U | 5.0 | U |
| Antimony | 0.03 | U | 0.03 | U | 0.03 | U | 0.03 | U |
| Arsenic | 0.2 | U | 0.2 | U | 0.2 | U | 0.2 | U |
| Bismuth | 0.049 | J | 0.62 | J | 0.049 | J | 0.049 | J |
| Boron | 11 | | 10 | | 11 | | 11 | |
| Barium | 0.03 | | 0.53 | J | 0.044 | J | 0.044 | J |
| Beryllium | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U |
| Cadmium | 0.03 | U | 0.03 | U | 0.03 | U | 0.03 | U |
| Cobalt | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Chromium | 1 | U | 1 | U | 1 | U | 1 | U |
| Copper | 1 | U | 1 | U | 1 | U | 1 | U |
| Iron | 10 | U | -- | | 10 | U | 10 | U |
| Lead | 0.05 | U | 0.05 | U | 0.05 | U | 0.05 | U |
| Lithium | 0.36 | | 0.41 | J | 0.42 | J | 0.42 | J |
| Manganese | 0.58 | | 0.61 | | 0.6 | | 0.62 | |
| Mercury | 0.0002 | U | 0.0002 | U | 0.0002 | U | 0.0002 | U |

**Table 2-5**
**Analytical Results from Well Brine Samples Used in the Predictive Ecological Risk Assessment**

| Analyte | Sample Concentrations[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PVUBIF 16031001 | | | | PVUBIF 16031002 | | | |
| | Primary Analysis (1603232-3) | | Duplicate Analysis (1603232-6) | | Primary Analysis (1603232-4) | | Duplicate Analysis (1603232-7) | |
| Molybdenum | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Nickel | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Phosphorus | 0.57 | J | 0.52 | J | 0.52 | J | 0.53 | J |
| Selenium | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Silicon | 2.7 | | 3.0 | | 2,600 | | 2.8 | |
| Silver | 0.01 | U | 0.01 | U | 0.01 | U | 0.01 | U |
| Strontium | 31 | | 32 | | 32 | | 32 | |
| Tin | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Titanium | 2.0 | U | 2.0 | U | 2.0 | U | 2.0 | U |
| Thallium | 0.02 | U | 0.02 | U | 0.02 | U | 0.02 | U |
| Uranium | 0.01 | U | 0.01 | U | 0.01 | U | 0.01 | U |
| Vanadium | 0.1 | U | 0.1 | U | 0.1 | U | 0.1 | U |
| Zinc | 2.0 | U | 2.0 | U | 2.0 | U | 2.0 | U |
| **General Chemistry and Miscellaneous Analytes** | | | | | | | | |
| pH | 6.32 | | -- | | 6.29 | | -- | |
| specific Conductivity (umhs/cm) | 237,000 | | -- | | 238,000 | | -- | |
| Total alkalinity (as CaCO3) | 200 | | -- | | 200 | | -- | |
| Total organic carbon (TOC) | 1.0 | U | -- | | 1.0 | U | -- | |
| Dissolved organic carbon (DOC) | -- | | 1.0 | U | -- | | 1.0 | U |
| Total dissolved solids (TDS)[2] | 850,000 | | -- | | 580,000 | | -- | |
| Total suspended solids (TSS) | 20 | U | -- | | 20 | U | -- | |
| Hydrogen sulfide | 57 | | -- | | 53 | | -- | |
| Ammonia (as N) | 17 | | -- | | 15 | | -- | |
| Methane | 1.2 | | -- | | 1.1 | | -- | |
| Total Phosphorus | 0.033 | | -- | | 0.018 | J | -- | |

**Notes:**
[1]All concentrations are milligrams per liter (mg/L)
[2]TDS results are anomalously high based on concentrations of other analytes.
**Qualifiers:**
J = estimated value (between the reporting limit and method detection limit)
U = below the given reporting limit

The chemistry of the well water described above will change as the water moves through the evaporation pond system. It is noted that the initial water is at about 75% of saturation for sodium chloride (approximately 36%). Therefore, approximately 25% of the water is expected to be lost through evaporation as the water moves through the concentrator pond(s), increasing the concentrations proportionally. The less soluble salts (e.g., calcium sulfate [gypsum] and calcium carbonate) will likely precipitate out before the water reaches the concentrator outflow. It is expected that this will remove essentially all of the calcium and the associated sulfate and bicarbonate before the brine is transferred to the crystallizer ponds. The water in the crystallizer ponds will be at or near saturation for all other remaining salts, which will be precipitating out of solution. Non-sodium chloride salts (e.g., potassium chloride and salts of trace elements) will become “impurities” in the sodium chloride bed of the crystallizers; however, magnesium salts will tend to stay in solution, becoming a dominant cation in the bittern when it is removed and transferred to the bittern pond.

## 2.5 Potential Ecological Hazards

Several types of potential hazards to ecological resources will be associated with the evaporation pond alternative at the PVU. These have been subdivided into three main types—habitat loss, physical hazards, and chemical hazards. Each of these is described in the following subsections.

### 2.5.1 Habitat Loss

The siting and construction of the facility will require the replacement of existing habitat with large areas of non-functional habitat. The evaporation pond system, including roads, berms, and supporting facilities, will probably require the removal of 350 to 400 acres of existing habitat. In addition to the direct loss of biota occupying that area (including plants, invertebrates, reptiles (and possibly amphibians), and small mammals, the loss of this area will also entail the following:

- Loss of foraging area for large ungulates (e.g., deer and elk), especially with regard to the use of the valley floor as wintering habitat;
- Loss of breeding habitat for migratory and resident birds; and
- Disruption of movement and travel corridors used by wildlife to traverse the area.

### 2.5.2 Physical Hazards

Physical hazards include those aspects of the evaporation ponds that present a direct hazard to biota (i.e., wildlife) not associated with chemical toxicity. These include aspects of design, operation, and physical characteristics of hypersaline water. The physical hazards considered in this PERA include:

- Osmotic potential—Regardless of the actual chemical composition, high TDS results in a high osmotic potential in the water that is capable of drawing water through skin exposed to that water resulting in dehydration of the exposed individual. Although the plumage of waterfowl is water repellent by means of overlapping outer feathers coated with oil produced by the uropygial gland, a duck resting or swimming on hypersaline water can lose body water through the exposed skin of the legs and cloaca.

- Feather disruption—To function properly for waterproofing and thermoregulation, the structure of body feathers must be maintained. Feathers are intricate structures consisting of a central shaft with a row of "barbs: coming off of each side. Each barb is similarly structured with a row of small "barbules" that link to surrounding barbules by means of minute "hooklets" that line the barbules. Birds maintain the structure and integrity of the feathers through preening with their bills. In hypersaline water, salt crystals can begin to form around the barbules, disrupting the function of the hooklets and causing the structure of the feathers to fail. This, in turn, can lead to a loss of the waterproofing provided by intact feathers and waterlogging of the bird. Waterlogging can result in hypothermia, sinking, and even drowning of the bird.

- Salt encrustation—With continued contact with hypersaline water, feathers may become encrusted with salt crystals. If allowed to continue, salt crust can affect the bird's ability to fly, or even walk out of the water. In conjunction with waterlogging, the weight of the salt encrustation can pull the bird lower into the water, potentially leading to drowning. Salt encrustation occurs when one or more salts are at saturation or are in a condition of supersaturation. Salts for which the solubility is dependent upon water temperature (e.g., sodium sulfate and sodium carbonate) are particular encrustation hazards due to changes in solubility during sudden cold snaps causing supersaturation conditions and rapid crystal formation on solid objects, such as the feathers of waterfowl attracted to the water as a migratory layover. Sodium chloride solubility, however, is not strongly influenced by temperature.

- Bank design—Steep banks surrounding saline and hypersaline ponds can entrap waterfowl within the pond, leaving them susceptible to the other hazards (physical and chemical) associated with the pond (feather disruption, salt encrustation, salt toxicity e, etc.). Entrapment by steep banks would be associated with the loss of the ability to fly, either due to salt encrustation or the toxic effects of salt ingestion.

- Vehicular traffic—The transport of the harvested salt to a landfill will require an increase in vehicular traffic between the evaporation pond facility and the landfill site (totaling approximately 180,000 tons per year). With increased truck traffic, especially along paved highways, comes the increased risk of wildlife strikes. The expected loss of wildlife from vehicle strike is dependent upon the roundtrip haulage distance. The distance of haulage will be dependent upon the selected locations for both the evaporation pond facility and the landfill, which may be as little as zero (if the landfill is located as part of the facility) to approximately 30 miles or more.

### 2.5.3 Chemical Hazards

Chemical hazards are primarily associated with the toxic effects of the brine constituents resulting from an internal exposure to the chemical constituent. The two principal routes of internal exposure by wildlife are ingestion and inhalation (dermal contact may also result in internal exposure, but is considered insignificant relative to ingestion). Ingestion of brine constituents would most likely be the result of the direct ingestion of brine as drinking water. Other routes of ingestion exposure include preening of salt crystals from feathers, scavenging of dead animals from the ponds or near the ponds, incidental ingestion of salt-affected soil, and the deliberate ingestion of salt ("licking") from the stockpiles or at the landfill. It should be noted that direct food chain ingestion other than scavenging is unlikely because the well water is too saline to support life in the ponds.

Through these ingestion pathways, the receptor may be exposed to potentially toxic levels of salts (particularly sodium, potassium, and magnesium cations) and trace elements (e.g., strontium, boron, and lithium). Potential toxicities of these metals are discussed in Section 3.2.

The inhalation hazard is primarily associated with a single well water constituent—hydrogen sulfide ($H_2S$). Because of the potential human health risk associated with the $H_2S$ content of the water, the water will be treated prior to being pumped into the surge pond to chemically convert the $H_2S$ to safer forms. The current recommendation for $H_2S$ control is a sodium hypochlorite oxidation system at the point of release to the surge pond. The treatment with sodium hypochlorite would be followed by treatment with reducing agents to eliminate residual chlorine, and the addition of ferric chloride to help precipitated solids settle in the surge pond. Because hypochlorite oxidation of $H_2S$ generates sulfuric acid, and both the reducing agent and ferric chloride are also acidic, the pH of the brine will be brought back to neutral by the addition of caustic or lime. It is predicted that, because this process is based on oxidation/reduction, essentially all of the $H_2S$ will be removed from the brine before it is released into the surge pond, eliminating the potential for an inhalation hazard from $H_2S$ at this facility. Other chemical parameters of the water (salt concentrations, pH, etc.) will not be significantly changed.

## 2.6 Conceptual Site Models

CSMs provide a verbal and/or graphical representation of the potential pathways by which the ecological receptors of a site may be exposed to the hazards posed by a site or its environmental conditions. In this section, separate CSMs are provided for each of the four principal phases of the project. These four phases are:

1. Project Siting and Construction
2. Evaporation Pond Design

3. Evaporation Pond Operation and Maintenance
4. Waste Product Transport, Storage, and Disposal

Details of the specific hazards associated with each of the phases are provided in Section 2.5.

### 2.6.1 Project Siting and Construction

The two principal ecological hazards associated with the construction of this facility will be the loss of habitat and the disruption of wildlife movement patterns. The siting of the facility will determine the degree of this effect, i.e., whether the habitat lost is of high quality to local wildlife populations and whether important or critical travel corridors are disrupted by the placement of the ponds. Further, increased vehicular traffic associated with the construction may also have deleterious effects on wildlife.

### 2.6.2 Evaporation Pond Design

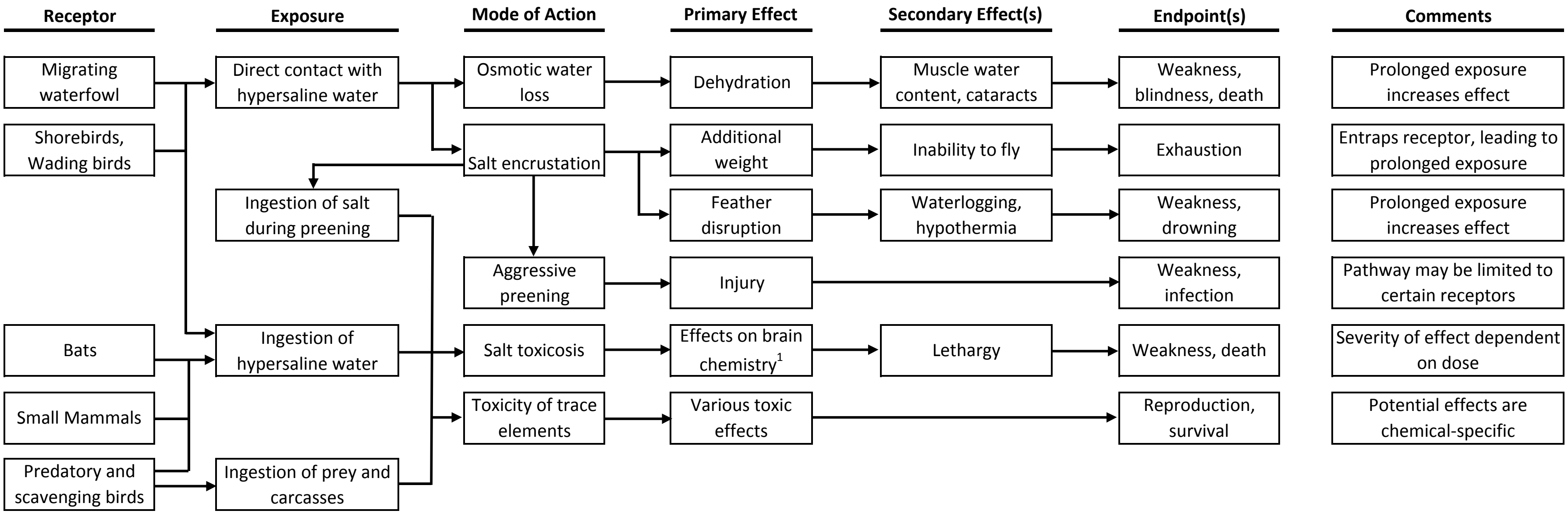
Entrapment is a key issue in pond design. Escaping from the pond is critical to the survival of salt-affected waterfowl as well as other animals that may have come to the shoreline or fallen into the pond. As described in Section 2.5, steep banks can impede the ability of salt-laden or -dosed waterfowl from being able to leave the pond. Further, it is assumed in this PERA that the ponds will be lined to prevent the infiltration of brine back into the groundwater aquifers of the Paradox Valley. The texture of the lining material, if exposed around the shoreline, will also be an important factor in potential entrapment of wildlife. Smooth liners will exacerbate the potential for entrapment, while a coarse or rough surface, in combination with moderately sloped banks, will facilitate animal’s ability to escape the brine.

If the ponds are not lined, brine will likely infiltrate through the bottom and percolate through the substratum beneath the ponds. Depending on the amount of lateral migration around the ponds, this brine may contact deeper plant roots around the pond facility, potentially killing those plants, or could emerge as seeps along local drainages where wildlife could be exposed outside of the exclusion fence.

### 2.6.3 Evaporation Pond Operation and Maintenance

A graphical representation of the CSM for the pond operation and maintenance phase is shown in Figure 2-3. As described in Section 2.1.2, the salinity of the brine entering the system will increase as it flows from the surge pond through concentrator pond(s), and finally to the crystallizer and bittern ponds. Exposure pathways will vary with the type of receptor.

For waterfowl and (to a lesser extent) shorebirds, the first complete exposure pathway to the hypersaline water is with first direct contact with the water, initiating osmotic water loss through the skin. This would happen at any of the ponds, but would likely be more pronounced at the lower end of the system (starting at the lower end of the concentrator) where osmotic potential is highest. Consumption of the water (possibly driven by dehydration, will lead fairly rapidly to




[1]Other potential effects include lung edema, muscle degeneration, cardio-myopathy, hepatic and other organ congestion, conjunctivitis, and lens opacity.

**Figure 2-3. Conceptual Site Model for the Evaporation Pond Operation and Maintenance Phase of the Proposed Solar Evaporation Pond System, Paradox Valley Unit, Colorado**

salt toxicosis (see Section 3.2) which can have multiple physiological and behavioral effects that will affect the bird's ability to escape from the pond or its survival out of the pond if it can escape. These birds will also be exposed to the trace elements in the water; although most of those that have the highest potential for toxic effects (e.g., arsenic, cadmium, selenium, etc) are at very low concentrations compared to the salt cations.

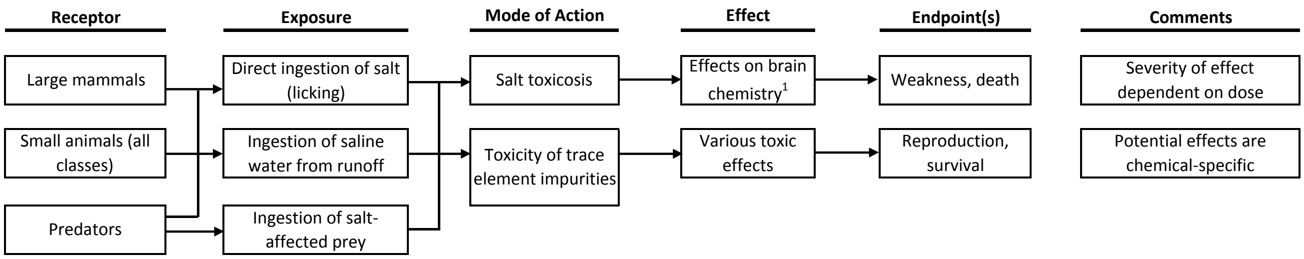
At the lower end of the pond system, salt concentrations at or above saturation will begin to crystalize on feathers, leading to the effects of feather disruption and encrustation (see Section 2.5). Because the well water in this system is dominated by sodium chloride rather than sodium sulfate or carbonates, the crystallization process is less affected by temperature change than, for example, trona ponds. Therefore, this system should be much less prone to sudden, large die-offs from salt encrustation as are ponds with other types of salts.

Other wildlife species, including mammals, reptiles, and birds other than waterfowl and shorebirds may also attempt to drink from the saline and hypersaline ponds and may also be adversely affected by salt toxicosis. If then taken by a predator or scavenged after death, the predator or scavenger will be orally exposed to the salt accumulated in the body. Of particular concern at this site is the rich bat community of the Paradox Valley. Bats often drink from open bodies of water by "skimming" the surface with their lower jaw extended to scoop in water. If skimming is done at the evaporation ponds, exposure of bats to the constituents in the brine would result. Again, it is noted that trace elements would also be consumed by these wildlife receptors; however, the potential for adverse effects are low due to the very low concentrations of these elements in the water.

### 2.6.4 Waste Product Transport, Storage, and Disposal

The final phase of the operation would be the transport, storage, and disposal of the solid, harvested salt and the waste products (bittern and bittern solids). The CSM for this phase is shown in Figure 2-4. Exposure pathways for the bittern pond are similar to those of the crystallizers shown in Figure 2-3 and are not repeated; however, the chemistry of the bittern will be very different from that of the crystallizers in that a large proportion of the sodium chloride will have been removed, leaving a brine much richer in magnesium salts. Trace elements not precipitated out in the crystallizers will also remain at higher concentrations, although the exact chemical composition of the bittern is not known.

With regard to the harvested salt, the potential physical hazards to wildlife due to the increased truck traffic from the hauling operation has been previously discussed (Section 2.5). Transient salt resulting from handling and transport operations may affect soils surrounding the loading area, transport routes, and the landfill area. Runoff control systems may also accumulate salts, making them available for ecological exposure. Finally, there will be a potential for mammals to consume salt directly as a dietary supplement.




[1]Other potential effects include lung edema, muscle degeneration, cardio-myopathy, hepatic and other organ congestion, conjunctivitis, and lens opacity.

**Figure 2-4. Conceptual Site Model for the Waste Product Transport, Storage, and Disposal Phase of the Proposed Solar Evaporation Pond System, Paradox Valley Unit, Colorado**

Finally, it should be noted that it is assumed that the pond facility and (probably) the landfill will be fenced with game fencing to exclude access by large mammals, such as elk and deer. Therefore, exposure pathways to these potential receptors are considered incomplete. Other large receptors, such as coyotes, will also be restricted from access.

## 2.7 Potentially Affected Ecological Resources

As indicated in the above CSMs, waterfowl (including ducks, geese, swans, coots, grebes, and loons) are the resource most vulnerable to the hazards posed by the evaporation pond system. This is especially true during fall and spring migrations when large numbers of these birds are moving through the area and may be attracted by the large areas of surface water presented by these ponds. During adverse weather events, these birds may seek shelter on these ponds and may be held to the ponds by the weather through a critical (potentially fatal) period of exposure.

Shorebirds and wading birds (e.g., herons and cranes) are also potentially affected due to direct dermal contact at legs and feet as well as potential consumption of water, but are less vulnerable than birds that swim in the water (i.e., waterfowl). Upland birds (from surrounding habitats and migrants) may also access the ponds and use them for drinking water; therefore, these species are also considered potentially exposed to the chemical hazards posed by the facility. Predatory birds (e.g., raptors and owls) and scavengers (e.g., vultures, ravens, and magpies) may be indirectly exposed to higher levels of salts when they consume prey or carcasses of animals that have been consuming the brine from the ponds or are encrusted with salt from the ponds.

Terrestrial wildlife other than birds (mammals, reptiles, and amphibians) may also be affected by the evaporation ponds due to ingestion of brine or salt-affected soils or food. As indicated in Section 2.6, it is assumed that large mammals, such as elk and deer will be excluded from the facility by wildlife fencing. Smaller mammals (rodents, rabbits, and small predators), reptiles (lizards and snakes), and amphibians (possibly the Great Basin spadefoot and Woodhouse's toad) will be able to go through the fence and may be exposed to the brine in the ponds. For the mammals and reptiles, direct ingestion of brine from the ponds would be the most likely route of exposure, while for the amphibians, direct contact with the brine presents the more significant hazard. As noted previously, bats are able to fly over the fencing and skim water from the ponds.

The brine in the ponds (all of the ponds) will be too saline to support aquatic invertebrates, even brine shrimp and brine flies. However, flying insects may be attracted to the water surface and be adversely affected by contact with or consumption of the water.

Plants are unlikely to be significantly affected by the ponds following their construction. The water will be too saline for the colonization of wetland plants, such as cattails and rushes, or even algae. Roads and berms around the ponds will inhibit the re-establishment of vegetation around the margins of the ponds. Salts will be managed to prevent significant dispersal into surrounding ecosystems.

Similarly, aquatic receptors and local aquatic communities (e.g., in the Dolores River) will not be affected because the evaporation ponds will be a closed system with no releases of saline water to any existing aquatic community.

### 2.8 Assessment and Measurement Endpoints

Assessment endpoints represent an explicit expression of the actual environmental values to be protected at the PVU evaporation pond system. Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological component(s) chosen as the assessment endpoints.

Representative species were selected as surrogates for wildlife that may be present at the evaporation ponds site based on the likelihood of exposure and sensitivity to salt brine, migratory pathways, and other factors, such as life history parameters, presence or likely presence at the site, representatives of receptor class, and bioavailability of toxicological data for these and similar species. The five surrogate species chosen to represent the terrestrial mammals and aquatic birds are as follows:

- Eared grebe (*Podiceps nigricollis*), representing waterfowl with small body size
- Northern shoveler (*Anas clypeata*), representing waterfowl with medium body size
- Canada Goose (*Branta canadensis*), representing waterfowl with large body size
- Deer Mouse (*Peromyscus maniculatus*), representing small, upland mammals (including bats)
- Black-throated Sparrow (*Amphispiza bilineata*), representing upland songbirds (passerines)
- Red-tailed Hawk (*Buteo jamaicensis*), representing carnivorous and scavenging birds

These wildlife species favor habitats consistent with conditions of evaporation ponds and may potentially be found in the area. Thus, the life history and behavior of these species ensure a conservative estimate of risk. Because body size can influence the level of exposure, the three waterfowl species selected represent a range of body sizes. It should be noted that in this PERA, “waterfowl” is used to include any avian species that habitually swims on the surface of water and can potentially include ducks, geese, swans, loons, grebes, coots, phalaropes, and pelicans. This broad definition is due to the fact that some of the adverse effects from contact with saline and hypersaline water by birds (e.g., feather disruption and salt encrustation) are linked to direct contact between the water and feathers, which occurs when the bird swims free in the water (not merely wading into it).

The selection of receptors did not include large terrestrial mammals because the site will be fenced (with game fencing) to prevent large mammals (e.g., deer and elk) from entering the evaporation pond area. The fence will not prevent small mammals (represented by the deer mouse) from entering the area. The potential for risk to bats from drinking saline water is assumed to be represented by the potential risk to deer mouse through the same exposure pathway. No toxicity data for salt ingestion by bats was found to support a separate analysis of bats from other small mammals; however, published information (Griffiths et al., 2014) indicates that bats avoid saline water for drinking.

Risk to songbirds (represented by the black-throated sparrow) is conservatively represented through the drinking water pathway under the assumption that all water consumed is from the hypersaline pond(s). A carnivorous avian receptor (red-tailed hawk) was included in the risk quantification to represent raptors that might feed on small mammals that have ingested water from the evaporation pond. The red-tailed hawk also represents avian scavengers (e.g., vultures, ravens, and magpies) that may feed on the carcasses of animals that have died around the margins of the pond (potentially from ingestion of the water). Scavenging by larger birds (e.g., the red-tailed hawk) is evaluated because (1) they may use the evaporation pond occasionally due to their larger foraging range and (2) an approach is available to model potential salt content in a small mammal carcass based on estimated water ingestion rate. Dead or dying insects could also be an exposure pathway for scavenging birds; however, it is uncertain whether insects will be attracted to the water or, if so, whether their tissue salt content will be significantly affected (increased) by contact with that environment.

The preliminary assessment and measurement endpoints for this PERA are presented in Table 2-6. For each of these assessment and measurement endpoint pairs, a representative ecological receptor species or group is identified.

**Table 2-6**
**Assessment and Measurement Endpoints for the**
**Predictive Ecological Risk Assessment,**
**Proposed Solar Evaporation Pond Facility,**
**Paradox Valley Unit, Paradox Valley, Colorado**

| Functional Group | Assessment Endpoint | Representative Receptor | Measure of Exposure | Measurement Endpoint |
|---|---|---|---|---|
| Waterfowl | Survival, health, and reproduction of waterfowl exposed to COPECs[1] in brine facility | Northern shoveler; Eared grebe; Canada Goose | Measured COPEC concentrations in brine modeled as an oral dose to the receptor | Comparison of predicted oral dose to avian-specific TRVs |
| Upland wildlife | Survival, health, and reproduction of upland wildlife exposed to COPECs in brine facility | Deer mouse Black-throated sparrow | Measured COPEC concentrations in brine modeled as an oral dose to the receptor | Comparison of predicted oral dose to mammalian-specific TRVs |
| Carnivorous birds | Survival, health, and reproduction of carnivorous birds exposed to COPECs in brine and food items at the facility | Red-tailed hawk | Measured COPEC concentrations in brine and modeled COPEC concentrations in small mammal tissues modeled as an oral dose to the receptor | Comparison of predicted oral dose to avian-specific TRVs |

[1]Chemicals of potential ecological concern (COPECs) include major salt cations and detected trace elements in the well water samples.

**Abbreviations:**
COPEC = Chemical of potential ecological concern
TRV = Toxicity reference value

# 3.0 ANALYSIS

The Analysis phase presents the two primary components of risk: the Exposure Estimation and the Effects Evaluation. The objective of the Analysis is to provide the ingredients necessary for determining or predicting ecological responses under the exposure conditions of interest. Analysis connects the Problem Formulation with Risk Characterization. The Assessment Endpoints and CSMs developed during problem formulation provide the focus and structure for the Analysis phase.

## 3.1 Exposure Estimation

The Exposure Estimation quantitatively evaluates the potential pathways of exposure appropriate to the assessment endpoints and ecological receptors at the evaporation pond. In the Exposure Estimation, exposure assumptions are summarized to present the conservative parameters used for each surrogate species. It should be noted that this Exposure Estimation focuses on the estimation of oral doses to constituents of potential ecological concern[3] (COPECs) that may be experienced by the selected representative receptors that drink or (in the case of the red-tailed hawk) eat from the evaporation ponds or its margins. Based on known toxic concerns, the COPECs at this facility will include the four major salt cations (sodium, potassium, magnesium, and calcium) and detected trace metals (aluminum, barium, boron, bismuth, lithium, manganese, and strontium). Although silicon was also detected, it was not included as a COPEC due to its low potential toxicity. Exposures to physical hazards, such as salt encrustation, osmotic water loss, and vehicle strikes, are directly related to measures of salt concentrations in the brine or estimates of vehicular traffic and do not require the level of species-specific calculation as the estimations of dose described below.

The maximum detected COPEC concentrations from the well water samples described in Section 2.4 were used as the exposure point concentrations (EPCs) for surface water exposure for both avian and (small) mammalian receptors. These EPCs represent the chemical conditions of the water entering the system at the surge pond. With the exception of a small degree of decline in these concentrations during the winter months (due to precipitation inputs exceeding evaporative loss), the concentrations represent the minimum level of exposure that will be experienced by the receptors at the facility. By the time the water reaches the outflow of the concentrator pond, it is estimated that approximately 25% of the water will be lost to evaporation, thereby raising the sodium chloride concentration to its saturation point and the concentrations of constituents by 33%. As specific salts reach their saturation points, they will begin to precipitate out of solution. It is predicted that calcium salts (specifically calcium sulfate and calcium carbonate) will precipitate out within the concentrator pond, essentially removing all calcium from the brine.

[3] Constituents of potential ecological concern include all detected chemical constituents in the exposure medium (brine) that may result in adverse effects in ecological receptor(s) from exposure to the medium through one or more specific exposure pathways.

It should be noted that the brine that will be pumped into the surge pond will already be hypersaline, with total dissolved solids (TDS) at approximately 26%. With subsequent evaporation from the pond(s), the salinity will increase from this baseline to saturation. The extremely high osmotic potential of this water makes it uninhabitable to essentially all aquatic organisms and even exceeds the salinity tolerances of brine shrimp (*Artemia* spp.) and brine flies (*Ephydra* spp.) (see Appendix A). Therefore, the salinity of the brine entering the system is sufficient to preclude the survival of any potential aquatic food organisms (including plant, brine shrimp, and brine flies) in the ponds. For this reason, no predicted food chain exposures associated with the water itself were predicted to exist for the evaporation ponds. One potential food chain exposure was predation or scavenging by birds on small vertebrates or carcasses at or near the water's edge.

Exposure factors for representative receptor species were identified based on conservative assumptions for exposure to COPECs. The exposure factors for each receptor are presented in Appendix B, Tables B-1 through B-6. With the exception of the red-tailed hawk, oral exposures to COPECs in the evaporation pond water were assumed to be limited to the direct ingestion of water from the evaporation ponds at a rate equal to the normal daily water ingestion rate of the species as presented in USEPA's *Wildlife Exposure Factors Handbook* (1993). Food ingestion pathways for these receptors (excluding the red-tailed hawk) were not evaluated due to the fact that no food base is predicted to be present in the evaporation ponds because of the high salinity. Exposure frequency and area or seasonal use factors were conservatively set at 1, making the assumption that the receptor obtains 100% of its water ingestion from the evaporation pond. Therefore, the assumed water ingestion rate represents a short term (one day) dose of COPECs to the receptor if that receptor drinks at its normal daily rate from the pond. This dose can be considered an acute dose and therefore is applicable to short duration visits to the pond. This PERA also assumes that the bioavailability of the brine constituents is 100 percent while in solution, but precipitates settle out of the water and are not part in the water ingestion pathway.

For the red-tailed hawk, the food ingestion rate (on a wet weight basis) was allometrically[4] estimated from the regression equation for carnivorous birds presented in Nagy's *Food Requirements of Wild Animals: Predictive Equations for Free-living Mammals, Reptiles, and Birds* (Nagy, 2001). The COPEC content of the deer mouse is based on the concentration that would be present in the deer mouse's body after consuming one day's worth of drinking water (3.1 milliliters [mL]) from the evaporation pond, assuming no subsequent elimination. This is probably a very conservative estimation of potential salt content because the primary brine constituents are probably not retained for a significant period after ingestion and do not bioaccumulate to a significant degree over time. The red-tailed hawk was assumed to consume mice at this level of COPEC content for at least one day of normal food consumption.

[4] Based on a regression relationship with body weight.

### 3.2 Effects Evaluation

The ecological effects evaluation identifies the toxicity benchmarks that will be used in the characterization of risk associated with the exposure estimations derived as described in Section 3.1, above. Toxicity reference values (TRVs) are the toxicity benchmarks for exposures expressed as oral doses quantified in units of milligrams of the COPEC consumed per kilogram of receptor body weight per day (mg/kg-day). TRVs may be based on benchmarks derived from controlled toxicity tests on species that are taxonomically similar to the site-specific representative receptor species. Depending on the desired application of the TRV, they may be based on one or more levels of response. No-observed-adverse-effect levels (NOAELs), for example, are conservative toxicity benchmarks and represent the upper range of doses that failed to show toxic responses in the test organism. Lowest-observed-adverse-effect levels (LOAELs) are considered the next level up from the NOEAL and represent the level at which toxic effects were first detected in the tested individuals. Endpoint effects for NOAEls and LOAELs may be lethality (resulting in death) or sublethal (adverse effects other than death). For ecological risk assessments, sublethal effects that are considered to be ecologically relevant are typically limited to adverse effects on reproduction or growth; however, behavioral and physiological effects (e.g., lethargy and sensory disruption) can also effect the animal's ability to survive in the wild. Such effects were considered to be ecologically relevant in this PERA.

The lethal dose to 50% of the exposed population (the median lethal dose, or $LD_{50}$) is a common toxicity benchmark used to compare the relative lethality between chemicals. $LD_{50}$'s are typically based on responses to single doses or short-duration (less than one week) dosing at high levels. These dosings are referred to as "acute." NOAELs and LOAELs may also be based on acute dosing, but are more often based on "chronic" (26 weeks or more) or "subchronic" (1 to 26 week) duration studies. Chronic NOAELs and LOAELs are typically less than subchronic NOAELs and LOAELs due to cumulative toxic effects with longer exposure times. For this reason, chronic NOAELs are typically used as the basis for highly conservative TRVs under the assumption that exposures that do not exceed that level, even under conditions of long-term exposure, will not result in ecologically relevant adverse effects.

To provide an initial (highly conservative) screening of the estimated exposures, chronic NOAELs for each of the COPECs were used (when available) to derive a preliminary set of TRVs. These TRVs for the receptor species are presented in Table 3-1 and 3-2 for birds and mammals, respectively. Summaries of the toxicity information upon which these are based (the toxicological profiles) are included in Appendix C. It should be noted that, in addition to the derivation of chronic NOAELs from primary literature sources, secondary sources based on compilations of published toxicity studies (e.g., the USEPA ecological soil screening level [Eco-SSL] documents [USEPA, 2005 and 2007] and compilations from Oak Ridge National Laboratory [Sample et al., 1996]) were used.

The purpose of the initial screening based on chronic NOAELs is to eliminate COPECs that show exposures below those highly conservative TRVs. These COPECs can be eliminated from further consideration as potential risk drivers due to a negligible potential for toxic exposure in any of the receptors. For COPECs that show exposures exceeding the chronic NOAEL-based TRVs, the level of potential toxic response is assessed based on comparisons of exposure to much less conservative TRVs (acute $LD_{50}$'s). Exceedances of these benchmarks will indicate a potential for severe effects (i.e., mortality) from short-term exposure at the evaporative pond system. The acute $LD_{50}$'s used in this level of the risk analysis are also presented in Table 3-1 and 3-2 for birds and mammals, respectively.

**Table 3-1**
**Avian Toxicity Reference Values**

| Chemical | Avian Test Species | NOAEL (mg/kg-day) | $LD_{50}$ (mg/kg) | Acute or Chronic and applied conversion | Duration of Study | Endpoint | Reference |
|---|---|---|---|---|---|---|---|
| **Major Salt Cations** | | | | | | | |
| Calcium | Insufficient avian toxicity data | | | | | | |
| Magnesium | Leghorn Chicken | 28 | -- | Chronic | 5-week | Egg production | Hess & Britton, 1997 |
| | | -- | 670 | Chronic LOAEL x 10 | 5-week | Egg production | Hess & Britton, 1997 |
| Potassium | Insufficient avian toxicity data | | | | | | |
| Sodium (as sodium chloride) | House Sparrow | 79 | -- | Acute NOAEL x 0.1 | Single dose | Mortality | Bollinger et al., 2005 |
| | House Sparrow | -- | 1256** | Acute | Single dose | Mortality | Bollinger et al., 2005 |
| | dabbling ducks | 210** | -- | Chronic | -- | Brain/plasma Na concentrations | Nystrom & Pehrsson, 1988 |
| | dabbling ducks | -- | 1700** | Acute | Single dose | Mortality | Meteyer et al., 1997 |
| **Trace Elements** | | | | | | | |
| Aluminum | Ringed dove | 110 | -- | Chronic | 4 months | Reproduction | Carriere et al. 1986; Sample et al., 1996 |
| Barium | Chickens (1-day old) | 20.8 | -- | Subchronic x 0.1 | 4 weeks | Survival/growth | Johnson et al., 1960; Sample et al., 1996 |
| Bismuth | Chicken | 44 | -- | Chronic | 8 weeks | Dietary toxicity; reproduction; body weight changes | Hermayer et al., 1977 |
| Boron | Mallard duck | 28.8 | -- | Chronic | 6 weeks | Reproduction | Smith & Anders, 1989; Sample et al., 1996 |
| Lithium | Insufficient avian toxicity data | | | | | | |
| Manganese | (Multiple) | 179 | -- | Chronic | -- | Geometric mean of multiple NOAELs | USEPA, 2007a |
| Strontium | Insufficient avian toxicity data | | | | | | |

**Table 3-1**
**Avian Toxicity Reference Values**

**Notes:**

** NOAEL or $LD_{50}$ value adjusted; tox study examined NaCl therefore, values were adjusted to account for only the sodium portion of the salt.
NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
$LD_{50}$ = Median lethal dose
mg/kg = milligrams per kilogram of body weight
mg/kg-day = milligrams per kilogram (of body weight) per day

**Table 3-2**
**Mammalian Toxicity Reference Values**

| Compound | Mammalian Test Species | NOAEL (mg/kg-day) | $LD_{50}$ (mg/kg) | Acute or Chronic and applied conversion | Duration of Study | Endpoint | Reference |
|---|---|---|---|---|---|---|---|
| **Major Salt Cations** | | | | | | | |
| Calcium (as calcium chloride) | Mouse | 7.0 | -- | Acute $LD_{50}$ x 0.01 | Single dose | Mortality | HSDB, 2016 |
| | | -- | 700** | Acute | | | |
| Magnesium (as magnesium chloride) | Rat | 7.14 | -- | Acute $LD_{50}$ x 0.01 | Single dose | Mortality | HSDB, 2016 |
| | | -- | 714** | Acute | | | |
| Potassium (as potassium chloride) | Mouse | 2.01 | -- | Acute $LD_{50}$ x 0.01 | Single dose | Mortality | HSDB, 2016 |
| | | -- | 201** | Acute | | | |
| Sodium (as sodium chloride) | Rodent | 20** | -- | Acute $LD_{50}$ x 0.01 | Single dose | Mortality | Bertram, 2997 as cited in Bollingeret al., 2005 |
| | Mouse | -- | 1580** | Acute | Single dose | Mortality | Brownlee et al., 2000 |
| **Trace Elements** | | | | | | | |
| Aluminum | Mouse | 1.93 | -- | Chronic | >1 year | Reproduction | Ondreicka et al. 1996; Sample et al., 1996 |
| Barium | (Multiple) | 51.8 | -- | Chronic | -- | Geometric mean of multiple NOAELs | USEPA, 2005 |
| Bismuth | Rat (Crj:CD(SD)(IGF) | 100 | -- | Subchronic x 0.1 | 28 days | Growth | Sano et al., 2005 |
| Boron | Rat | 28 | -- | Chronic | >1 year | Reproduction | Weir & Fisher, 1972; Sample et al., 1996 |
| Lithium (as lithium carbonate) | Charles River rats (female) | 16.9 | -- | Chronic | 6th - 19th day of pregnancy | Reproduction | ECHA, 2016a |

| Compound | Mammalian Test Species | NOAEL (mg/kg-day) | $LD_{50}$ (mg/kg) | Acute or Chronic and applied conversion | Duration of Study | Endpoint | Reference |
|---|---|---|---|---|---|---|---|
| Manganese | (Multiple) | 51.5 | -- | Chronic | -- | Geometric mean of multiple NOAELs | USEPA, 2007b |
| Strontium | Wistar rat | 580 | -- | Chronic | 3 years | Growth | Kshirsagar, 1976; ATSDR, 2004 |

**Notes:**

** NOAEL and $LD_{50}$ value adjusted; tox study examined chloride salt; therefore, values were adjusted to account for only the cation portion of the salt.

NOAEL = No Observed Adverse Effect Level

$LD_{50}$ = Median lethal dose

mg/kg = milligrams per kilogram of body weight

mg/kg-day = milligrams per kilogram (of body weight) per day

# 4.0 RISK CHARACTERIZATION

## 4.1 Project Siting and Construction

Based on the CSM for this phase of the project (Section 2.6.1), the selection of the solar evaporation pond alternative will require the conversion of approximately 350 to 400 acres of existing natural and agricultural habitat into biologically unusable land and open water habitat of hypersaline ponds, berms, salt stockpiles, roads, and other supporting facilities. The 50-year life expectancy of this facility will essentially make this removal a “permanent” feature of the valley ecosystem. Vegetation and other sedentary or less mobile species of the existing habitat (e.g., small mammals, reptiles, amphibians) will be destroyed within the construction area. Although it is assumed that efforts will be made to minimize the direct negative effects on more mobile species (e.g., large mammals and breeding birds) during construction, these individuals will be forced to relocate their activity to other areas, putting pressure on the surrounding population to absorb these individuals. It is uncertain whether the surrounding habitat has the capacity to absorb displaced individuals; therefore, their future survival or reproductive capacity is put at risk by the construction even if they escape from the area unharmed.

A secondary risk involves the disruption of movement corridors through the area, such as along drainages or established trails. Corridors are used by large mammals and migrating birds to move between patches of habitat or summer and winter habitat. Construction of the large solar evaporation pond facility will likely cross at least some travel corridors and thereby disrupt the established movement patterns of wildlife in the area. This will result in at least minor adverse effects to the individuals and populations that use the disrupted corridors. See Appendix D for potential site descriptions.

## 4.2 Evaporation Pond Design

As indicated in the CSM for this phase of the proposed project (Section 2.6.2), bank design is a factor that could result in increased risk to ecological receptors. Steep inward-facing banks create a hazard of entrapment in the ponds for both terrestrial vertebrates that may be attracted to the pond or casually encounter it, and waterfowl that have alighted on the pond and may require onshore escape due to salt encrustation or salt toxicosis. Entrapment for these individuals will most likely lead to death in the pond. Bank design that allows escape will reduce the risk of this outcome in many cases. However, it should be noted that in advanced stages of encrustation or toxicosis, merely leaving the pond without access to fresh water may be insufficient to avert death.

## 4.3 Evaporation Pond Operation and Maintenance

As described in the CSM for this phase of the proposed project (Section 2.6.3), the potential hazards associated with pond operation and maintenance are associated with direct contact with and ingestion of the brine within the evaporation ponds. These hazards include osmotic dehydration through areas of exposed skin (feet and cloacal area), feather disruption and salt encrustation, and the toxicity of ingested water. The potential for risk associated with each of hazards is described in the following sections.

### 4.3.1 Osmotic Dehydration

The 1979 study by Colorado State University (CSU) for the PVU (Herin et al., 1979) provides the basis for the potential risk to waterfowl from osmotic dehydration (see Appendix C for details). In this study, mallards were exposed to brine taken from the Paradox Valley pumping station (sodium chloride concentration =270,000 mg/L) without food or water. Signs of severe dehydration were observed within 36 hours of exposure. Outwardly, these signs included changes in the ducks' behavior from an initial period of high activity and excitability followed by lethargy and unresponsiveness and finally coma and death. Hypothermia was a secondary effect of the water loss and electrolyte imbalance caused by this exposure. An $LC_{50}$ of 250,000 mg/L was determined; however, it was also concluded that the effects of dehydration and hypothermia would be limited if provided with water and food (Herin et al., 1979). Based on this study, the risk of mortality in waterfowl that remain on any of the ponds for 36 hours or more is considered high. This time window will shorten as the concentration of salt (and the osmotic potential of the water) increases through the sequence of evaporative ponds.

### 4.3.2 Feather Disruption and Salt Encrustation

The potential for formation of crystals on solid surfaces (e.g., feathers) is dependent upon whether the concentrations of one or more salts in the water are at (or above) saturation. For some salts (e.g., sodium sulfate), the saturation point is strongly influenced by water temperature; therefore, crystallization can occur suddenly in conditions of declining air temperature. Sodium chloride, which dominates the PVU brine, is not strongly influenced by temperature, making the formation of crystals more predictable. The well water entering the system at the surge pond will be at approximately 75% saturation for sodium chloride, therefore is unlikely to present a risk for feather disruption or salt encrustation in waterfowl that may alight in this pond. The same will continue into the concentrator pond(s), although, as water is lost from this pond, saturation will be approached, and possibly reached near the outlet. The potential for adverse effects due to crystallization in this portion of the system is uncertain. Risk does exist in the crystallization ponds where the water will be and will remain at saturation. This risk will also remain at the bittern pond.

### 4.3.3 Toxicity

As indicated in Sections 3.1 and 3.2, there is a potential for wildlife to be exposed to COPECs in the evaporation ponds through the ingestion of water and prey. Further, exposures to these COPECs have the potential to produce toxic responses, including death. The goal of the risk quantification presented in this section is to integrate the results of the Exposure Estimation and the TRVs identified in the Effects Evaluation to determine the potential risk to ecological receptors arising from potential exposure to brine constituents detected in surface water in the evaporation ponds. This risk estimation for wildlife was performed using the hazard quotient (HQ) method that compares exposure (as estimated daily dose) to its selected toxicity benchmark (the TRV) as a simple ratio defined as:

$$Hazard\ Quotient = \frac{Estimated\ Daily\ Dose}{TRV}$$

Where both the estimated daily dose and TRV are in units of mg/kg-day, making the HQ unitless. Thus, an HQ value less than 1 indicates that the estimated daily dose is less than the TRV and is therefore unlikely to result in adverse ecological effects. An HQ value equal to or greater than 1 generally indicates that a potential for adverse ecological effects may exist. If it can be assumed that the effects of the individual chemicals within the receptor are additive, the individual, chemical-specific HQs for a particular receptor can be added to generate a hazard index (HI). The HI represents a conservative estimate used to indicate whether multiple constituents at a site might pose a potential risk even when an individual brine constituent may not. A HI equal to or greater than 1 generally indicates that a potential for adverse effects exists.

It should be noted that when the exposures are based on generally conservative assumptions (e.g., water ingestion rates that are based on the normal consumption rate without behavioral aversion) leading to an likely overestimation of the actual exposure, and the TRVs are also conservatively based (e.g., based on chronic NOAELs), thereby overestimating the actual toxicity thresholds of the chemicals, the resulting HQs will overestimate the true potential for risk. This approach is used to eliminate with a high degree of certainty those COPECs that are unlikely to contribute to the toxicity risk, allowing for further, more focused evaluation of the potential for risk from those COPECs that failed this initial, highly conservative screening. The following subsections discuss risk estimates to the representative wildlife receptors, both as the conservative, NOAEL-based screening and the focused assessment of the potential risk drivers as based on acute $LD_{50}$ values.

#### 4.3.3.1 NOAEL-based Screening Assessment

Surface water brine constituents were identified for the evaporation pond system by analyzing groundwater samples that would be pumped into the surge pond in the future, if evaporation is deemed feasible (see Section 2.4). Therefore, the quantification of risk to wildlife receptors (specifically, small mammals, terrestrial birds, and migratory waterfowl) for the evaporation pond was performed. For screening purposes, these potential risks were initially calculated using TRVs based on chronic NOAELs. For this screening, the COPECs were separated into two groups—the major salt cations (sodium, potassium, magnesium, and calcium) and the detected trace elements (aluminum, barium, bismuth, lithium, manganese, and strontium). Appendix B, Tables B-7 through B-12 present the HQ calculations for this evaluation. These are summarized in Table 4-1.

Deer Mouse

As shown in Table 4-1, three of the major salt cations had a HQ greater than 1 for the deer mouse. Sodium, potassium, magnesium, and calcium had HQs of 812, 397, 41, and 36, respectively. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 1,286, which indicates a potential for adverse effects to small mammals. Sodium contributes ~63 percent, potassium contributes ~31 percent, and magnesium and calcium each contributes ~3 percent of the HI. The sum of the HQs for the remaining brine constituents was below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to small mammals.

Black-throated Sparrow

For the black-throated sparrow, two of the major salt cations had HQs greater than 1 (Table 4-1). Sodium and magnesium had HQs of 340 and 17.5, respectively. Insufficient toxicity information is available to derive avian TRVs for potassium and calcium. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 358, which indicates a potential for adverse effects to upland songbird (passerine) species that may drink surface water from the evaporation pond. Sodium contributes ~95 percent of the HI while magnesium contributes ~5 percent of the HI. The sum of HQs for the remaining brine constituents were below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to songbirds of the area.

Red-tailed Hawk

For the red-tailed hawk, two of the major salt cations had a HQ greater than 1 (Table 4-1). Sodium and magnesium had HQs of 52 and 11, respectively. Insufficient toxicity information is available to derive avian TRVs for potassium and calcium. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 64, which indicates a potential for adverse effects to terrestrial carnivorous birds who feed exclusively on small mammals drinking surface water from the evaporation pond. Sodium contributes ~81 percent of the HI while magnesium contributes ~17 percent of the HI. The sum of the HQs for the remaining brine constituents was below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to terrestrial carnivorous birds.

## Table 4-1
## Summary of NOAEL- and $LD_{50}$-based Hazard Quotient and Hazard Index Calculations
## Predictive Ecological Risk Assessment, Paradox Valley Unit Solar Evaporation Ponds
## Paradox Valley, Colorado

**Major Salt Cations (HQs)**

| | Deer Mouse | | Black-throated Sparrow | | Red-tailed Hawk: Food Ingestion | | Red-tailed Hawk: Water Ingestion | | Eared Grebe | | Northern Shoveler | | Canada Goose | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Constituent** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** |
| Sodium | **812** | **10** | **340** | **21** | **23** | **2.8** | **30** | **3.7** | **40** | **4.9** | **36** | **4.5** | **22** | **2.8** |
| Potassium | **397** | **4.0** | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Magnesium | **41** | 0.41 | **17** | 0.7 | **7.2** | 0.30 | **4.1** | 0.17 | **5.4** | 0.23 | **5.0** | 0.21 | **3.1** | 0.13 |
| Calcium | **36** | 0.36 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Hazard Index:** | **1286** | **15** | **358** | **22** | **30** | **3.1** | **34** | **3.8** | **45** | **5.1** | **41** | **4.7** | **26** | **2.9** |

**Detected Trace Elements (HQs)**

| | Deer Mouse | | Black-throated Sparrow | | Red-tailed Hawk: Food Ingestion | | Red-tailed Hawk: Water Ingestion | | Eared Grebe | | Northern Shoveler | | Canada Goose | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Constituent** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** | **NOAEL** | **$LD_{50}$** |
| Aluminum | 0.26 | -- | 0.0076 | -- | 0.0031 | -- | 0.0018 | -- | 0.0024 | -- | 0.0022 | -- | 0.0013 | -- |
| Barium | 0.0015 | -- | 0.0062 | -- | 0.0026 | -- | 0.0014 | -- | 0.0019 | -- | 0.0018 | -- | 0.0011 | -- |
| Bismuth | 0.00092 | -- | 0.0034 | -- | 0.0014 | -- | 0.00080 | -- | 0.0011 | -- | 0.00098 | -- | 0.00060 | -- |
| Boron | 0.058 | -- | 0.093 | -- | 0.038 | -- | 0.022 | -- | 0.029 | -- | 0.027 | -- | 0.016 | -- |
| Lithium | 0.0037 | -- | NA | -- | NA | -- | NA | -- | NA | -- | NA | -- | NA | -- |
| Manganese | 0.0018 | -- | 0.00085 | -- | 0.00035 | -- | 0.00020 | -- | 0.00026 | -- | 0.00024 | -- | 0.00015 | -- |
| Strontium | 0.0081 | -- | NA | -- | NA | -- | NA | -- | NA | -- | NA | -- | NA | -- |
| **Hazard Index:** | 0.33 | -- | 0.11 | -- | 0.046 | -- | 0.03 | -- | 0.035 | -- | 0.032 | -- | 0.020 | -- |

**Table 4-1**
**Summary of NOAEL- and $LD_{50}$-based Hazard Quotient and Hazard Index Calculations**
**Predictive Ecological Risk Assessment, Paradox Valley Unit Solar Evaporation Ponds**
**Paradox Valley, Colorado**

**Notes:**
**Bolded** HQs/HIs ≥ 1.0.
-- = Not calculated
HI = Hazard Index
HQs = Hazard quotients
NA = Not available (insufficient toxicity information to develop TRV)
NOAEL = No Observable Adverse Effects Level
$LD_{50}$ = Median Lethal Dose
TRV = Toxicity Reference Value

Eared Grebe

As shown in Table 4-1, the NOAEL-based risk estimates calculated for the eared grebe had HQs greater than 1 for two of the major salt cations. Sodium and magnesium had HQs of 40 and 5.4, respectively. Insufficient toxicity information is available to derive avian TRVs for potassium and calcium. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 45, which indicates a potential for adverse effects to small waterfowl species that may drink surface water from the evaporation pond. Sodium contributes ~88 percent of the HI while magnesium contributes ~12 percent of the HI. The sum of HQs for the remaining brine constituents were below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to small waterfowl species.

Northern Shoveler

The NOAEL-based risk estimates calculated for the northern shoveler again showed two major salt cations having HQs greater than 1 (Table 4-1). Sodium and magnesium had HQs of 36 and 5.0, respectively. Insufficient toxicity information is available to derive avian TRVs for potassium and calcium. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 41, which indicates a potential for adverse effects to medium-sized waterfowl species that may drink surface water from the evaporation pond. Sodium contributes ~88 percent of the HI while magnesium contributes ~12 percent of the HI. The HQs for the remaining brine constituents were below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to medium-sized waterfowl species.

Canada Goose

As with the other avian receptors, the NOAEL-based HQs calculated for the Canada goose exceeded 1 for two major salt cations. Sodium and magnesium had HQs of 22 and 3.1, respectively. Insufficient toxicity information is available to derive avian TRVs for potassium and calcium. None of the detected trace elements had a HQ equal to or greater than 1. The HI was 26, which indicates a potential for adverse effects to large waterfowl species that may drink surface water from the evaporation pond. Sodium contributes ~88 percent of the HI while magnesium contributes ~12 percent of the HI. The HQs for the remaining brine constituents were below 1.0, indicating that the remaining constituents are not likely to cause adverse ecological effects to large waterfowl species.

#### 4.3.3.2 Focused Risk Evaluation

The conservative estimations of risk using the NOAEL-based TRVs demonstrate that the trace elements detected in the well water samples are at concentrations well below those that can be considered potentially toxic to wildlife receptors. However, all four major salt cations (sodium, potassium, magnesium, and calcium) showed HQs greater than 1 for at least the mammalian receptor, indicating that the potential for toxicity cannot be rejected (potassium and calcium could not be evaluated for the avian receptors due to a lack of toxicity information). The level of potential toxicity is further evaluated in this focused risk evaluation by recalculating the HQs based on more stringent toxicity benchmarks (acute $LD_{50}$'s). The purpose is to determine whether the levels of these salt cations are of concern from very low levels of ingestion. These recalculations are based on the same estimated daily dose levels used in the NOAEL-based risk estimations. These exposures are based on the maximum surface water brine concentrations from the well water analyses (Section 2.4) and represent conditions of the input water only. As water is lost through evaporation, these concentrations, and the underlying risk, will increase.

Appendix B, Tables B-13 through B-18 present the HQ calculations for this evaluation. These are summarized in Table 4-1. The following subsections describe the refined analyses of risk for each of the representative receptors.

Deer Mouse

Table 4-1 presents the acute $LD_{50}$-based risk estimates calculated for the deer mouse exposure to the four major salt cations (sodium, potassium, magnesium, and calcium). HQs exceeded 1 for both sodium (HQ = 10) and potassium (HQ = 4), but not for magnesium (HQ = 0.41) or calcium (HQ = 0.36). Therefore, the input well water can be considered to be potentially acutely toxic to small mammals that consume less than one day's volume of drinking water from the ponds. For sodium, this volume would be one tenth of the daily water consumption rate, or 0.31 mL of water ingested by the deer mouse (approximately 0.01 US fluid ounces [fl oz]). For potassium, the potentially lethal volume would be approximately 0.78 mL (0.026 fl oz).

Neither magnesium nor calcium can be considered at acutely lethal levels in the surge pond and concentrator pond(s). Calcium, as indicated previously, is likely to precipitate out of the water in the concentrator pond. However, magnesium will likely stay in the water and become a component of bittern. A 2.5 increase in the initial magnesium concentration will bring it to a potentially lethal concentration to small mammals.

Black-throated Sparrow

Table 4-1 presents the acute $LD_{50}$-based risk estimates calculated for the black-throated sparrow exposure to sodium and magnesium. HQs exceeded 1 for sodium (HQ = 21); therefore, the input well water can be considered to be potentially acutely toxic to upland songbirds from the consumption of less than one day's volume of drinking water from the ponds based solely on its sodium content. Based on the HQ, this volume would be approximately 5% of the daily water consumption rate, or 0.16 mL (approximately 0.005 fl oz) of water ingested by the black-throated sparrow.

For magnesium, the HQ based on the $LD_{50}$ is less than 1 (HQ = 0.7); therefore, magnesium is not considered an acutely lethal COPEC in the surge pond and concentrator pond waters for small waterfowl. It should be noted that the $LD_{50}$ for magnesium (670 mg/kg) is based on an upward conversion of a LOAEL (67 mg/kg-day) using an uncertainty factor of 10. However, this

LOAEL is based on a sublethal effect (reduced egg production), and therefore is likely to underestimate the actual $LD_{50}$ for magnesium in birds. In the crystallizer pond(s), the potential for magnesium toxicity will be overshadowed by that of sodium, which will be at its saturation point (for sodium chloride). It is uncertain, but likely, that magnesium will reach acutely toxic concentrations in the bittern pond.

Red-tailed Hawk

Table 4-1 presents the focused risk estimates calculated for the red-tailed hawk. Two exposure pathways were evaluated for this receptor--the ingestion of prey (small mammals) that have consumed brine from the evaporation pond(s), and the ingestion of water from the pond(s). Using TRVs based on $LD_{50}$ values for oral exposure, HQs for sodium ingestion exceeded 1 for both pathways (HQ for prey ingestion = 2.8; HQ for water ingestion = 3.7). The combined risk from both pathways is 6.5. Therefore, the input well water can be considered potentially acutely toxic to carnivorous and scavenging birds from the consumption of food that has been exposed to the brine water and from consumption of less than one day’s volume of drinking water from the ponds based solely on its sodium content. Based on the HQs, this volume would be approximately 27% of the daily water consumption rate, or about 17 mL (approximately 0.58 fl oz) of water ingested by the red-tailed hawk.

For food ingestion (approximately 0.33 kg wet weight per day), the risk model indicates that approximately 36% of this amount (if exposed to the evaporation ponds) could contain a potentially lethal amount of sodium (as based on the $LD_{50}$). This would be approximately 118 grams, which is approximately 5.6 times the assumed body weight of the deer mouse (21 grams). It is unlikely that a predatory or scavenging bird will consume more than five small rodents from the area of the ponds in a day; it is more likely that the single, potentially lethal dose would come from a larger species, such as ground squirrel or cottontail.

For magnesium, the HQs for both pathways are less than 1 (HQ = 0.30 for prey ingestion and HQ = 0.17 for water ingestion) and the sum of the HQs for both pathways (0.47) is also less than 1. Therefore, magnesium is not considered an acutely lethal COPEC in the surge pond and concentrator pond waters for predatory and scavenging birds. Again, it should be noted that this $LD_{50}$ is based on a sublethal LOAEL for reduced egg production, and therefore is likely to underestimate the actual $LD_{50}$ for magnesium in birds. In the concentrator and crystallizer pond(s), the concentration of magnesium will increase as water is lost; however, its increasing toxicity will be overshadowed by that of sodium. It is uncertain, but likely, that magnesium will reach acutely toxic concentrations in the bittern pond.

Eared Grebe

Table 4-1 presents the acute $LD_{50}$-based risk estimates calculated for the eared grebe exposure to sodium and magnesium. HQs exceeded 1 for sodium (HQ = 4.9). Therefore, the input well water can be considered to be potentially acutely toxic to small waterfowl species from the consumption of less than one day's volume of drinking water from the ponds based solely on its sodium content. Based on the HQ, this volume would be approximately one fifth of the daily water consumption rate, or 7.1 mL (approximately 0.24 fl oz) of water ingested by the eared grebe.

For magnesium, the HQ based on the $LD_{50}$ is less than 1 (HQ = 0.23); therefore, magnesium is not considered an acutely lethal COPEC in the surge pond and concentrator pond waters for small waterfowl. Again, it should be noted that this $LD_{50}$ is based on a sublethal LOAEL for reduced egg production, and therefore is likely to underestimate the actual $LD_{50}$ for magnesium in birds. In the crystallizer pond(s), the potential for magnesium toxicity will be overshadowed by that of sodium, which will be at its saturation point (for sodium chloride). It is uncertain, but likely, that magnesium will reach acutely toxic concentrations in the bittern pond.

*Northern Shoveler*

Table 4-1 presents the focused risk estimates calculated for the northern shoveler. Using TRVs based on $LD_{50}$ values for oral exposure, HQs exceeded 1 for sodium (HQ = 4.5). Therefore, the input well water can be considered to be potentially acutely toxic to medium-sized waterfowl species from the consumption of less than one day's volume of drinking water from the ponds based solely on its sodium content. Based on the HQ, This volume would be approximately 22% of the daily water consumption rate, or 9.3 mL (approximately 0.31 fl oz) of water ingested by the northern shoveler.

For magnesium, the HQ based on the $LD_{50}$ is less than 1 (HQ = 0.21); therefore, magnesium is not considered an acutely lethal COPEC in the surge pond and concentrator pond waters for medium-sized waterfowl. Again, it should be noted that this $LD_{50}$ is based on a sublethal LOAEL for reduced egg production, and therefore is likely to underestimate the actual $LD_{50}$ for magnesium in birds. In the crystallizer pond(s), the potential for magnesium toxicity will be overshadowed by that of sodium, which will be at its saturation point (for sodium chloride). It is uncertain, but likely, that magnesium will reach acutely toxic concentrations in the bittern pond.

*Canada Goose*

Table 4-1 presents the acute $LD_{50}$-based risk estimates calculated for the Canada goose exposure to sodium and magnesium. HQs exceeded 1 for sodium (HQ = 2.8), Therefore, the input well water can be considered to be potentially acutely toxic to large waterfowl species from the consumption of less than one day's volume of drinking water from the ponds based solely on its sodium content. Based on the HQ, This volume would be approximately 36% of the daily water consumption rate, or 40 mL (approximately 1.4 fl oz) of water ingested by the Canada goose.

For magnesium, the HQ based on the $LD_{50}$ is less than 1 (HQ = 0.13); therefore, magnesium is not considered an acutely lethal COPEC in the surge pond and concentrator pond waters for large waterfowl. Again, it should be noted that this $LD_{50}$ is based on a sublethal LOAEL for reduced egg production, and therefore is likely to underestimate the actual $LD_{50}$ for magnesium in birds. In the crystallizer pond(s), the potential for magnesium toxicity will be overshadowed by that of sodium, which will be at its saturation point (for sodium chloride). It is uncertain, but likely, that magnesium will reach acutely toxic concentrations in the bittern pond.

#### 4.3.3.3 Ingestion Risk Summary

The NOAEL-based risk estimations (HQs and HIs) are considered highly conservative and are only used to screen the COPECs. Those COPEC with NOAEL-based HQs and HIs less than 1 can be eliminated from further consideration as potential risk drivers while those with HQs or HIs exceeding 1 are identified for further (focused) evaluation of potential toxicity to the representative receptors. As indicated in Section 4.3.3.1, the NOAEL-based HQs and HIs for the detected trace elements (aluminum, barium, bismuth, lithium, manganese, and strontium) were all less than 1 indicating that there is no likelihood of hazard to the ecological receptors from these elements in the brine. The trace elements were therefore eliminated from further risk evaluation. HQs exceeded 1 for the four major salt cations (sodium, potassium, magnesium, and calcium) and they were carried forward into the focused assessment.

In the focused assessment (Section 4.3.3.2), the TRVs were based on $LD_{50}$ values when such toxicological benchmarks were available for the cation and receptor class (bird or mammal). In the refined risk evaluation, HQs for all receptors were greater than 1 for the sodium exposure, ranging from 2.8 to 10. These included both the direct ingestion of water from the ponds and the ingestion of prey or carcasses of animals that may have ingested water from the ponds. The HQ for potassium was also greater than 1 for the small mammal (deer mouse), but $LD_{50}$ values for potassium were not found for birds.

HQs for magnesium were all less than 1 (ranging from 0.13 to 0.41). The HQ for calcium was also less than 1 for the small mammal (deer mouse), but an $LD_{50}$ value for calcium was not found for birds. Because these HQs are about 2.5- to 8-times less than 1, indicating that, with loss of water through evaporation, the concentrations of magnesium in the crystallizer and bittern ponds will likely reach toxic levels to wildlife. Calcium is considered less of a potential problem since it will likely be lost to precipitation in the concentrator pond, when sodium is still the dominant risk driver.

In summary, these results indicate that all waters in the evaporation pond system, from the surge pond to the bittern pond, can be considered as acutely toxic to wildlife from oral ingestion. Ingestion may be from direct ingestion of the water or from consuming prey or carcasses from around the ponds. It should be noted that the doses estimated in this section through standard ingestion modeling do not include additional (“incidental’) ingestion of salt crystals that may occur through preening of salt-laden feathers and consumption of salt-crusted carcasses. These ingestion pathways may accelerate the achievement of a lethal dose in these receptors.

### 4.4 Waste Product Transport, Storage, and Disposal

Three types of "waste" products will be generated by the solar evaporation pond system—crystalline salt (primarily sodium chloride) harvested and dried from the crystallizer ponds, bittern solids harvested and dried from the bittern pond, and bittern. The crystalline salt will be at least temporarily stockpiled at the facility and transported by truck to the landfill or possibly to a buyer or other recipient with a secondary use (e.g., for road salt). Potential risks to ecological receptors through this process include:

- Risk to wildlife due to increased highway traffic by trucks
- Risk to wildlife (particularly mammals) from the deliberate or incidental ingestion of salt at or around storage areas and along roadways
- Risk to vegetation along roadways from the incidental loss of salt during transport

Based on Colorado Department of Transportation (CDOT) 2015 data on reported wildlife road kills in CDOT Region 5 (containing the Paradox Valley) (CDOT, 2016), approximately 85% of reported road kills were deer and 5% elk, indicating that these two large ungulates are highly vulnerable to be struck by vehicles (although the "reported" road kills may underestimate road kills of smaller species that go unreported). It is also of note that 39% of the deer incidents occurred in the last three months of the year (October through December), which is when the harvesting of the salt from the crystallizer ponds would likely occur. If the salt is hauled away from the facility during this time (without being stockpiled), the risk of deer strike will likely be greater than that for hauling later in the year.

Exposure of wildlife to salt in and around the storage areas will likely be minimal. The migration of salt from the areas will be limited by the fact that sodium chloride crystals tend to aggregate, forming clumps or crusts that are resistant to transport by wind (either from a stockpile or from a truck). Once in the soil, the salts will dissolve with precipitation and move deeper into the soil where incidental ingestion of the soil is unlikely. Mammals, however, may deliberately lick the salt as a dietary supplement. This is likely to be a self-regulating form of exposure, since it is unlikely to lead to excessive sodium exposure to the point of toxicity. That being said, the concentration of potassium in the salt needs to be considered, since potassium (as potassium chloride) is more toxic to mammals than sodium.

As indicated above, it is unlikely that significant amounts of salt will escape from the facility to surrounding ecosystems from airborne transport during handling operations and from stockpiling. It is likely that some salt will fall or be blown from trucks during transport to the disposal facility. This salt has the capacity to accumulate along the roadsides and adversely affect the vegetation. Although both sodium and chloride are highly mobile in the environment, Trahan and Peterson (2007) found a 61% increase in sodium levels in soils adjacent to salted roads in Colorado versus control (off-road) sites. Sodium tends to replace other cations in the soil thereby reducing its nutrient content, although Trahan and Peterson found that the nutrient content in the plant tissues along the roadsides was not adversely affected by the reduced nutrient content of the soil. Leaf tissue damage (necrosis) and reduced photosynthesis were observed in the salt-affected roadside vegetation along with higher levels of sodium, chloride, and magnesium in the tissues with respect to controls. Leaf damage was most closely correlated with chloride content rather than sodium or magnesium. It should be noted that the reduction in photosynthesis (with respect to the control site plants) was limited to the winter months when the salt was applied and did not extend into the growing season. Although the amount of evaporation pond salt expected to be lost from the trucks during the transport operation is uncertain, it is unlikely to reach the levels of customary road salting to de-ice road surfaces[5]. Therefore the additional risk to the roadside vegetation is likely to be negligible.

The management of bittern solids presents a greater risk to ecological receptors than that of the crystallizer solids because the bittern solids will be richer in magnesium and other elements other than sodium (e.g., barium, boron, and lithium) that may be more intrinsically toxic than sodium. The exact composition of the bittern solids has not been determined; therefore, its potential toxicity to wildlife, and its concomitant risk, is not determined.

Likewise, the composition of the bittern in the bittern pond is not known other than the fact that as it continues the process of evaporation, salts will be at saturation and continue to precipitate out (form solids) with time. Therefore, the bittern pond will present both a toxicity hazard and physical hazard (salt encrustation and osmotic dehydration) to waterfowl that may alight on this pond. Because of the removal of most of the sodium in the crystallization ponds, it is likely that the bittern will be significantly more toxic to wildlife than the water in any of the preceding ponds from magnesium and other “impurities” that were not previously lost through the evaporative process.

### 4.5 Uncertainty Assessment

In attempting to predict the potential for risk to ecological resources for a proposed facility, uncertainties exist at almost all levels. These uncertainties arise from imperfect knowledge of what will be in the brine through the life of the system, how and when the various brine components will be lost (as solids) through the evaporative process, how this process might be affected by the $H_2S$ control process, and how the final salt product and by-products (solid and liquid) will be handled and disposed of. Overlying these uncertainties are those of potential exposure to physical and chemical hazards by ecological receptors throughout this process. In this PERA, the assumptions are made concerning the potential exposure pathways that may

[5]CDOT typically applies 500 pounds of sand/salt mixture per lane mile on icy roads (Trahan and Peterson, 2007). The quantity of salt (assumed to be mostly sodium chloride) in the mixture can be as high as 20% (ESSD Research Group, 2007). Therefore, on a two lane highway, such as Highway 90, which is salted in the winter (Andrew Nicholas, pers. comm., July 28, 2016), a typical sand/salt application might release 200 pounds of salt per mile.

exist in the proposed facility; however, these are largely based on predictions of likely behavior in wildlife based on observations from other facilities and may not be transferable to the PVU facility. In general, assumptions of exposure and effect used to predict potential risk in this PERA are conservative and are more likely to overestimate rather than underestimate the potential for ecological risk., Thus, this PERA is designed to minimize the probability of falsely concluding that there is no or minimal risk when, in fact, there is a potential for significant risk.

With regard to the quantitative assessment of risk from the ingestion of brine constituents, uncertainties exist with regard to the modeling of potential exposure and the toxicity benchmarks by which the risk is evaluated. Key uncertainties associated with this PERA that may have the most impact on the risk results include the following:

- ***Use of chronic NOAEL as screening toxicological benchmarks –*** Chronic NOAELs are initially used as the toxicological benchmarks for risk evaluation to conservatively screen out COPECs that are unlikely to significantly contribute to risk, even under conditions of chronic exposure. The use of chronic NOAELs is expected to result in an overestimation of risk.

- ***Exposure assumptions –*** In the PERA, the exposure frequency is set to 1, thereby making the assumption that the receptor obtains 100 percent of its water (or food, in the case of the red-tailed hawk) ingestion from the evaporation pond, at least for a short period of time. This assumes that water (and food) consumption will occur at normal rates regardless of salt or other chemical content in these media. In reality, some aversion to consuming these media by the receptors is likely to occur.

- ***Ecotoxicity data used for TRV calculation –*** Toxicity data used to determine TRVs are from available literature sources and are not site-or receptor-specific. The form and bioavailability of the chemical in the study environment may differ from those in the pond system. In some cases, standard uncertainty factors (UFs) are used to estimate different toxicity endpoints from these literature sources (e.g., subchronic to chronic exposure, $LD_{50}$ to NOAEL, etc). The use of literature-based toxicity data may result in overestimation or underestimation of risk.

- ***Gaps in the ecotoxicological data record –*** Many of the COPECs in the PVU brine are not considered toxic except at very high concentrations. Because such conditions are rarely encountered or are just recently becoming recognized, the toxicological base for developing benchmark values for wildlife is not strong, especially for birds. An adequate record of toxicological data was not found to support avian TRVs for calcium, potassium, lithium, and strontium. Although these represent gaps in the risk evaluation (potentially resulting in an underestimation of risk), the high levels of potential risk from sodium and (probably) magnesium will overshadow the minor contributions to risk by these elements.

- ***Intraspecies extrapolation –*** Species differ with respect to absorption, metabolism, distribution, and excretion of constituents. It is basically assumed in this PERA that the receptor's ability to physiologically handle the constituents in the brine are the same as (or at least not significantly different from) those of the test species. This assumption, if wrong, may result in either overestimation or underestimation of risk.

- ***Use of single point concentration data –*** Although the risk predictions are based on recent samples of PVU well water (using the maximum detected concentration for each COPEC), the data sets consisted of two analyses of two duplicate samples. Therefore, the risk predictions are based on data from a single point in time. Variations in analyte concentrations over the course of the year or over the operational life of the facility are uncertain and may lead to variations in risk to ecological receptors that may be exposed to these brines.

- ***Small mammal tissue concentrations*** – The small mammal tissue concentration used to estimate potential risk to predatory and scavenging birds is based on the quantity of the COPEC within the volume of water that a small mammal (i.e., deer mouse) ingests in one day. The exposure pathway assumes that the small mammal ingests its entire daily water intake amount and immediately thereafter falls prey to the predator or dies and is consumed by the scavenger. Both of these assumptions are conservative and likely overestimate the risk to the predatory and scavenging bird (represented by the red-tailed hawk).

- ***Additive HI calculation*** - The HIs were calculated by adding chemical-specific HQs, assuming the additive effect of the individual chemicals. It is likely that the trace elements detected in the brine (e.g., barium, boron, bismuth, lithium, and manganese) have distinct modes of toxicity and effects endpoints; therefore, assumption of additive effects may overestimate the total risk to wildlife receptors at the evaporation ponds.

Uncertainties also exist for the physical hazards as well. For example, a predicted increase risk to wildlife from road kills from the use of trucks to haul salt to an off-site disposal facility (and the return of that truck to the evaporation pond facility) is predicated on factors such as the haulage distance, the seasonality of salt harvesting, the operating window for hauling, and the likelihood of wildlife using roadsides or crossing roads during the hauling period. Each of these affect the potential risk of wildlife/vehicle strike along the haul route, although the net effect is largely uncertain. It is also uncertain whether a small increase in roadkill incidents will adversely affect wildlife populations of the area.

## 5.0 SUMMARY AND RECOMMENDATIONS

Under the assumption that the solar evaporation pond facility is the selected alternative for the continued disposal of brine at the PVU, approximately 350 to 400 acres of existing habitat (natural and/or agricultural) will be replaced with evaporation ponds that will not be usable by wildlife. Based on the current habitat conditions at the three potential evaporation pond sites (Appendix D), none of these sites contain habitat that is significant or critical to the continued ecological functions of the Paradox Valley or the wildlife populations that use it. No populations of sensitive species are anticipated to be affected by the construction of the facility provided that the construction is conducted within the normal guidelines for environmental protection. Further, the increased highway traffic that may be incurred during the operation of the facility is not anticipated to create a significant risk to wildlife populations through road kills. Most, if not all, of the hauling traffic will be during daylight hours when wildlife activity is low and driver visibility is high.

Unquestionably, the very high salinity of the waters in the evaporation pond system will present a significant potential hazard to wildlife of all classes, but particularly to waterfowl. This hazard is from both physical and toxicological effects on the organisms that may contact or consume the water. In particular, the levels of sodium throughout the system will be at potentially toxic levels to at least birds and mammals that may consume the water (the toxicity to reptiles and amphibians is uncertain). Potassium is also at toxic levels for mammals and magnesium will likely be at toxic levels for birds and mammals within the crystallizers, and may be the primary toxin in bittern. The toxicity of potassium to birds is not known, but some evidence indicates that it enhances the toxic effect of sodium exposure. Frequent or habitual predation or scavenging by birds around the margins of the ponds has the potential to result in sodium toxicosis.

Osmotic water loss from exposed areas of skin (e.g., feet and cloaca) can lead to severe dehydration and possible death in waterfowl that sit on the water for extended periods (approximately 36 hours). (Amphibians would also be highly susceptible to osmotic dehydration if an individual were to enter or otherwise directly contact the water to a significant degree.) Salt encrustation and feather disruption are physical hazards that can occur when the water is at or above the saturation point for some salts. For waterfowl, salt encrustation can lead to hypothermia, waterlogging, and drowning. In this pond system, salt encrustation would likely be at the lower end of the concentrator pond(s) and throughout the crystallizer ponds and bittern pond.

The actual risk to these receptors will largely be determined by behavioral responses to the water. Most species should show an aversion to prolonged contact or consumption of the saline and hypersaline waters. For example, anecdotal evidence (Griffiths et al., 2014) indicates that bats avoid saline water as drinking sources. For waterfowl, the ability to escape from the saline pond is often critical to their survival. However, their ability to escape by flight can be limited by the toxic effects of salt consumption, dehydration, hypothermia, and/or the excess weight from salt encrustation or waterlogging. If near the shoreline, walking out of the pond can be crucial; however, this may not be possible if the banks are too steep. It should be noted that reaching fresh water after leaving the saline pond may not always be possible or successful and mortality can occur around the banks of the saline pond.

Risk can be minimized by the implementation of one or more mitigation methods. Several of these are described in the following section. These include both active and passive methods, including barriers (netting and wires), hazing of various types, and providing alternative habitat. These various potential methods are then discussed with regard to their applicability to the proposed PVU facility within the context of an adaptive management system.

## 5.1 Evaluation of Avian Mitigation and Deterrence Techniques

An evaluation of avian mitigation and deterrence methods was conducted to identify appropriate techniques that may be effective in reducing potential risks and hazards to avian species, including migratory species, associated with the evaporation ponds. Avian deterrence may be necessary in preventing the use of the ponds by avian species and the resulting risk of mortality. This evaluation reviews the effectiveness of available bird deterrence techniques and the appropriateness of each technique for the proposed evaporation ponds at the PVU.

Deterrence techniques and their respective effectiveness in deterring avian species from using evaporation ponds and hypersaline lakes were reviewed in various published documents. Table 5-1 lists the deterrence techniques evaluated for applicability to the proposed evaporation ponds at the PVU based primarily on information provided by SWCA Environmental Consultants (2012), which was compiled from Marsh et al.'s (1991) assessment. Eight of the techniques are referred to as "passive" and are aimed at deterring waterfowl from using the ponds and require no human intervention other than the preventative installation of some visual cue or device. Fifteen of the techniques are "active" and require some type of human action based on observations of the use of the ponds by avian species. Some active and passive techniques have been shown to be more effective than others or less prone to bird habituation. In evaluating bird deterrence techniques and strategies, environmental conditions (e.g., wind) and cost also play an important role. The applicability of these techniques for the evaporation ponds is based on expected site conditions and the effectiveness of the techniques based on other assessments.

Several of the avian deterrence techniques evaluated in Table 5-1 may be viable options for the proposed evaporation ponds at the PVU. Construction and operation of year-round freshwater habitat adjacent to the evaporation ponds to provide alternate wetland habitat can be an effective method of reducing exposure to avian species. These alternate habitats can be as shallow as 4-6 inches for effective foraging. Predator exclusion fences may be necessary along the freshwater habitat (Evaporation Ponds Technical Committee, 1999). Calculations from USFWS (1995) indicate an average compensation ratio (the acreage of freshwater ponds required based on the acreage of evaporation ponds) of 10 percent, with a range of 1 to 30 percent. The compensation ponds should be located within 3 kilometers of the evaporation ponds and can be operated as a flow-thru system to reduce impacts of evaporation on water quality (Evaporation Ponds Technical Committee, 1999). Although construction and operation of alternate habitat may have a relatively high cost depending upon the acreage required, alternate habitats have been successful in reducing exposure to avian species.

Water-spraying devices, such as rotating sprinklers, can be effective in deterring some avian species (SWCA Environmental Consultants, 2012). Such devices are probably most effective and economical for protecting small ponds. To be effective, the water spray must cover most or the entire pond or birds may enter between the spraying water. Because birds may habituate to a continuous spray, best results occur when sprinklers are operated on an on-off cycle. The start-up noise and sudden spray of water helps deter the birds from using the pond. Although this method may not be as effective as others, there is a process whereby pond water is pumped through a large number of elevated sprinkler heads to increase water evaporation. This patented process was developed in Israel by Ormat Engineering, Inc., to concentrate brine waters for mineral recovery (Bradford et al. 1989). Observations of its use in Israel indicate that waterbirds prefer not to enter the shower spray. This may be a potential method to both increase evaporation and keep birds from using the ponds. A previous study found that the spray may need to only cover about 50 percent of the surface to move gulls, but it is suspected that more coverage would be needed to repel all water-loving species and that the spray patterns would have to be nearly overlapping and cover most of the entire pond surface to effectively reduce the bird numbers. This may be a viable option for the proposed evaporation ponds at the PVU, but the practicality due to the size of the ponds and salt plugging of the water sprays may be of concern.

Active hazing techniques may be an effective method in reducing exposure to avian species. An integrated hazing program, which includes human patrols on foot, by boat, or in vehicles and in combination with trained dogs, may be successful active deterrence methods (SWCA Environmental Consultants, 2012). Hazing waterbirds by airboats or boats propelled by outboard motors is recommended in some situations and presents another means of transportation for human patrols. Boats are particularly useful for large pond sites where hazing from shore is not effective in moving birds from the center of the pond. However, boat use may not be practical in shallow ponds and there may be issues with transporting a boat between ponds. Reactions vary among species, and many may rapidly habituate or, if approached too closely, move only a short distance away and return soon after the people depart. Use of airboats is most effective for waterfowl. The effectiveness of these active hazing methods may be increased by incorporating other frightening stimuli, such as sirens, horns, boom cannons, or firing cracker shells. However, frequent loud noises may have a negative public reaction.

**Table 5-1**

**Avian Mitigation and Deterrence Techniques Evaluated for Evaporation Ponds**

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Alternative habitats – Construction and operation of year-round freshwater habitat adjacent to the evaporation ponds to provide alternate wetland habitat. The habitats can be as shallow as 4-6 inches for effective foraging. Freshwater ponds may require predator exclusion fences (Evaporation Ponds Technical Committee, 1999). Calculations from USFWS (1995) indicate an average compensation ratio (the acreage of freshwater ponds required based on the acreage of evaporation basins) of 10%, with a range of 1% to 30%. | Alternative habitats can be an effective method of reducing exposure to birds. The compensation ponds should be located within 3 kilometers of the evaporation ponds. They can be operated as a flow-thru system to reduce impacts on evaporation/water quality (Evaporation Ponds Technical Committee, 1999). | Relatively high cost based on design, construction, and operation. Water supply costs can also be expensive (Evaporation Ponds Technical Committee, 1999). |
| Active | Avian Rehabilitation – Construction, training, and operation of on-site rehabilitation facilities to capture and rehabilitate stressed birds. Once captured, the birds would be washed, rehydrated, and released at a suitable location away from the evaporation ponds. Birds that do not respond adequately to the on-site rehabilitation would be taken to a specialized rehabilitation facility for additional treatment (USGS, 2004). | Rehabilitation can be effective for birds that are able to be captured at lower exposure levels. Some mortality of birds is likely. | High cost and personnel training requirement; potential off-site treatment. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Gunfire/Cracker shells – Gunfire with ammunition or fixed projectiles. These devices rely on an explosion or other type of loud noise, and sometimes light flashes or smoke, to deter birds. | These devices can be especially useful in situations where sites need only be protected for relatively short periods of time (e.g., 1–4 weeks). Bird species can become habituated to these noises if used repeatedly over a long period of time. | Use of cracker shells can be effective in the short-term, but may not provide long-term deterrence without additional measures. Frequent loud noises may have negative public reaction. |
| Active | Human patrols – On foot, or in vehicles, generally used in combination with other techniques, such as shooting or firing cracker shells, to provide variety in an integrated hazing program. Trained dogs may be used in combination with humans.<br><br>Boat Use – Hazing waterbirds by airboats or boats propelled by outboard motors is recommended in some situations and presents another means of transportation for human patrols. Boats are particularly useful for large pond sites where hazing from shore is not effective in moving birds from the center of the pond. | Reactions vary among species, and many may rapidly habituate or, if approached too closely, move only a short distance away and return soon after the people depart. Use of airboats is most effective for waterfowl. | This method is effective and would likely be supplemented with other deterrents. Boat use may not be practical in shallow ponds and issues with transporting a boat between ponds. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | <u>Biosonics</u> – Creating acoustical signals emitted by birds and other animals, such as distress or alarm calls, to acoustically repel birds. | More effective than the use of unnatural sounds and noises to repel nuisance birds as the birds do not habituate as rapidly to the distance or alarm calls.<br><br>Not all bird species emit alarm or warning calls, however, and the distinction between alarm and distress calls is not clear for some species. Warning calls are most commonly emitted by gregarious species, and large flocks usually are more responsive than small flocks or individuals. | May be considered as a supplement to human patrols and cracker shells. |
| Active | <u>Fireworks</u> – The loud unnatural noises produced by these devices, especially when exploded overhead, frighten most birds away from the source of the noise, at least temporarily. | Birds can habituate to such noises; however, if used with occasional gunfire, they may perceive them to be a real danger for a longer period. | Potential fire danger from errant fireworks minimizes or eliminates use of this option. Would be a supplement to other deterrents. Frequent loud noises may have negative public reaction. |
| Active | <u>Gas-operated exploders (gas or propane cannons)</u> – Produce extremely loud, intermittent explosions, usually at fixed 1- to 10-minute intervals as desired, that exceed the blast of a 12-gauge shotgun. | Migratory species usually are more effectively repelled than are resident species firmly established at a site. Habituation can be a problem when using gas exploders. Birds may become accustomed to the loud blasts after only a few days. | May be effective, but habituation may lessen effectiveness. Frequent loud noises may have negative public reaction. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Sonic devices (Av-Alarm) – The original Av-Alarm units emit loud, intermittent, electronically synthesized sounds that are similar to the noisy chirping of a large number of birds. These are sometimes referred to as synthetic bird alarm sounds. Such sounds are supposed to cause psychological “jamming” in birds and other pest animals. | These have been found to be relatively ineffective, and biosonics seem to work better. In most field tests, birds were scared away only temporarily. | More effective methods exist. |
| Active | High frequency sound devices – Ultrasonic frequencies are those exceeding 20,000 cycles per second (cps). Their main attraction for pest control is that ultrasonic sounds are neither audible nor disturbing to humans. | Ultrasonic devices have not been proven efficacious for repelling birds. Hearing ranges for several bird species have been measured in the laboratory. Power requirements may be too high because ultrasonic frequencies diminish much more rapidly than audible sounds with increasing distance from their source. | More effective techniques are available. |
| Active | Portable, marine-type radar system – Portable radar systems have been developed that can detect incoming birds and trigger specific hazing devices “on demand.” | Linking the hazing systems described above to a radar-based triggering system reduces the tendency of birds to habituate to regularly or randomly timed triggering of the hazing devices. Using this type of system, Stevens et al. (2000) found that waterfowl were 12.5-times less likely to fly over the ponds, 4.2-times less likely to land, and mortality of those that did was reduced by a factor of 6.5. | A radar-linked hazing system would provide continuous (day and night) control of acoustic hazing devices. Power (which can be off-line) and maintenance would be required. Due to the size of the PVU pond system, multiple radar stations may be required. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Trained falcons and hawks – These can be used to disperse birds. They are often used in conjunction with another method. | Most studies on the effectiveness of trained birds of prey involved dispersing birds from airports and runways. | More effective techniques are available. |
| Active | Aircraft – Aircraft represent a costly, but often highly effective means of hazing birds from large areas. Types of aircraft used or tested include fixed-winged airplanes, ultra-light recreational aircraft, helicopters, and radio- controlled model aircraft. Model aircraft may be designed to look like birds of prey. | Bird reactions can be influenced by many factors, including noise levels, height, color, speed, and flight pattern of the aircraft; their previous experience with aircraft; whether birds are migrants or well-established residents; and probably others. Nevertheless, where appropriate and feasible, hazing by aircraft can be a highly effective method of dispersing birds. Use of model aircraft is less effective. Birds often become habituated and return to the site after the aircraft has landed. | May be effective, but habituation may lessen effectiveness. Could be a useful supplement to other deterrents. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Water-spraying devices – Water sprays from rotating sprinklers can be used to deter some bird species. Such devices are probably most effective and economical for protecting small ponds. To be effective, the water spray must cover most or the entire pond or birds may enter between the spraying water. Because birds may habituate to a continuous spray, best results occur when sprinklers are operated on an on-off cycle. The start-up noise and sudden spray of water helps startle and frighten the birds. | In general, this method is not very effective. However, there is a process whereby pond water is pumped through a large number of elevated sprinkler heads to increase water evaporation. This patented process was developed in Israel by Ormat Engineering, Inc., to concentrate brine waters for mineral recovery (Bradford et al. 1989). Observations of its use in Israel indicate that waterbirds prefer not to enter the shower spray. This may be a potential method to both increase evaporation and keep birds from using the ponds. A previous study found that the spray need to only cover about 50% of the surface to move gulls, but it is suspected that more coverage would be needed to repel all water-loving species and that the spray patterns would have to be nearly overlapping and cover most of the entire pond surface to effectively reduce the bird numbers. | Practicality may be of concern due to size of ponds and salt plugging of water sprays. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Active | Underwater sounds – Underwater acoustical devices currently being used or experimentally tested for deterring marine mammals may be worthy of investigation for repelling waterbirds from containment ponds. Underwater sounds of appropriate frequencies and loudness might be disturbing to diving birds (e.g., ducks, grebes, etc.) and waders (e.g., avocets, stilts, dowitchers) that submerge their heads below the water surface to obtain food. If effective in causing the birds to leave the pond area, the devices could be used singly or alternately to provide variety to a hazing program by intermittently combining underwater sound with other scare methods (e.g., gas exploders, shell crackers, etc.), thereby furthering the concept of variability in negative reinforcement. | Underwater sound has several important advantages over airborne sound. When used near residences, it would not be disturbing to people. Secondly, the sound and its projection are not influenced by strong winds. However, the shallowness of the water in some evaporation ponds may work against its potential effectiveness. The effects of disturbing the pond bottom sedimentation would also have to be considered. | Not practical due to size of ponds, active harvesting of ponds, and corrosive nature of brine. |
| Active | Electric shockers – Electrified wires providing nonlethal shocks have been used as a repelling tactile stimulus to deter birds. Although operating on high voltages, they are not lethal because of low amperages. | The birds must come into direct contact with the charged wires in order to be repelled, and this proves to be the major limiting factor in their usefulness. | Not practical due to size of ponds and active harvesting. |

| **Active or Passive** | **Description** | **Estimated Effectiveness** | **Applicability** |
|---|---|---|---|
| Active | Air horns and sirens – Air horns operate with compressed air to produce a loud, braying blast. The interval between blasts is determined by the operator and can be varied as desired with an automatic timer. Sirens may be used, if mounted on a truck for mobility. | Electric or air-produced nonspecific, audible loud sounds have limited potential for bird hazing. Because of expense, they are best used for protecting small areas or adding variety to a hazing program incorporating other frightening stimuli. | May be considered as a supplement to human patrols. |
| Passive | Evaporation Pond Design - Design techniques to discourage avian use can be incorporated into the pond design. These include minimum water depths and steep bank slopes. These techniques can discourage certain avian species from entering or continuing to use the ponds (Evaporation Ponds Technical Committee, 1999). | Reduces some avian usage, depending on species (Evaporation Ponds Technical Committee, 1999). | Should be considered supplemental to other methods. |
| Passive | Colored water – Waterfowl may avoid red- and orange-dyed water, with more tendency to avoid orange water. | The feasibility and practicality of coloring the water of larger ponds seems questionable from a cost basis. | Coloring water is not a viable option as it would also color the salts, eliminating their marketability. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Passive | Scarecrows and predator models – Scarecrows (human form) and models of owls and hawks may be effective. Scarecrow and raptor models should appear lifelike, be highly visible, and be moved frequently at the site to help alleviate habituation. Floating a human form scarecrow in a pond may deter non-resident waterfowl from entering a pond. | Dangling streamers or reflectors from scarecrows and using brightly colored loose clothing may help increase their effectiveness because they move in the wind and birds react more readily to colored and moving objects. If possible, a sound or motion triggered by the presence of birds may greatly increase the effectiveness of the model. Animated models of raptor species may also be effective. | May be effective, but habituation may lessen effectiveness. |
| Passive | Lights – These can include flashing lights, strobes, rotating beacons, and spotlights. | Birds become habituated to lights quickly. Most of the studies that tested the effectiveness of lights involved birds feeding at night at fish hatcheries. | More effective techniques are available. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Passive | Aerial visual devices – Includes colored balloons, hawk-shaped kites, and balloon- supported hawk kites. Balloons may be painted with eyespots to increase the fright response. These types of deterrents need to be moved around to reduce habituation. | Free-flying kites work best in a breeze or moderate wind but may not be suitable in calm conditions or in strong winds. Some birds may habituate to the presence of balloons and hawk kites if exposed for long periods. Some wind movement of the balloons or kites suspended from balloons is preferred as the motion increases the fright responses of birds.<br><br>Using the hawk kite and balloon together is usually more effective than using either alone. Response appears to vary among species as some birds habituate more rapidly than others to the presence of hawk kites. | Should be considered supplemental to other methods. |
| Passive | Flagging, reflectors, and reflecting tape – Various types of visual devices have been used or tested as frightening stimuli, including bird-scaring reflecting tape, various types of reflectors and spinners, and colored flags and streamers. | Birds become habituated to these techniques rapidly. Efficacy depends on the bird species present and the type and size of area that needs protection. Wind conditions also are important because motion increases their effectiveness. Most of these devices probably are not effective for any prolonged length of time if used alone. Some may, however, provide temporary protection, which may be extended somewhat when used with other bird-scaring methods or techniques (e.g., gas exploders, pyrotechnics). | Should be considered supplemental to other methods. |

| Active or Passive | Description | Estimated Effectiveness | Applicability |
|---|---|---|---|
| Passive | Overhead wires – Networks of overhead wires have been used with varying degrees of success. The wires are suspended horizontally in one direction or criss-crossed to form a grid or irregularly shaped network of lines above the area needing protection.<br><br>Monofilament fishing line or stainless steel or other types of non-rusting wire is most commonly used for overhead wiring. | Overhead wire networks can be expensive to install, but they generally require little maintenance other than replacing an occasional broken wire. The wire must be sufficiently strong to withstand strong winds and occasional bird impacts. In some situations, however, depending on wire spacing and species present, birds may become entangled in wires, necessitating periodic inspections to release them.<br><br>Perimeter wires or fencing may be needed at some sites to prevent birds from landing and walking into a protected area from the side. This type of learned entrance behavior frequently occurs with some bird species. | Not practical due to size of pond area, ability for waterfowl to walk into ponds, and difficulties during salt removal. |
| Passive | Netting – Complete enclosure by netting or screening can be an effective method of excluding birds from a site needing protection. It is the only sure method for total exclusion. | The feasibility and costs of netting a containment pond depend on its size and configuration. Netting creates a hazard of entanglement for birds and would require frequent inspection. Access to entangled birds may be difficult. Netting also deteriorates and would require periodic replacement. It can also be collapsed by snow/ice accumulation or damaged by high winds. | Not practical due to active harvesting of ponds. |

Table information from SWCA Environmental Consultants (2012) except as noted.

It should be noted that different waterfowl species migrate at different times of day. Species that migrate during daylight hours and rest and feed from dusk to dawn would require monitoring and hazing late in the day. Nocturnal migrants, such as eared grebes, may alight in the early morning hours and are more likely to be present on the water during daylight hours than at night. Therefore, monitoring and hazing during the migratory seasons will need to consider potential migrant arrivals from pre-dawn hours. Hazing systems can be linked to portable (marine type) radar systems that can detect incoming birds and trigger specific hazing devices "on demand." These systems are active both day and night and reduce the tendency of birds to habituate to regularly or randomly timed triggering of the devices.

Some of the avian deterrence techniques evaluated in Table 5-1 are not considered viable options for the proposed evaporation ponds at the PVU. Overhead wiring or netting pose several issues. Depending upon wire/netting spacings and species present, birds may become entangled or entrapped in wires and netting, necessitating periodic inspections to release them and potentially resulting in bird mortalities. Overhead wiring and netting are not practical due to proposed active harvesting of the ponds. Other deterrence techniques may not be practical due to the size of the ponds, proposed active harvesting of the ponds, the corrosive nature of brine, and negative public reaction to loud sounds.

## 5.2 Adaptive Management Approach

It is recommended that the avian mitigation and deterrence methods for the proposed evaporation ponds at the PVU be implemented under an adaptive management process. Monitoring and assessment of avian deterrence will be an ongoing process and will be adjusted based on species composition/behavior, seasonality, or other factors as appropriate.

In Section 5.1, an evaluation of mitigation measures was conducted to identify appropriate avian deterrence techniques that may be effective to reduce potential risks and hazards to avian species, including migratory species, associated with the evaporation ponds. The following activities describe mitigation measures that could be applied at the PVU evaporation ponds. The first four would be conducted for all of the PVU evaporation ponds and the fifth (netting) would only be considered viable for the bittern pond. The efficacy of the activities, and the need for less or more of the activities, will be assessed and modified accordingly as part of the adaptive management process.

### Activity 1 - Human Patrols

This activity will serve as both a deterrence (foot patrols and vehicles moving around the ponds will disturb birds), as well as providing a method to monitor and assess avian use of the ponds. Monitoring reports would be completed to note bird species, numbers, and frequency of use. The monitoring reports will also include all other wildlife observations made during the patrol, including mammals (large and small), reptiles, and amphibians either seen in proximity to the ponds or found dead in or near the ponds. Based on these monitoring reports, any trends in use of the ponds by waterfowl and other wildlife would be evaluated, and additional mitigation activities could be recommended. These could include implementing the activities below, or possibly reductions in monitoring frequency. New mitigation or deterrence techniques could also be evaluated as they become known or are reported in the literature. Monitoring and assessment would continue to occur during all mitigation activities, and adaptive management would be used to determine if additional mitigation activities are required.

In conjunction with these patrols and in anticipation that salt-affected waterfowl (or other wildlife) will be encountered during such patrols, it is recommended that a basic wildlife recovery station be created at the pond facility as part of its original design where live, affected birds that can be captured can be taken and provided fresh water for cleaning and drinking, and a safe, warm, and dry environment can be provided for recovery. Appropriate permitting would be required for the capture and handling of these birds.

**Activity 2 – Hazing**

Hazing at the PVU ponds could be implemented if monitoring and assessment of the ponds indicates significant use by waterfowl with observations of adverse effects. The recommended initial techniques are biosonics (distress/alarm calls or calls/decoys of predatory birds to acoustically/visually repel birds from the pond environments) or gas-operated exploders (gas or propane boom cannons). Biosonics can be more effective than the use of unnatural sounds and noises to repel nuisance birds as the birds do not habituate as rapidly to alarm calls. However, the use of biosonics would be dependent on the type of birds using the ponds and whether or not there are alarm calls that are effective for that species. Data from the monitoring reports would be used to determine which species calls would be required.

Boom cannons that produce extremely loud, intermittent explosions, could also be used. Birds can become acclimated to the loud blasts in a short time period, so frequent monitoring would be required to determine the effectiveness of this activity.

Hazing systems as described above can be linked to a portable (marine type) radar system that can detect incoming birds and trigger specific hazing devices “on demand.” These systems reduce the tendency of birds to habituate to regularly or randomly timed triggering of the devices. Using this type of system, Stevens et al. (2000) found that waterfowl were 12.5-times less likely to fly over the ponds, 4.2-times less likely to land, and mortality of those that did was reduced by a factor of 6.5.

**Activity 3 – Boat/Drone Use**

In ponds where the hazing activities in Activity 2 might not be as effective (e.g., if the sounds do not effectively cover the entire ponds), hazing by boats propelled by outboard motors (where depth allows) or airboats may be effective. In lieu of a boat, a flying drone device equipped with a noisemaker might be utilized. With the recent availability and advanced technology of drone equipment, using the drones to fly over and disturb waterfowl may be an effective means for mitigation. Some drones may even allow for pre-programmed flight patterns, simplifying their use over the ponds. Using a drone may also be less time consuming than moving boats between the ponds; however, it may not be effective for grebes and diving ducks, which may react by diving beneath the surface of the water rather than flushing.

**Activity 4 – Alternative habitat (construction of a freshwater pond)**

Construction and operation of freshwater habitat in the vicinity of the PVU ponds would provide alternate wetland habitat for waterfowl. This method is generally effective, but is more expensive than the other activities, and would require ongoing operations and maintenance costs. In addition to the possible attraction of migrating waterfowl to a safe environment for resting and feeding, it would provide waterfowl that have alighted on evaporation ponds and are either repelled by or flushed off of the brine a place to which to escape and rehydrate or remove salt crystals.

The development of an alternative freshwater pond at the PVU site would have two significant drawbacks: 1) providing a source of freshwater to the pond, which may not be locally available, and 2) keeping the water available (ice-free) during migration periods. Because the freshwater supply will probably be limited, minimization of the freshwater pond size and lining of the pond will be essential to the implementation. However, the pond will still need to be large enough to be found by birds that may have been visually attracted to, then repelled by, the evaporation ponds. A pond size of 3 to 6 acres (approximately 1 to 2% of the total evaporation pond size) would be considered the minimum size to make this alternative effective. The suggested minimum percentages of the total evaporation pond size (1 to 2%) correspond with the minimum compensation pond sizes (approximately 1.3%) determined by the USFWS (1995) for evaporation basins in the Central Valley of California based on selenium risk (in one case, the compensation area for a 260-acre evaporation basin was calculated to be 3 acres).

Because winter migrants are the most likely type of wildlife to be affected by the evaporation ponds, the freshwater pond size can be seasonally altered to be at its maximum (6 acres) during the migratory period and allowed to drop to a minimum pool size (3 acres) during the summer months. To keep the water fresh, it would require either a continuous source, flow-through system or periodic flushing and refilling. The shoreline should be irregular (i.e., not simply square or rectangular), with both open water and narrower inlets. Portions of the shoreline should be vegetated with cattails and/or bulrushes to increase the visual attractiveness to waterfowl. The pond should be within the wildlife exclusion fence to minimize terrestrial predator visits, and no trees or structures that could serve as perches for raptors should be allowed around the pond. During the fall and winter, decoys may be used to further entice migrants to use the freshwater habitat.

Freezing of the freshwater pond surface during the migration periods (late summer through early fall and late winter through early spring) will render it unusable by waterfowl and methods to keep the water surface open (ice-free) may need to be found before this option can be considered viable. Opening the water surface may be especially important during early or late winter storm events that could force migrating waterfowl to seek refuge on any available water body and simultaneously cause the freshwater surface to freeze over. An artificial or solar heating system may be needed to accomplish this; however, it may be possible to tap the heat of the brine in the evaporation ponds to warm the freshwater pond.

**Activity 5 – Netting (bittern pond only)**

A fifth activity, netting, is specific to the bittern pond. Because of the high concentrations of salt and the consistency of the salt solution, netting may be required to completely exclude birds from this pond to avoid potential entrapment and mortality. If human patrols note frequent use and/or entrapment, netting may be considered in lieu of the other activities to prevent avian mortality.

Completely enclosing the bittern pond by netting or screening would be an effective method of excluding birds completely. It is the most effective method for total exclusion. If birds are observed becoming entrapped in the bittern pond, or if frequent use by birds is noted, this activity may be implemented before attempting the other activities to provide an immediate solution.

It should be noted that the current plan for the facility is a 24-acre bittern pond for further evaporation and volume reduction of the bittern and a separate 3-acre pond for storage. However, initial tests of the brine have indicated very low magnesium levels and potentially little or no bittern production (Amec FW, 2016c); therefore, the actual need for bittern pond(s) may be much less than these plans indicate.

**Adaptive Management Strategy**

The aforementioned activities will start with Activity 1. Monitoring of the ponds under Activity 1 will include documentation of birds and other wildlife that may have been adversely affected (injured or killed) by contact with the brine or its salts. All instances of observed injury or mortality will be evaluated weekly, monthly, and quarterly for trends that may require the initiation of a mitigation action. For birds, the increased level of mitigation will be implemented in the form of any of Activities 2 through 5, above. Other classes of wildlife (large or small mammals, reptiles, and amphibians) may require other actions, such as exclusion fence repair or modification.

Implementation of mitigation actions will be based on thorough evaluation of the information available, including species affected, probable cause of injury or death (ingestion or dehydration versus encrustation), pond(s) showing affects, and possible correlations with weather conditions and migration patterns. Professional judgement will be used to ascertain whether the data indicate trends in injury or mortality that warrant action and can be effectively countered through the implementation of one or more specific actions. If the escalated Activity has no effect on reducing bird impacts in the next three month time period or during the next equivalent season, then an additional management Activity may be employed at that pond unit until bird effects are minimized to the extent practical. Design of each Activity would be performed at the time that a need is identified and the design will be informed by site observations of bird effects.

## 6.0 REFERENCES

Amec Foster Wheeler (Amec FW). 2016a. Pond Optimization Study 2 for Paradox Valley Unit Evaporation Ponds: Site Selection Report (Final). Amec Foster Wheeler Environment & Infrastructure. August 2016.

Amec FW. 2016b. Paradox Valley Unit Salinity Control Investigations Study 1 – Hydrogen Sulfide Management Bedrock, Colorado: Treatment Options Bench Testing Report (Final). Amec Foster Wheeler Environment & Infrastructure. August 2016.

Amec FW. 2016c. Findings and Recommendation Report, Paradox Valley Unit Byproducts Disposal Study (Final). Amec Foster Wheeler Environment & Infrastructure. August 2016.

Baars, D.L., 2000. "The Colorado Plateau: a geologic history." UNM Press. https://books.google.com/books?id=CHut1M-yAb0C&pg=PA63#v=onepage&q&f=false Accessed 2016.

Baker, A.A., Dane, C.H., Reeside, J.B., Jr., 1993. Paradox formation of eastern Utah and western Colorado: American Associate of Petroleum Geologists Bulletin. http://ngmdb.usgs.gov/Geolex/UnitRefs/ParadoxRefs_9763.html Accessed April 2016.

Bradford, D.F., D. Drezner, J.D. Shoemaker, and L. Smith. 1989. Evaluation of Methods to Minimize Contamination Hazard to Wildlife using Agricultural Evaporation Ponds in the San Joaquin Valley, California. Final Report to the California Department of Water Resources (Contract No. STCA/DWR B57037). Los Angeles: Environmental Science and Engineering Program, University of California.

Bureau of Land Management. 2009. West Paradox Land Health Assessment. Uncompahgre Field Office. Available online at http://www.blm.gov/co/st/en/fo/ufo/land_health.html. Accessed March 2016.

Bureau of Land Management. 2010. East Paradox Land Health Assessment. Uncompahgre Field Office. Available online at http://www.blm.gov/co/st/en/fo/ufo/land_health.html. Accessed March 2016.

Bureau of Land Management. 2015. BLM Colorado Sensitive Wildlife Species of the Uncompahgre Field Office. Available online at http://www.blm.gov/co/st/en/fo/ufo/wildlife_and_vegetation/sensitive_wildlife.html. Accessed March 2015.

Chafin, D.T., 2003. United States Geological Survey. Effect of the Paradox Valley Unit on the Dissolved-Solids Load of the Dolores River near Bedrock, Colorado, 1988-2001. http://pubs.usgs.gov/wri/wri02-4275/pdf/wrir02-4275.pdf Accessed April 2016.

Chapman, S.S., Griffith, G.E., Omernik, J.M., Price, A.B., Freeouf, J., and Schrupp, D.L. 2006. Ecoregions of Colorado (color poster with map, descriptive text, summary tables, and photographs). Reston, Virginia. U.S. Geological Survey (map scale 1:1,200,000). Available online at http://ulpeis.anl.gov/documents/dpeis/references/pdfs/Chapman_et_al_2006.pdf. Accessed March 2016.

Chenoweth, W.L., 1987. Paradox Valley, Colorado; A collapsed salt anticline. Geological Society of American centennial Field Guide – Rocky Mountain Section. http://ulpeis.anl.gov/documents/dpeis/references/pdfs/Chenoweth_1987.pdf Accessed April 2016.

Colorado Division of Wildlife. 2013. Explore Wild Colorado: Paradox Valley. Colorado Birding Trail. Available online at http://coloradobirdingtrail.com/site/paradox-valley/. Accessed March 2016.

Colorado Herpetological Society. 2016. Online Guide to the Amphibians and Reptiles of Colorado. Available at http://www.coloherps.org/index.html. Accessed March 2016.

Dein, F.J.; L.A. Baeten, C.U. Meteyer, M.K. Moore, M.D. Samuel, P.D. Miller, C. Murphy, S. Sissler, C.W. Jeske, J.R. Jehle Jr., J.S. Jaeger, B. Bauer, and S.A. Mahoney. 1997. Investigation into Avian Mortality in the Playa Lakes Region of Southeastern New Mexico. US Geological Survey, Biological Resources Division, National Wildlife Health Center, National Wetlands Research Center.

Dunning, J.B., Jr. 1993. *CRC Handbook of Avian Body Masses*, CRC Press, Boca Raton, Florida.

ESSD Research Group. 1994. *Environmentally Sensitive Sanding and Deicing Practices*. CDOT-CTI-95-5. Colorado Department of Transporation. November 25, 1994.

Evaporation Ponds Technical Committee, 1999. Evaporation Ponds Final Report. Report prepared for San Joaquin Valley Drainage Implementation Program. 78 pp.

Fort Lewis College. 2014. Lower Dolores River Implementation, Monitoring and Evaluation Plan for Native Fish. Available online at http://ocs.fortlewis.edu/drd/pdf/Lower-Dolores-River-Implementation-Monitoring-and-Evaluation-Plan-for-Native-Fish-June%202014.pdf. Accessed March 2015.

Griffiths, S.R., D.B..Donato, L.F. Lumsden, and G. Coulson. 2014. Hypersalinity Reduces the Risk of Cyanide Toxicosis to Insectivorous Bats Interacting with Wastewater Impoundments at Gold Mines. *Ecotoxicology and Environmental Safety* 99: 28-34.

Hayes, M.A., Hall, R. 2008. Bats in the Paradox Valley Area and Gunnison Gorge National Conservation Area: Results of Mist-Netting and Acoustic Surveys During 2008. University of Colorado.

Hazardous Substances Data Bank (HSDB). 2016. Online database maintained by the National Library of Medicine. Available at http://toxnet.nlm.nih.gov

Kowalski, D., R. Anderson, J. White, and B. Nehring. 2010. Native Fish of the Lower Dolores River Status, Trends, and Recommendations. Slideshow. Colorado Division of Wildlife. Available online at http://ocs.fortlewis.edu/drd/pdf/Dolores%20Native%20Fish%20Status%20and%20Trends%202010danmarch2010.pdf. Accessed March 2015.

Nagy, Kenneth A. 2001. *Food Requirements of Wild Animals: Predictive Equations for Free-Living Mammals, Reptiles, and Birds*. Nutrition Abstracts and Reviews, Series B, Vol. 71, No. 10. October 2001.

Sample, B.E., D. M. Opresko, and G. W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. *ES/ER/TM-86/R3*, Oak Ridge National Laboratory, Oak Ridge, Tennessee..

Stevens, G.R., J. Rogue, R. Weber, and L. Clark. 2000. Evaluation of a Radar-activated, Demand-performance Bird Hazing System. *International Biodegradation & Biodeterioration*. 45(2000):129-137.

SWCA Environmental Consultants, 2012. HB Project Solar Evaporation Ponds, Stepped Avian Monitoring and Mitigation Plan. Report prepared for Intrepid Potash, Inc. 21 pp.

Trahan, N.A., and C.M. Peterson. 2007. *Factors Impacting the Health of Roadside Vegetation*. CDOT-DTD-R-2005-12. Colorado Department of Transportation. April 2007.

U.S. Department of the Interior and Bureau of Reclamation. 2013. Western Colorado Area Office Paradox Valley Unit. http://www.usbr.gov/uc/wcao/progact/paradox/ Accessed April 2016.

U.S. Environmental Protection Agency (USEPA), 1993. *Wildlife Exposure Factors Handbook*. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-93/187.

USEPA. 1998. *Guidelines for Ecological Risk Assessment*. Final. Risk Assessment Forum. Washington, DC EPA/630/R-95/002F. April 1998.

USEPA, 2005. *Ecological Soil Screening Level for Barium.* Interim Final. OSWER Directive 9285.7-63. U.S. Environmental Protection Agency Office of Emergency and Remedial Response

USEPA, 2007. *Ecological Soil Screening Level for Manganese*. Interim Final. OSWER Directive 9285.7-71. U.S. Environmental Protection Agency Office of Emergency and Remedial Response

U.S. Fish and Wildlife Service (USFWS), 1995. Compensation Habitat Protocol for Drainwater Evaporation Basins. Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service, Sacramento, CA. 26 pp.

WestWater Engineering. 2009. Biological Survey Report Energy Fuels-Piñon Ridge Mill Montrose County Colorado. Available online at https://www.colorado.gov/cdphedir/hm/Radiation/licenseapplication/rpt(1)biologicalsurvey.pdf. Accessed March 2015.

# APPENDICES

# APPENDIX A

# APPENDIX A

## Derivation of Target Reporting Limits Based on Ecological Toxicity Thresholds

As part of the predictive ecological risk assessment (PERA) for the proposed evaporation pond system at the Paradox Valley Unit (PVU), the potential effects of oral exposure of avian and mammalian wildlife to trace elements in the pond were evaluated. Samples of the brine that will be pumped into the evaporation pond(s) have been analyzed for the broad range of metals (Table A-1). With the exception of the major salt cations (e.g., sodium, potassium, calcium, and magnesium), these metals are considered to be trace elements. Analytical reporting limits for these elements should therefore be less than the concentrations that would be potentially toxic to these wildlife receptors.

It is important to note that the brine that would be pumped into the evaporation pond will already be hypersaline, with total dissolved solids (TDS) at approximately 28%. With subsequent evaporation from the pond(s), the salinity will increase from this baseline to saturation. The extremely high osmotic potential of this water makes it uninhabitable to essentially all aquatic organisms and even exceeds the likely salinity tolerances of brine shrimp (*Artemia* spp.) and brine flies (*Ephydra* spp.). In the Great Salt Lake (GSL) of Utah, *Artemia franciscana* and *Ephydra gracilis* provide an important food source to migratory waterfowl; however, the salinity of the GSL ranges between about 8 and 18%. At higher levels of salinity, these species exhibit lower survival, reproduction, and body size, with an upper tolerance limit of these species is about 26% or less[6]. For this reason, it is not expected that the evaporation pond(s) will support an aquatic community or a food chain that will lead to wildlife exposures due to bioaccumulation of trace elements into the tissues of aquatic food items.

The most likely pathway of exposure to trace elements by wildlife is through the direct consumption of the water. However, again, due to the high salinity of the water in the evaporation pond(s), they are not expected to be regular (chronic) source of drinking water for these receptors since it would have an adverse taste and long-term consumption of the water would probably result in adverse physiological effects due to the salts. However, the target reporting limits for the PERA are based on the water ingestion pathway for avian and mammalian receptors. The target reporting are estimated from the following equation:

$$TRL = 1000 \times UF \times \frac{TRV}{WIR}$$

where:

TRL = target reporting limit (micrograms per liter [µg/L])

UF = uncertainty factor (0.1, unitless)

TRV = toxicity reference value (milligrams per kilogram body weight per day [mg/kg-day])

WIR = water ingestion rate (liters per kilogram body weight per day [L/kg-day])

1000 = conversion factor from mg/L to µg/L

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[6] Brown, P. 2010. "Salinity Tolerance of *Artemia* and *Ephydra*: Uncertainties and Discrepancies." Available at: www.fogsl.org/issuesforum/2010/wp-content/uploads/2010/05/Brown_FOGSL_Presentation.pdf

The toxicity reference values (TRVs) for avian and mammalian receptors are shown in Table A-1. When available, the TRVs are from the U.S. Environmental Protection Agency's (USEPA) Ecological Soil Screening (Eco-SSL) documents[7]. When not available from the Eco-SSL documents, TRVs derived by Oak Ridge National Laboratory[8] were used. As noted in Table A-1, TRVs were not available for all metal analytes from these sources. In those cases, the achievable laboratory reporting limit was assumed to be adequate. If a TRV was only available for one wildlife class (bird or mammal), the TRL was based on the available TRV. The TRVs used were conservatively based no-observed-adverse-effect levels (NOAELs) for chronic oral exposure.

The water ingestion rates (WIRs) were taken from the USEPA *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187a, December 1993). WIRs typically decrease with increasing body weight. TRLs were initially calculated based on two receptors, mallard and cottontail, that are approximately equal in size (~1.0 kg) and are likely receptors at the PVU. For conservatism the TRLs were also calculated for two receptors of lesser body weight, the marsh wren (~0.01 kg) and deer mouse (~0.020 kg). The WIRs for the mallard and cottontail were 0.058 and 0.097 liters per kilogram per day (L/kg-day), respectively, while those for the marsh wren and deer mouse were 0.28 and 0.19 L/kg-day, respectively.

An uncertainty factor of 0.1 was applied to the TRLs to ensure that the TRL is a conservative estimate; however, conservatism is also inherent in both the TRVs and WIRs used. Specifically, the TRVs are based on chronic NOAELs, which are likely to underestimate the actual threshold of toxicity for these wildlife receptors and WIRs were based on small receptors that will have higher WIRs than those most likely to be drinking water from the evaporation pond.

The final TRL was selected as the minimum TRL among the receptors. Table A-1 shows the final TRLs as based on the most conservative receptors (marsh wren and deer mouse) and the "expected" receptors (mallard and cottontail). In all cases, the laboratory reporting limit is less than the TRL.

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[7] Available at: www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents/

[8] Sample, B.E., C.M., Opresko, and G.W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory, Oak Ridge, TN. 227 pp., ES/ER/TM-86/R3.

**Table A-1. Derivation of Target Reporting Limits for Potential Trace Elements Based on Ecological Toxicity Thresholds**

| Parameter | Toxicity Reference Values (mg/kg-day) | | | | Estimated Toxic Threshold for Representative Receptors (µg/L) (water ingestion rate in parentheses) | | | | Minimum Treshold x Uncertainty Factor (UF = 0.1) | | Target Reporting Limits (µg/L) | | Achievable Reporting Limits (ug/L) | Method Detection Limit (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Birds | | Mammals | | Expected Receptors | | Conservative Receptors | | | | | | | |
| | TRV | Source | TRV | Source | Mallard (0.058 L/kg-day) | Cottontail (0.097 L/kg-day) | Marsh Wren (0.28 L/kg-day) | Deer Mouse (0.19 L/kg-day) | Expected Receptors | Conservative Receptors | Expected Receptors | Conservative Receptors | | |
| Aluminum | 109.7 | ORNL | 1.93 | ORNL | 1891379 | 19897 | 391786 | 10158 | 1990 | 1016 | 2000 | 1000 | 500 | 189 |
| Antimony | -- | -- | 0.059 | Eco-SSL | -- | 608 | -- | 311 | 61 | 31 | 60 | 30 | 3 | 2.27 |
| Arsenic | 2.24 | Eco-SSL | 1.04 | Eco-SSL | 38621 | 10722 | 8000 | 5474 | 1072 | 547 | 1100 | 550 | 50 | 3.58 |
| Barium | 20.8 | ORNL | 51.8 | Eco-SSL | 358621 | 534021 | 74286 | 272632 | 35862 | 7429 | 36000 | 7400 | 10 | 9.41 |
| Berrylium | -- | -- | 0.532 | Eco-SSL | -- | 5485 | -- | 2800 | 548 | 280 | 550 | 280 | 5 | 1.45 |
| Bismuth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2000 | 976 |
| Boron | 28.8 | ORNL | 28 | ORNL | 496552 | 288660 | 102857 | 147368 | 28866 | 10286 | 29000 | 10000 | 500 | 64.1 |
| Cadmium | 1.47 | Eco-SSL | 0.77 | Eco-SSL | 25345 | 7938 | 5250 | 4053 | 794 | 405 | 800 | 400 | 3 | 1.27 |
| Chromium | 2.66 | Eco-SSL | 2.4 | Eco-SSL | 45862 | 24742 | 9500 | 12632 | 2474 | 950 | 2500 | 950 | 100 | 7.36 |
| Cobalt | 7.61 | Eco-SSL | 7.33 | Eco-SSL | 131207 | 75567 | 27179 | 38579 | 7557 | 2718 | 7600 | 2700 | 10 | 2.1 |
| Copper | 4.05 | Eco-SSL | 5.6 | Eco-SSL | 69828 | 57732 | 14464 | 29474 | 5773 | 1446 | 5800 | 1400 | 100 | 20.4 |
| Iron | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | - | 1000 | 127 |
| Lead | 1.63 | Eco-SSL | 4.7 | Eco-SSL | 28103 | 48454 | 5821 | 24737 | 2810 | 582 | 2800 | 580 | 5 | 1.98 |
| Lithium | -- | -- | 9.4 | ORNL | -- | 96907 | -- | 49474 | 9691 | 4947 | 9700 | 5000 | 100 | 30.5 |
| Manganese | 179 | Eco-SSL | 51.5 | Eco-SSL | 3086207 | 530928 | 639286 | 271053 | 53093 | 27105 | 53000 | 27000 | 20 | 7.35 |
| Mercury | 0.45 | ORNL | 1 | ORNL | 7759 | 10309 | 1607 | 5263 | 776 | 161 | 780 | 160 | 0.2 | 0.06 |
| Molybdenum | 3.5 | ORNL | 0.26 | ORNL | 60345 | 2680 | 12500 | 1368 | 268 | 137 | 270 | 140 | 10 | 4.41 |
| Nickel | 6.71 | Eco-SSL | 1.7 | Eco-SSL | 115690 | 17526 | 23964 | 8947 | 1753 | 895 | 1800 | 1800 | 50 | 23.4 |
| Selenium | 0.29 | Eco-SSL | 0.143 | Eco-SSL | 5000 | 1474 | 1036 | 753 | 147 | 75 | 150 | 75 | 10 | 4.25 |
| Silicon | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | - | 5000 | 1740 |
| Silver | 2.02 | Eco-SSL | 6.02 | Eco-SSL | 34828 | 62062 | 7214 | 31684 | 3483 | 721 | 3500 | 700 | 1 | 0.41 |
| Strontium | -- | -- | 263 | ORNL | -- | 2711340 | -- | 1384211 | 271134 | 138421 | 270000 | 140000 | 10 | 3.77 |
| Thallium | -- | -- | 0.0074 | ORNL | -- | 76 | -- | 39 | 8 | 4 | 8 | 4 | 2 | 0.34 |
| Tin | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | - | 50 | 6.78 |
| Titanium | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | - | 200 | 47.4 |
| Uranium | 16 | ORNL | 3.07 | ORNL | 275862 | 31649 | 57143 | 16158 | 3165 | 1616 | 3200 | 1600 | 1 | 0.46 |
| Vanadium | 0.344 | Eco-SSL | 4.16 | Eco-SSL | 5931 | 42887 | 1229 | 21895 | 593 | 123 | 600 | 120 | 10 | 2.72 |
| Zinc | 66.1 | Eco-SSL | 75.4 | Eco-SSL | 1139655 | 777320 | 236071 | 396842 | 77732 | 23607 | 78000 | 24000 | 200 | 71.1 |
| Zirconium | -- | -- | 1.74 | ORNL | -- | 17938 | -- | 9158 | 1794 | 916 | 1800 | 1000 | 5 | 1.5 |

Sources of TRVs:

Eco-SSL = U.S. Environmental Protection Agency's Ecological Soil Screening documents, Available at: www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents/

ORNL = Sample, B.E., C.M., Opresko, and G.W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory, Oak Ridge, TN. 227 pp., ES/ER/TM-86/R3.

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# APPENDIX B

**TABLE B-1**
**DEER MOUSE EXPOSURE PARAMETERS**
**PREDICTIVE ECOLOGICAL RISK ASSESSMENT**
**Paradox Valley Solar Evaporation Ponds, Colorado**

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **Deer Mouse** | Order: *Rodentia* Family: *Muridae*<br>Species: *Peromyscus maniculatus* | |
| Body Weight (BW)(kg) | Average adult weight is 0.021 kg (USEPA, 1993). | 0.021 kg |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of deer mouse was estimated based on allometric regression model using body weight (USEPA, 1993): $IRw = 0.099(BW\ in\ kg)^{0.9}$ | 0.0031 L/day |
| Exposure Frequency (unitless) (EF) | The deer mouse is a year-round resident (USEPA, 1993). | 1 |

$$\text{Estimated intake (mg/kg-day)} = \frac{(C_W \times IR_W \times EF)}{BW}$$

Where:
$C_W$ = Chemical concentration in water (mg/L)
$IR_W$ = Ingestion rate of water (L/day)
EF = Exposure frequency (unitless)
BW = Body weight (kg)

**Notes:**
kg kilograms
mg/L milligrams per liter
L/day liters per day
mg/kg-day milligrams per kilogram per day

**Sources:**
USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

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# TABLE B-2
# BLACK-THROATED SPARROW EXPOSURE PARAMETERS
# PREDICTIVE ECOLOGICAL RISK ASSESSMENT
# Paradox Valley Solar Evaporation Ponds, Colorado

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **Black-Throated Sparrow** | Order: *Passeriformes* Family: *Emberizidae*<br>Species: *Amphispiza bilineata* | |
| Body Weight (BW)(kg) | Average adult weight is 0.0135 kg with a range of 0.0102 kg to 0.0164 kg (Dunning, 1993). | 0.0135 kg |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of eared grebe was estimated based on allometric regression model using body weight (USEPA , 1993): IRw = 0.059(BW in kg)$^{0.67}$ | 0.0033 L/day |
| Exposure Frequency (unitless) (EF) | The black-throated sparrow is a migratory species that is present in Colorado during the summer months (breeding season). As a conservative approach, an EF of 1 was assumed. | 1 (Maximum Exposure) |

$$\text{Estimated intake (mg/kg-day)} = \frac{(C_W \times IR_W \times EF)}{BW}$$

Where:
- $C_W$ = Chemical concentration in water (mg/L)
- $IR_W$ = Ingestion rate of water (L/day)
- EF = Exposure frequency (unitless)
- BW = Body weight (kg)

**Notes:**

| | |
|---|---|
| kg | kilograms |
| mg/L | milligrams per liter |
| L/day | liters per day |
| mg/kg-day | milligrams per kilogram per day |

**Sources:**


USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

Dunning, J.B., 1993. *CRC Handbook of Avian Body Masses*. CRC Press, Boca Raton, Florida.


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**TABLE B-3**
**RED-TAILED HAWK EXPOSURE PARAMETERS**
**PREDICTIVE ECOLOGICAL RISK ASSESSMENT**
**Paradox Valley Solar Evaporation Ponds, Colorado**

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **<u>Red-tailed Hawk</u>** | Order: *Accipitriformes* Family: *Accipitridae*<br>Species: *Buteo jamaicensis* | |
| Body Weight (BW)(kg) | Average adult weight is 1.126 kg (USEPA, 1993). | 1.126 kg |
| Dietary Makeup | Red-tailed hawks hunt primarily from an elevated perch, often near woodland edges. Small mammals are the primary prey, but they also feed on a wide variety of food based on availability, including birds, lizards, snakes, and large insects (USEPA, 1993). As a conservative approach, the dietary composition is assumed to be 100% mammals. | Mammals – 100% |
| Ingestion Rate for Food ($IR_F$) (kg/day) | $IR_F$ of red-tailed hawk estimated using the Nagy (2001) fresh matter intake (FMI) equation for carnivorous birds: $y(\text{grams})=3.048(\text{BW in grams})^{0.665}$. | 0.33 kg/day |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of red-tailed hawk was estimated based on allometric regression model using body weight (USEPA, 1993): $IRw = 0.059(\text{BW in kg})^{0.67}$ | 0.064 L/day |
| Site Foraging Frequency (SFF) (unitless) | The SFF is the ratio of the site area to home range, not to exceed a maximum value of 1.0. As a conservative approach, the SFF of 1 was assumed. | 1 (Maximum Exposure) |
| Exposure Frequency (unitless) (EF) | Red-tailed hawks are year-round residents in Colorado (USEPA, 1993). | 1 |

**TABLE B-3**
**RED-TAILED HAWK EXPOSURE PARAMETERS**
**PREDICTIVE ECOLOGICAL RISK ASSESSMENT**
**Paradox Valley Solar Evaporation Ponds, Colorado**

Estimated intake (mg/kg-day) = $\frac{SFF \times IR_F \times EF \times [(EPC_M \times P_M)]}{BW} + \frac{(C_W \times IR_W \times EF)}{BW}$
(wet weight)

Where:

| | | | |
|---|---|---|---|
| Where: | $EPC_M$ | = | Exposure point concentration for mammals (mg/kg)* |
| | $P_M$ | = | Proportion of the diet comprised of mammals (unitless) |
| | $C_W$ | = | Chemical concentration in water (mg/L) |
| | $IR_F$ | = | Ingestion rate of food (kg/day, wet weight) |
| | $IR_W$ | = | Ingestion rate of water (L/day) |
| | SFF | = | Site Foraging Frequency (unitless) |
| | EF | = | Exposure frequency (unitless) |
| | BW | = | Body weight (kg) |

*Assumes $EPC_M$ is based on concentration of water that small mammals (i.e., deer mouse) ingest in one day; deer mouse IRw and maximum surface water concentration used to estimate $EPC_M$.

**Notes:**

| | |
|---|---|
| kg | kilograms |
| % | percent |
| kg/day | kilograms per day |
| mg/kg | milligrams per kilogram |
| mg/L | milligrams per liter |
| L/day | liters per day |
| mg/kg-day | milligrams per kilogram per day |

**Sources:**

USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

Nagy, K.A., 2001. *Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds*. Nutrition Abstracts and Reviews, Series B 71, 21R-31R.

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**TABLE B-4**
**EARED GREBE EXPOSURE PARAMETERS**
**PREDICTIVE ECOLOGICAL RISK ASSESSMENT**
**Paradox Valley Solar Evaporation Ponds, Colorado**

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **Eared Grebe** | Order: *Podicipediformes* Family: *Podicipedidae*<br>Species: *Podiceps nigricollis* | |
| Body Weight (BW)(kg) | Average adult weight is 0.468 kg with a range of 0.200 kg to 0.735 kg. At its fall staging area, the eared grebe more than doubles its body weight (The Cornell Lab of Ornithology, 2016). | 0.468 kg |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of eared grebe was estimated based on allometric regression model using body weight (USEPA , 1993): IRw = $0.059(\text{BW in kg})^{0.67}$ | 0.035 L/day |
| Exposure Frequency (unitless) (EF) | The eared grebe is a migratory species that is present in Colorado during the summer months (breeding season) (The Cornell Lab of Ornithology, 2016). As a conservative approach, an EF of 1 was assumed. | 1 (Maximum Exposure) |

$$\text{Estimated intake (mg/kg-day)} = \frac{(C_W \times IR_W \times EF)}{BW}$$

Where:

| | | |
|---|---|---|
| $C_W$ | = | Chemical concentration in water (mg/L) |
| $IR_W$ | = | Ingestion rate of water (L/day) |
| EF | = | Exposure frequency (unitless) |
| BW | = | Body weight (kg) |

**Notes:**

| | |
|---|---|
| kg | kilograms |
| mg/L | milligrams per liter |
| L/day | liters per day |
| mg/kg-day | milligrams per kilogram per day |

**Sources:**


USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

The Cornell Lab of Ornithology, 2016. Eared Grebe. https://www.allaboutbirds.org/guide/Eared_Grebe/lifehistory.


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# TABLE B-5
# NORTHERN SHOVELER EXPOSURE PARAMETERS
# PREDICTIVE ECOLOGICAL RISK ASSESSMENT
# Paradox Valley Solar Evaporation Ponds, Colorado

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **Northern Shoveler** | Order: *Anseriformes* Family: *Anatidae*<br>Species: *Anas clypeata* | |
| Body Weight (BW)(kg) | Average adult weight is 0.610 kg with a range of 0.400 kg to 0.820 kg (The Cornell Lab of Ornithology, 2016). | 0.610 kg |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of northern shoveler was estimated based on allometric regression model using body weight (USEPA , 1993): $IRw = 0.059(BW\ in\ kg)^{0.67}$ | 0.042 L/day |
| Exposure Frequency (unitless) (EF) | The northern shoveler is a migratory species at the site (The Cornell Lab of Ornithology, 2016), but is assumed to be a year-round resident. As a conservative approach, an EF of 1 was assumed. | 1 (Maximum Exposure) |

$$\text{Estimated intake (mg/kg-day)} = \frac{(C_W \times IR_W \times EF)}{BW}$$

Where:
$C_W$ = Chemical concentration in water (mg/L)
$IR_W$ = Ingestion rate of water (L/day)
EF = Exposure frequency (unitless)
BW = Body weight (kg)

**Notes:**

| | |
|---|---|
| kg | kilograms |
| mg/L | milligrams per liter |
| L/day | liters per day |
| mg/kg-day | milligrams per kilogram per day |

**Sources:**


USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

The Cornell Lab of Ornithology, 2016. Northern Shoveler. https://www.allaboutbirds.org/guide/Northern_Shoveler/lifehistory.


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**TABLE B-6**
**CANADA GOOSE EXPOSURE PARAMETERS**
**PREDICTIVE ECOLOGICAL RISK ASSESSMENT**
**Paradox Valley Solar Evaporation Ponds, Colorado**

| EXPOSURE PARAMETER | DESCRIPTION | VALUES SELECTED FOR EXPOSURE/RISK CALCULATIONS |
|---|---|---|
| **Canada Goose** | Order: *Anseriformes* Family: *Anatidae*<br>Species: *Branta canadensis* | |
| Body Weight (BW)(kg) | Average adult weight is 2.62 kg for wintering geese in Colorado. Body weight reaches its maximum just prior to or during the spring migration (USEPA, 1993). | 2.62 kg |
| Ingestion Rate for Water ($IR_W$) (L/day) | IRw of Canada goose was estimated based on allometric regression model using body weight (USEPA , 1993): IRw = $0.059(\text{BW in kg})^{0.67}$ | 0.112 L/day |
| Exposure Frequency (unitless) (EF) | The Canada goose is a year-round resident at the site (The Cornell Lab of Ornithology, 2016).<br>. | 1 |

$$\text{Estimated intake (mg/kg-day)} = \frac{(C_W \times IR_W \times EF)}{BW}$$

Where: $C_W$ = Chemical concentration in water (mg/L)
$IR_W$ = Ingestion rate of water (L/day)
EF = Exposure frequency (unitless)
BW = Body weight (kg)

**Notes:**
kg kilograms
mg/L milligrams per liter
L/day liters per day
mg/kg-day milligrams per kilogram per day

**Sources:**
USEPA, 1993. *Wildlife Exposure Factors Handbook*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187. December, 1993.

The Cornell Lab of Ornithology, 2016. Canada Goose. https://www.allaboutbirds.org/guide/Canada_Goose/id.

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## TABLE B-7

### Risk Estimates for Deer Mouse - NOAEL-based Analysis
### Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[(a)] (mg/L) | Deer Mouse NOAEL TRV (mg/kg-day) | Deer Mouse Intake (mg/kg-day)[(b)] | Hazard Quotient (HQ) Unitless[(c)] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 20.0 | 16,238 | **812** |
| **Potassium** | 5,400 | 2.01 | 797 | **397** |
| **Magnesium** | 2,000 | 7.14 | 295 | **41** |
| **Calcium** | 1,700 | 7.00 | 251 | **36** |
| | | | **Hazard Index:** | **1286** |
| **Detected Trace Elements** | | | | |
| Aluminum | 3.4 | 1.93 | 0.502 | 0.26 |
| Barium | 0.53 | 51.8 | 0.0782 | 0.0015 |
| Bismuth | 0.62 | 100 | 0.0915 | 0.00092 |
| Boron | 11 | 28 | 1.62 | 0.058 |
| Lithium | 0.42 | 16.9 | 0.062 | 0.0037 |
| Manganese | 0.62 | 51.5 | 0.0915 | 0.0018 |
| Strontium | 32 | 580 | 4.72 | 0.0081 |
| | | | **Hazard Index:[(d)]** | 0.33 |

Notes:
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value
(a) Maximum surface water concentration in BIF samples collected in 2016.
(b) Intake for Deer Mouse:

$$\text{Estimated Intake (mg/kg-day)} = \frac{C_W * IR_W * EF}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.0031 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.021 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

**TABLE B-8**

**Risk Estimates for Black-throated Sparrow - NOAEL-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Black-throated Sparrow NOAEL TRV (mg/kg-day) | Black-throated Sparrow Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 79 | 26,889 | **340** |
| **Potassium** | 5,400 | NA | 1320 | NA |
| **Magnesium** | 2,000 | 28 | 489 | **17.5** |
| Calcium | 1,700 | NA | 416 | NA |
| | | | **Hazard Index:** | **358** |
| **Detected Trace Elements** | | | | |
| Aluminum | 3.4 | 110 | 0.831 | 0.01 |
| Barium | 0.53 | 20.8 | 0.1296 | 0.0062 |
| Bismuth | 0.62 | 44 | 0.1516 | 0.003444 |
| Boron | 11 | 28.8 | 2.69 | 0.093 |
| Lithium | 0.42 | NA | 0.1027 | NA |
| Manganese | 0.62 | 179 | 0.1516 | 0.00085 |
| Strontium | 32 | NA | 7.82 | NA |
| | | | **Hazard Index:[d]** | 0.11 |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration in BIF samples collected in 2016.
(b) Intake for Black-throated Sparrow:

$$\text{Estimated Intake (mg/kg-day)} = \frac{C_W * IR_W * EF}{BW}$$

**Where:**

$C_W$ = Concentration in water (mg/L) — Chemical-specific
$IR_w$ = Daily water Intake Rate (L/day) — 0.0033
EF = Exposure Frequency (unitless) — 1
BW = Body Weight (kg) — 0.0135

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

## TABLE B-9

### Risk Estimates for Red-Tailed Hawk - NOAEL-based Analysis
### Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Mammal Exposure Point Concentration[b] ($EPC_M$), mg/kg wet wt. | Red-Tailed Hawk NOAEL TRV (mg/kg-day) | Red-Tailed Hawk Intake--Food (mg/kg-day)[c] | Hazard Quotient (HQ) Food Unitless[d] | Red-Tailed Hawk Intake--Water (mg/kg-day)[c] | Hazard Quotient (HQ) Water Unitless[d] | Total Hazard Quotient (HQ) Unitless[d] |
|---|---|---|---|---|---|---|---|---|
| **Major Salt Cations** | | | | | | | | |
| **Sodium** | 110,000 | 16,238 | 210 | 4,759 | **23** | 6,252 | **30** | **52** |
| Potassium | 5,400 | 797 | NA | 541 | NA | 307 | NA | NA |
| **Magnesium** | 2,000 | 295 | 28 | 200 | **7.2** | 114 | **4.1** | **11** |
| Calcium | 1,700 | 251 | NA | 170 | NA | 96.6 | NA | NA |
| | | | | **Hazard Index:** | **30** | | **34** | **64** |
| **Detected Trace Elements** | | | | | | | | |
| Aluminum | 3.4 | 0.5 | 110 | 0.340 | 0.0031 | 0.193 | 0.0018 | 0.0049 |
| Barium | 0.53 | 0.08 | 20.8 | 0.0531 | 0.0026 | 0.0301 | 0.0014 | 0.0040 |
| Bismuth | 0.62 | 0.09 | 44 | 0.0621 | 0.0014 | 0.0352 | 0.00080 | 0.0022 |
| Boron | 11 | 1.6 | 28.8 | 1.10 | 0.038 | 0.625 | 0.022 | 0.060 |
| Lithium | 0.42 | 0.06 | NA | 0.0420 | NA | 0.0239 | NA | NA |
| Manganese | 0.62 | 0.09 | 179 | 0.0621 | 0.00035 | 0.0352 | 0.00020 | 0.00054 |
| Strontium | 32 | 4.7 | NA | 3.20 | NA | 1.82 | NA | NA |
| | | | | **Hazard Index:**[e] | 0.046 | | 0.026 | 0.072 |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration in BIF samples collected in 2016.

(b) Assumes $EPC_M$ is based on concentration of water that small mammals (i.e., deer mouse) ingest in one day.
$EPC_M$ = (Maximum Surface Water Concentration x $IR_W$) / Deer Mouse Body Weight
Deer mouse daily water intake rate ($IR_w$) (L/day) 0.0031
Deer mouse body weight (kg) 0.021

(c) Intake for Red-Tailed Hawk:
Estimated Intake (mg/kg-day) = $\frac{SFF*IR_F*EF*(EPC_M*P_M)}{BW} + \frac{(C_W*IR_W*EF)}{BW}$

**Where:**
SFF = Site Foraging Frequency 1
$IR_F$ = Daily Food Intake Rate (kg/day) wet wt. 0.33
$IR_w$ = Daily water Intake Rate (L/day) 0.064
EF = Exposure Frequency (unitless) 1
BW = Body Weight (kg) 1.13
$EPC_M$ = EPC for Mammals (mg/kg) Chemical-specific
$P_M$ = Proportion of Diet Comprised of Mammals (unitless) 1.00
(d) HQ = Intake/TRV
(e) Hazard Index = Sum of HQs for all COPCs

**TABLE B-10**
**Risk Estimates for Eared Grebe - NOAEL-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[(a)] (mg/L) | Avian NOAEL TRV (mg/kg-day) | Eared Grebe Intake (mg/kg-day)[(b)] | Hazard Quotient (HQ) Unitless[(c)] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 210 | 8,341 | **40** |
| Potassium | 5,400 | NA | 409 | NA |
| **Magnesium** | 2,000 | 28 | 152 | **5.4** |
| Calcium | 1,700 | NA | 129 | NA |
| | | | **Hazard Index:** | **45** |
| **Detected Trace Elements** | | | | |
| Aluminum | 3.4 | 110 | 0.258 | 0.0024 |
| Barium | 0.53 | 20.8 | 0.0402 | 0.0019 |
| Bismuth | 0.62 | 44 | 0.0470 | 0.0011 |
| Boron | 11 | 28.8 | 0.834 | 0.029 |
| Lithium | 0.42 | NA | 0.0318 | NA |
| Manganese | 0.62 | 179 | 0.0470 | 0.00026 |
| Strontium | 32 | NA | 2.43 | NA |
| | | | **Hazard Index:[(d)]** | 0.035 |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2016.
(b) Intake for Eared Grebe:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W*IR_W*EF)}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.035 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.468 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

**TABLE B-11**

**Risk Estimates for Northern Shoveler - NOAEL-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Avian NOAEL TRV (mg/kg-day) | Northern Shoveler Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 210 | 7,640 | **36** |
| Potassium | 5,400 | NA | 375 | NA |
| **Magnesium** | 2,000 | 28 | 139 | **5.0** |
| Calcium | 1,700 | NA | 118 | NA |
| | | | **Hazard Index:** | **41** |
| **Detected Trace Elements** | | | | |
| Aluminum | 3.4 | 110 | 0.236 | 0.0022 |
| Barium | 0.53 | 20.8 | 0.0368 | 0.0018 |
| Bismuth | 0.62 | 44 | 0.0431 | 0.00098 |
| Boron | 11 | 28.8 | 0.764 | 0.027 |
| Lithium | 0.42 | NA | 0.0292 | NA |
| Manganese | 0.62 | 179 | 0.0431 | 0.00024 |
| Strontium | 32 | NA | 2.22 | NA |
| | | | **Hazard Index:[d]** | 0.032 |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2016.
(b) Intake for Northern Shoveler:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W * IR_W * EF)}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.042 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.610 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

## TABLE B-12

### Risk Estimates for Canada Goose - NOAEL-based Analysis
### Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Avian NOAEL TRV (mg/kg-day) | Canada Goose Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 210 | 4,723 | **22** |
| Potassium | 5,400 | NA | 232 | NA |
| **Magnesium** | 2,000 | 28 | 85.9 | **3.1** |
| Calcium | 1,700 | NA | 73.0 | NA |
| | | | **Hazard Index:** | **26** |
| **Detected Trace Elements** | | | | |
| Aluminum | 3.4 | 110 | 0.146 | 0.0013 |
| Barium | 0.53 | 20.8 | 0.0228 | 0.0011 |
| Bismuth | 0.62 | 44 | 0.0266 | 0.00060 |
| Boron | 11 | 28.8 | 0.472 | 0.016 |
| Lithium | 0.42 | NA | 0.0180 | NA |
| Manganese | 0.62 | 179 | 0.0266 | 0.00015 |
| Strontium | 32 | NA | 1.37 | NA |
| | | | **Hazard Index:[d]** | 0.020 |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2016.
(b) Intake for Canada Goose:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W*IR_W*EF)}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.112 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 2.62 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

## TABLE B-13

### Risk Estimates for Deer Mouse -$LD_{50}$-based Analysis
### Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Deer Mouse $LD_{50}$ TRV (mg/kg) | Deer Mouse Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 1580 | 16,238 | **10** |
| **Potassium** | 5,400 | 201 | 797 | **4.0** |
| Magnesium | 2,000 | 714 | 295 | 0.41 |
| Calcium | 1,700 | 700 | 251 | 0.36 |
| | | | **Hazard Index:** | **15** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration in BIF samples collected in 2016.
(b) Intake for Deer Mouse:

$$\text{Estimated Intake (mg/kg-day)} = \frac{C_W * IR_W * EF}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.0031 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.021 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

## TABLE B-14

**Preliminary Risk Estimates for Black-throated Sparrow - $LD_{50}$-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[(a)] (mg/L) | Black-throated Sparrow $LD_{50}$ TRV (mg/kg-day) | Black-throated Sparrow Intake (mg/kg-day)[(b)] | Hazard Quotient (HQ) Unitless[(c)] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 1,256 | 26,889 | **21** |
| **Potassium** | 5,400 | NA | 1320 | NA |
| **Magnesium** | 2,000 | 670 | 489 | 0.7 |
| Calcium | 1,700 | NA | 416 | NA |
| | | | **Hazard Index:** | **22** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration in BIF samples collected in 2016.
(b) Intake for Black-throated Sparrow:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W * IR_W * EF)}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.0033 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.0135 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

**TABLE B-15**

**Risk Estimates for Red-Tailed Hawk - $LD_{50}$-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Mammal Exposure Point Concentration[b] ($EPC_M$), mg/kg wet wt. | Red-Tailed Hawk $LD_{50}$ TRV (mg/kg) | Red-Tailed Hawk Intake--Food (mg/kg-day)[c] | Hazard Quotient (HQ) Food Unitless[d] | Red-Tailed Hawk Intake--Water (mg/kg-day)[c] | Hazard Quotient (HQ) Water Unitless[d] | Total Hazard Quotient (HQ) Unitless[d] |
|---|---|---|---|---|---|---|---|---|
| **Major Salt Cations** | | | | | | | | |
| **Sodium** | 110,000 | 16,238 | 1,700 | 4,759 | **2.8** | 6,252 | **3.7** | **6.5** |
| Potassium | 5,400 | 797 | NA | 541 | NA | 307 | NA | NA |
| **Magnesium** | 2,000 | 295 | 670 | 200 | 0.30 | 114 | 0.17 | 0.47 |
| Calcium | 1,700 | 251 | NA | 170 | NA | 96.6 | NA | NA |
| | | | | **Hazard Index:** | **3.1** | | **3.8** | **6.9** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value
(a) Maximum surface water concentration in BIF samples collected in 2015.
(b) Assumes $EPC_M$ is based on concentration of water that small mammals (i.e., deer mouse) ingest in one day.
$EPC_M$ = (Maximum Surface Water Concentration x $IR_W$) / Deer Mouse Body Weight

| | |
|---|---|
| Deer mouse daily water intake rate ($IR_w$) (L/day) | 0.0031 |
| Deer mouse body weight (kg) | 0.021 |

(c) Intake for Red-Tailed Hawk:

$$\text{Estimated Intake (mg/kg-day)} = \frac{SFF*IR_F*EF*(EPC_M*P_M)}{BW} + \frac{(C_W*IR_W*EF)}{BW}$$

**Where:**

| | |
|---|---|
| SFF = Site Foraging Frequency | 1 |
| $IR_F$ = Daily Food Intake Rate (kg/day) wet wt. | 0.33 |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.064 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 1.13 |
| $EPC_M$ = EPC for Mammals (mg/kg) | Chemical-specific |
| $P_M$ = Proportion of Diet Comprised of Mammals (unitless) | 1.00 |

(d) HQ = Intake/TRV
(e) Hazard Index = Sum of HQs for all COPCs

## TABLE B-16

### Risk Estimates for Eared Grebe -$LD_{50}$-based Analysis
### Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Avian $LD_{50}$ TRV (mg/kg) | Eared Grebe Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 1,700 | 8,341 | **4.9** |
| Potassium | 5,400 | NA | 409 | NA |
| Magnesium | 2,000 | 670 | 152 | 0.23 |
| Calcium | 1,700 | NA | 129 | NA |
| | | | **Hazard Index:** | **5.1** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2016.
(b) Intake for Eared Grebe:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W * IR_W * EF)}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.035 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.468 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

**TABLE B-17**

**Risk Estimates for Northern Shoveler -$LD_{50}$-based Analysis**
**Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds**

| Parameter | Maximum Surface Water Concentration[(a)] (mg/L) | Avian $LD_{50}$ TRV (mg/kg) | Northern Shoveler Intake (mg/kg-day)[(b)] | Hazard Quotient (HQ) Unitless[(c)] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 1,700 | 7,640 | **4.5** |
| Potassium | 5,400 | NA | 375 | NA |
| Magnesium | 2,000 | 670 | 139 | 0.21 |
| Calcium | 1,700 | NA | 118 | NA |
| | | | **Hazard Index:** | **4.7** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2016.
(b) Intake for Northern Shoveler:

$$\text{Estimated Intake (mg/kg-day)} = \frac{C_W * IR_W * EF}{BW}$$

**Where:**

| | |
|---|---|
| $C_W$ = Concentration in water (mg/L) | Chemical-specific |
| $IR_w$ = Daily water Intake Rate (L/day) | 0.042 |
| EF = Exposure Frequency (unitless) | 1 |
| BW = Body Weight (kg) | 0.610 |

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

## TABLE B-18
## Risk Estimates for Canada Goose - $LD_{50}$-based Analysis
## Predictive Ecological Risk Assessment for Paradox Valley Unit Solar Evaporation Ponds

| Parameter | Maximum Surface Water Concentration[a] (mg/L) | Avian $LD_{50}$ TRV (mg/kg) | Canada Goose Intake (mg/kg-day)[b] | Hazard Quotient (HQ) Unitless[c] |
|---|---|---|---|---|
| **Major Salt Cations** | | | | |
| **Sodium** | 110,000 | 1,700 | 4,723 | **2.8** |
| Potassium | 5,400 | NA | 232 | NA |
| **Magnesium** | 2,000 | 670 | 85.9 | 0.13 |
| Calcium | 1,700 | NA | 73.0 | NA |
| | | | **Hazard Index:** | **2.9** |

Notes:
NA - Not Available
NOAEL - No Observable Adverse Effects Level
TRV - Toxicity Reference Value

(a) Maximum surface water concentration collected from BIF samples in 2015.
(b) Intake for Canada Goose:

$$\text{Estimated Intake (mg/kg-day)} = \frac{(C_W * IR_W * EF)}{BW}$$

**Where:**

$C_W$ = Concentration in water (mg/L) — Chemical-specific
$IR_w$ = Daily water Intake Rate (L/day) — 0.112
EF = Exposure Frequency (unitless) — 1
BW = Body Weight (kg) — 2.62

(c) HQ = Intake/TRV
(d) Hazard Index = Sum of HQs for all COPCs

# APPENDIX C

# APPENDIX C

# TOXICITY PROFILES FOR CONSTITUENTS OF POTENTIAL ECOLOGICAL CONCERN

## 1.0 Sodium and Sodium Salts

**Birds**

Salt affects waterfowl in several ways: physical encrustation; osmotic effects; and salt toxicosis.

Physical encrustation

Physical encrustation of sodium salts occur when total dissolved solids (TDS) concentrations are greater than 300,000 parts per million (ppm)[1], conductivity is at least 70,000 micromhos per centimeter (µmhos/cm), and temperatures drop below 40°F. In trona ponds (soda ash industry waste ponds) where sodium sulfate predominates, sodium decahydrate precipitates out and crystallizes on solid objects in the ponds or on the water surface (Arenal et al., 2002; Sladsky, 2004; Gordus et al., 2002). In waterbodies receiving potash effluent (sodium and/or potassium chloride predominately), salt precipitation occurs when concentrations approach saturation and weather conditions are inclement (e.g., high winds and low ambient temperatures) (Dein et al., 1997).

Salt encrustation has been measured as heavy as 31% of body weight, a conservative estimate given that a considerable amount falls off during capture and subsequent handling of the birds (Gordus et al., 2002; Wobeser & Howard, 1987).

Studies have observed salt accumulation on birds such that their ability to fly and avoid predators is compromised. The physical weight of the salt adds to the overall weight of the bird and increases bioenergetic demands and energy expenditures for movement (Alemi, 1999).

Salt encrustation has been found to structurally damage feather integrity (Alemi, 1999) through the disruption of barbule/hooklet morphology. Water then bypasses the insulating function of the feathers, compromising thermoregulation and causing hypothermia and possibly death (Sladsky, 2004).

Jehl et al. (2012) concluded that waterfowl mortality at trona salt ponds is primarily a physical problem due to salt encrustation. Symptoms observed such as unstable body temperatures, coming ashore and dying within a few hours after encrustation, and increased mortality in stormy weather are not consistent with salt toxicosis.

[1] Salinity is not precisely equal to TDS but is considered equivalent by USEPA (1986) and the US Department of the Interior (1998).

Osmotic Effects

In a study conducted by Colorado State University for the PVU (Herin et al., 1979), the effects of exposure of waterfowl (mallards) to PVU brine was evaluated. Severe dehydration was observed in mallard following a 36-hour exposure to brine water[2] (sodium chloride concentration =270,000 ppm) without food or water. The study concluded that the water loss was likely due to an outward flow of body water through the skin of the lower legs and feet in response to an osmotic gradient between the salt water environment and the ducks internal fluids, cloacal mucosa, diarrhea, urine, salt gland secretions, and respiratory water vapor loss. The ducks' behavior consisted of an initial period of high activity and excitability followed by lethargy and unresponsiveness and finally coma and death. Chemically, this process is explained as an internal salt imbalance causes blood vessel dilation in the legs and thus, a considerable energy expenditure to maintain the duck's water balance. Osmotic water flux causes dehydration and a concomitant electrolyte imbalance which triggers an increased cardiac output and blood flow to the leg muscles. The dilated vessels released more body heat thus affording a chance for more water loss. An increase in metabolic rate occurs to fight these losses thus an increased respiratory rate and water vapor loss, more dehydration and electrolyte imbalance. This leads to diarrhea and further dehydration and electrolyte imbalance. An $LC_{50}$[3] of 250,000 ppm was determined but effects of dehydration and hypothermia would be limited if provided with water and food *ad libitum* (Table C-1) (Herin et al., 1979).

Salt Toxicosis

Salt toxicosis studies are limited to a few avian species and a correlation between symptoms and salt concentrations are not always available due to varying amounts of pesticides, differing sodium salts, and the presence of trace elements, such as selenium or lead.

When exposed to hypertonic saline drinking water, waterfowl osmoregulate by excreting excess sodium via the supraorbital salt gland with adult mallards tolerating water with up to 20,000 ppm of sodium chloride. They cannot survive on seawater (Mitcham & Wobeser 1988b), which is approximately 35,000 ppm. Ducklings are much less tolerant of salt and those less than one to three days old are unable to survive when provided with water from saline wetlands in North Dakota (Swanson et al. 1984).

Sodium concentrations of 8,800 and 12,000 ppm and specific conductivities of 67,000 and 35,000 µmhos/cm from two saline wetlands provided as drinking water for mallard ducklings caused 100% mortality (Mitcham & Wobeser 1988a) and sodium concentrations of 17,000 ppm in lake water (North Dakota) with no available freshwater may have contributed to a die off of adult waterfowl (Windingstad et al., 1987).

Hypersaline wetlands with conductivities greater than 35,000 µmhos/cm were shown to be toxic to mallard ducklings hatching on saline wetlands unless a source of freshwater was nearby (Mitcham and Wobeser 1988b) while wetlands with conductivities ranging from 77,000

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[2] Brine water was obtained from the Brine Pumping Station located in the Paradox Valley.
[3] $LC_{50}$ represents a lethal concentrations for 50% of the test animals.

µmhos/cm to 90,000 µmhos/cm were shown to be lethal to waterfowl (Dickerson & Ramirez, 1993). Over 70% of black-bellied whistling ducklings died within 30 minutes of entering a hypersaline lake (sodium concentrations over 135,000 ppm).

Salt toxicosis was not observed in birds in hypersaline ponds in Bamforth National Wildlife Refuge during the study period (summer months 1992) although conductivities were high enough in the wetlands to cause such effects. The authors hypothesize that salt toxicosis was not observed because the vast majority of birds at the refuge were American white pelicans and double-crested cormorants. Both species are piscivorous and thus, do not consume large quantities of salt. Also the lakes are shallow (0.2-0.5 m [meters]) and warm (average temperature = 21°C) in summer months when bird use is heaviest. This authors noted salt crystallization occurred when water temperatures dropped below 3°C and therefore, there was a potential for avian salt toxicosis (Dickerson & Ramirez, 1993).

In the San Joaquin Valley, consistent exposure to saline waters (concentration not specified) by adult ducks and ducklings has been shown to result in reduced hatching success, physiological stress, reduced growth, and increased mortality; however, the availability of freshwater shortly after hatching is an important factor in reducing sub-lethal and lethal effects in young ducks. It should be noted that these saline water are contaminated with selenium at concentrations between 0.002 and 2 milligrams per kilogram (mg/kg) selenium. The authors also reported that ducks moved from waterbodies with high salinity to inlet areas with conductivities and TDS concentrations were reduced (Alemi, 1999).

Growth reduction has been observed at sodium levels of 821 ppm (Mitcham & Wobeser 1988a) and reduced feather growth, retarded molting, enlarged adrenal glands, reduced thymus size and bone strength were noted in mallard ducklings that drank water with 3,000 ppm sodium (Mitcham & Wobeser, 1988b).

Conjunctivitis, cataracts, myocardial and skeletal muscle degeneration, nephrosis, dehydration, bile stasis in the liver, and congestion in various organs have been described as symptoms associated with salt toxicosis in waterfowl at concentrations between 19,000 milligrams per liter (mg/L) and 36,950 mg/L (Wobeser & Howard, 1987; Meteyer et al., 1997; Windingstad et al., 1987). In other studies, gross lesions from dehydration, congestion of conjunctiva, lens opacity, increased mucus in the proventriculus and congestion of various organs, primarily in meninges of the brain were reported at sodium concentrations between 16,000 and 34,000 mg/L (Gorbus, 2002).

Meteyer et al.(1997) exposed mallards to saline water from several saline playa lakes from New Mexico. TDS concentrations ranged between 295,000 ppm and 315,000 ppm and 19% sodium, 49% chloride, 12% potassium, 12% sulfate, and 7% magnesium. After three hours, salt encrustation occurred and birds began to huddle quietly with little activity. One mallard turned in continuous slow, tight circles. All birds were heavily salt encrusted within 24 hours. Blepharitis[4], chemosis[5], and prolapse of the nictitating membrane was observed along with

[4] Inflammation of the eyelids
[5] Welling of the conjunctival tissue around the cornea

frequent blinking. Torticollis[6] was observed when the mallards were near death. One mallard was dead at 11 hours after placement on Laguna Tolston; the other four were dead within 22 hours. Brain necropsy and analysis determined sodium concentrations between 2,000 and 2,600 ppm in the experimental Toston birds and 1,670 to 3,511 ppm in waterfowl picked up in the wild at Laguna Toston. Waterfowl collected from Laguna Uno and Laguna Tres ranged from 1,530 to 2,808 while waterfowl and passerine (i.e., Crissal's thrasher) from Laguan Dos and Quatro ranged up to 32,811 ppm. The study extrapolated a lethal dose of 4,300 mg/kg for sodium chloride ingestion by mallards.

Bollinger et al. (2005) dosed house sparrows with road salt at concentrations of 2,000; 2,500; 3,000; 3,500; 4,000; 4,500; and 5,500 mg/kg without water to determine the lethal dose. Another group was exposed to 4,000; 6,000; or 8,000 mg/kg road salt with half allowed access to water and the remaining without water. Yet another group was orally dosed to sodium chloride at concentrations of 0, 500, 1500, 2500, or 3500 mg/kg for a dose response study. The results of the study indicated a lethal dose for 50% of the test animals (LD50) of 3,181 mg/kg when deprived of water and a no-observed-adverse-effects-level (NOAEL) of 2,000 mg/kg (Table C-1).

Biochemistry

Brain biochemical data indicates that brain sodium concentrations greater than 2,000 ppm are considered toxic (Meteyer, 1997; Sladsky, 2004). Brain sodium concentrations found in dead ruddy ducks along the agricultural evaporation ponds were greater than 1890 ppm compared to control ducks at <1,150 ppm (Gorbus et al., 2002) and in Canada geese in a highly saline lake in North Dakota (1,900-2,100 ppm)(Windingstad, et al., 1987). Brain sodium levels in trona ponds in Wyoming greatly exceeded mean values reported as toxic in other birds (average = 3,845 ppm; maximum 7,018 ppm) (Sladsky, 2004). In flue gas desulfurization ponds located in Wyoming, sodium concentrations in pond water between 52,000 mg/L and 66,000 mg/L resulted in brain sodium levels in waterbirds exceeding 1,800 ppm in less than three hours exposure (Ramirez 1992). Sodium concentrations in the brain ranged from 1,205 to 2,832 ppm (Dein et al., 1997) and between 1,910 and 2,200 ppm at National Wildlife Refuges in Montana with corresponding TDS values between 54,687 mg/L and 548,545 mg/L (Nelson & Reiten, 2007) (Table 1). In brine mining discharge lakes in California, brain sodium levels in water birds have been measured between 1,780 and 5,310 ppm when salt levels are 600,000 ppm salt and temperatures exceed 110oF (Hampton & Yamamoto, 2002).

In a study by Stolley et al. (2008), black-bellied whistling duckling brain sodium levels were measured at 2,680 to 14,100 ppm when exposed to hypersaline waters with sodium concentrations greater than 135,000 ppm and chloride levels nearly 185,000 ppm. Sulfate levels were approximately 5,000 ppm and TDS was 344,000 ppm.

Mean serum sodium levels in grebes are approximately 3,494 ppm (151.9 milli-equivalents per liter [mEq/L]); however, birds found on evaporation ponds have elevated sodium levels upwards of 3,738 ppm (162.5 mEq/L) when sodium concentrations in water were around 19,000 mg/L

[6] Abnormal and fixed twisting of the neck associated with muscular contracture.

(Meteyer et al., 1997; Sladsky, 2004). Sodium sera from northern shovelers at Sherlock Lake in Saskatchewan ranged from 3,388 to 3,751 mg/L (154 to 169 millimoles per liter (mmol/L)) compared to shovelers raised in captivity [3,220-3,450 mg/L (140-150 mmol/L]; sodium concentrations in water ranged between 30,800 and 36,950 mg/L (Wobeser & Howard, 1987). Sodium serum levels in playa lakes from southeastern New Mexico ranged from 3,388-3,751 ppm (147.3-163.1 mEq/L); sodium concentrations in water ranged between 12,000 mg/L and 80,125 mg/L (Dein et al., 1997). Ducklings in Saskatchewan exposed to 3,000 ppm saline water had serum sodium levels of 3,381 mg/L (147 mmol/L) (Mitcham and Wobeser, 1988b).

Some studies have hypothesized that avian salt glands are overwhelmed in highly saline environments because they do not show the typical morphological response. However, Jehl et al. (2012) surmised that salt gland data alone are equivocal because the period between arrival and death on trona ponds is likely too brief to elicit a morphological response.

Eared grebes have shown physiological equilibrium under a wide range of environmental conditions. Eared grebes feed largely on brine shrimp indicating that some alkaline water is ingested along with the prey. Mahoney and Jehl (1985) observed that grebes do not visit freshwater sources and were never seen to drink. Their study took eared grebes and placed them in sea water and water from Mono Lake. Normal feeding was observed in the sea water but the birds on the Mono Lake water fed little and did not dive, even with the approach of humans. The bird occasionally immersed its head to look for food but then it immediately stopped and shook its head vigorously for a long time. Blood analyses for hematocrits, serum osmolality, sodium, potassium, and pH did not differ from captive grebes or wild grebes at Mono Lake. Salt gland weights showed much seasonal variation reflecting the birds' geographic source and duration of stay at Mono Lake. Under high salinity conditions, grebe salt glands were expected to show great hypertrophy but there was only a 40% increase in salt gland size. Salt glands of Canada geese have been observed to become so enlarged when they are on saline lakes, that the shape of the entire head is affected. It appears that the wild birds require a period of taste acclimation before that can take advantage of the food supply at Mono Lake. Further, it was determined that the eared grebe is a filter-feeder and uses its large fleshy tongue to compress the prey against the smooth palate to remove water. The tongue's anatomy likely provides a major behavioral line of defense against osmotic stress and is sufficient to prevent the birds from swallowing much water, even when feeding underwater.

Based on the published data discussed above, the NOAEL for dabbling (*Anatidae*) ducks is 9,000 mg/kg salinity based on the Nystrom & Pehrsson (1988) study and the Moorman (1991) study and a NOAEL of 2,000 mg/kg is for passerines based on the Bollinger (2005) study.

**Mammals**

There is a paucity of data for the adverse effects on wildlife and only minimal data on salt toxicosis in laboratory animals and farm stock (e.g., swine, sheep, cattle).

Albino rats were fed sodium chloride as a percentage of their diet: 0.01%, 0.15%, 2.8%, 5.6%, 7%, 8.4%, and 9.8%. After three months, massive edemas were observed then at month six, those rats that survived had a sudden, precipitous weight loss and become emaciated,

**Table C-1. Avian Salt Toxicity Values**

| Species | Salinity or Dose | Effects/Comments | Reference | Derived Sodium NOAEL (mg/kg-d)[(a)] |
|---|---|---|---|---|
| Mallard | ~11000 ppm | Reduced growth | Swanson et al., 1984 | NA |
| | 8800-12000 ppm | 100% mortality of ducklings | Mitcham & Wobeser, 1988a | NA |
| | 9000-12000 ppm | NOAEL | Nystrom & Pehrsson 1988 | 210 |
| | 10,000-15,000 ppm | Level concern | Swanson et al., 1984 | NA |
| | 15000 ppm | 100% mortality (7-day old ducklings) | Barnes & Nudds, 1991 | NA |
| Mottled Duck | 9000 ppm | NOAEL: Threshold level for adverse effects | Moorman et al., 1991 | 250 |
| | 12000 ppm | Reduced growth, 10% mortality | | NA |
| | 15000 ppm | 90% mortality | | NA |
| | 18000 ppm | 100% mortality | | NA |
| Peking Duck | 20,000 ppm | Level of concern | Nystrom & Pehrsson 1988 | NA |
| Mallard | 4,300 mg/kg | Single lethal dose | Meteyer et al., 1997 | |
| Sandhill Crane | 1% (over 10 days) | Lethal dose | Brownlee et al., 2000 | NA |
| Chickens ($\leq$9 week old) | 4000 mg'kg | Lethal dose | Austic & Scott, 1991; Quigley & Waite, 1932 as cited in Meteyer et al., 1997 | NA |
| House sparrow | 2000 mg/kg | NOAEL | Bollinger et al., 2005 | 154 |
| | 3181 mg/kg | $LD_{50}$ | | NA |

Notes:

(a) Calculated NOAELs are for sodium only, based on Sample et al., 1996.

mg/kg = milligrams per kilogram
mg/kg-day = milligrams per kilogram (body weight) per day
ppm = parts per million

cachectic and died.  Animals exposed to the 7%, 8.4%, and 9.8% sodium chloride diets has greatly decreased serum proteins and all had severe anemia, hypertension, widespread lesions in the kidney and vascular lesions in the heart (Meneely et al., 1953).

Oral and inhalation routes for rats yield an acute $LD_{50}$ of 3,000 mg/kg and 1-hour $LC_{50}$ of 42,000 mg/L, respectively for salt (Bertram, 1997 as cited Bollinger et al., 2005) resulting in a NOAEL of approximately 20 mg/kg for rodents based on a modifying factor of 100 (acute to chronic, $LD_{50}$ to NOAEL) and accounting for the sodium only contribution.  The $LD_{50}$ for salt in mice is 4,000 mg/kg (Brownlee et al., 2000).

Acute sodium chloride doses for swine, equine, and bovines were determined at 2.2 g/kg body weight and 6 g/kg for ovine (Thompson, 2012).

In mammals, serum sodium in excess of 3,680 mg/L (160 mEq/L) is consistent with sodium toxicity (Sladsky, 2004).  Salt toxicosis was reported in eastern cottontail rabbits (*Sylvilagus floridanus*) and included loss of fear, depression, tremors, torticollis, retropulsion[7], partial paralysis and circling in one direction.

## 2.0 Barium

**Birds**

One-day old chicks were exposed to barium hydroxide in their diet for four weeks; concentrations evaluated were 250, 500, 1,000, 2,000, 4,000, 8,000, 16,000 and 32,000 mg/kg. No mortality was observed in birds exposed at dietary concentrations up to 2,000 mg/kg. Mortality was observed in all groups exposed to concentrations of 4,000 mg/kg as barium and higher.  Half the birds in the 8,000 mg/kg exposure group died, and all of the birds in the two highest exposure groups died.  Growth was significantly depressed in chicks fed barium at dietary concentrations of 4,000 and 8,000 mg/kg (Johnson et al. 1960).  An ingestion rate of 0.0126 kilograms per day (kg/day) (calculated using allometric equation from USEPA (1988) and body weight of 0.121 kg (USEPA 1988) were used to convert the mg/kg diet concentrations to units of milligrams per kilogram body weight per day (mg/kg-day)[8].  A lowest observable adverse effect level (LOAEL) of 416.5 mg/kg-day (4,000 mg/kg) and a NOAEL of 208.3 mg/kg-day (2,000 mg/kg) were calculated based on results of this experiment.  Based on the ecological significance of the endpoint (survival and growth) and because the LOAEL is the lowest cited adverse effect level for birds, the TRV values from this study will be used to evaluate the risk posed by barium to avian receptors.

As a note, the USEPA has not calculated an avian Eco SSL due to the paucity of data (USEPA, 2005).

[7] Spasmodic pushing out with the legs

[8] A mean body weight for 14-day old chicks and an estimated food consumption rate for two-week old chicks were used.

**Mammals**

Toxicity of barium was evaluated by exposing weanling Long-Evans rats to 5 mg/kg barium acetate in drinking water for life (Schroeder and Mitchener 1975). No adverse effects were observed at this exposure concentration; effects measured included median life-span, longevity, incidence of tumors, serum cholesterol, glucose and uric acid. A slight enhancement of growth was observed. A water ingestion rate of 0.053 L/day and body weight of 0.43 kg (USEPA, 1988) were used to convert the exposure concentration to units of mg/kg-day. A NOAEL of 0.062 mg/kg-day was calculated based on the results of this experiment.

Tardiff et al. (1980) exposed 4-week old Charles River rats to barium chloride in drinking water at concentrations of 0, 10, 50 or 250 mg/L (0, 1.9, 8.9, and 41.9 mg/kg-day, as reported by authors) for 13 weeks. The barium concentration in food was 6.6 micrograms per kilogram (µg/kg), barium was not detectable in control water, and measured barium concentrations in water solutions deviated less than 2% of calculated concentrations. No effects on food consumption, body weight, hematologic parameters, serum ions, serum enzymes, gross pathology or histopathology were observed. The rats exposed to 250 mg/L concentration consumed less water and had a significant decrease in relative adrenal weight when compared to control animals. Based on the lack of ecologically significant effects, the highest exposure dose tested in this experiment was considered a NOAEL (41.9 mg/kg-day).

Perry et al. (1989) evaluated toxicity of barium in drinking water to female Long-Evans rats exposed to concentrations of 0, 1, 10 or 100 mg/L for 16 months. Rats exposed to the 100 mg/L concentration exhibited significant increases in systolic pressure, depressed rates of cardiac contraction, depressed electrical excitability, and lower ATP content in the heart. The ecological significance of the observed effects is not known; therefore, this dose was considered a NOAEL. A water ingestion rate of 0.022 L/day and body weight of 0.435 kg (Perry et al. 1983) were used to convert the exposure concentrations to units of mg/kg-day. An estimated LOAEL of 51 mg/kg-day and a NOAEL of 5.1 mg/kg-day were calculated based on the results from this experiment.

Borzelleca *et al.* (1988) evaluated toxicity of barium chloride to Sprague-Dawley rats following 1-day doses of 30, 100, and 300 mg/kg and 10-day doses of 100, 145, 209, and 300 mg/kg, administered by oral gavage. The $LD_{50}$ limits for male and female rats were determined to be 419 and 408 mg/kg, respectively. Body weight was reduced at an exposure concentration of 300 mg/kg in both the 1 day and the 10 day studies. After a one day exposure to 30 mg/kg, females showed lower lung/brain weight and ovary/brain weight ratios and higher kidney/body weight ratios. In the 10 day study, females showed decreased liver/brain weight ratios following exposure to 145 mg/kg-day, and decreased kidney/brain weight ratios after exposure to 100, 145, and 209 (but not 300) mg/kg-day; males showed a decrease in leukocytes at 209 mg/kg-day. Based on effects on growth (body weight), a LOAEL of 300 mg/kg-day and a NOAEL of 209 mg/kg-day were identified from this experiment.

## 3.0 Bismuth

**Birds**

Groups of four, individually caged Single Comb White Leghorn hens, 22 weeks of age, were fed a practical corn-soy laying mash supplemented with four increasing levels of either zinc acetate, cadmium acetate, stannous oxide, lead oxide, bismuth trioxide or arsenic pentoxide for 8 weeks. Egg production was recorded daily, individual feed intake weekly, body weight bi-weekly, and each bird was artificially inseminated twice weekly. The supplemental dietary levels fed were Zn and Sn: 1; 100; 10,000; and 10,000 ppm; and Cd, Pb, Bi and As: 1; 10; 100; and 1,000 ppm. No significant differences in either feed intake, egg production or body weight change were noted in birds receiving supplemental Sn or Bi. Based on a no observed effect concentration (NOEC) of 1,000 ppm, the NOAEL is approximately 44 mg/kg-d (Hermayer et al., 1977).

**Mammals**

Bismuth nitrate was orally administered to rabbits (body weight between 2.3-3 kg) at doses of 70-74 mg/kg five days/week for 34 weeks without noticeable effects (Lechat et al., 1968[9] as cited in NAS, 1980).

No adverse effects were observed in mice when fed 4-32 mg/kg-day of tripotassium dicitrato bismuthate by gavage for 40 days; the highest dose decreased the healing time of experimentally induced ulcers (Wilson 1975a, as cited in NAS, 1980).

A 28-day repeated dose toxicity study was completed using rats (Crj: CD(SD) IGS) dosed with 40 mg/kg, 200 mg/kg and 1,000 mg/kg to determine effects on body weight and general pathology. No abnormal clinical signs and no significant body weight or food consumption differences were observed between the control group and any treatment group during dosing and recovery periods. A NOAEL of 1,000 mg/kg was determined in both sexes (Sano et al., 2005).

In rodents, bismuth is not toxic if administered orally as the $LD_{50}$ is >2,000 mg/kg (Dolara 2014) and the NOAEL is 1,000 mg/kg (Sano et al., 2005).

[9] English abstract available; article in French

## 4.0 BORON

### Birds

Adult mallard ducks were fed diets supplemented with 0, 30, 300, or 1,000 mg/kg boron. Hatching success of fertile eggs was significantly decreased for birds fed B at a concentration of 1,000 mg/kg. Hatching weight, duckling survival, and duckling weight gain were also reduced at this exposure concentration. Boron did not affect adult survival or egg fertility (Smith and Anders 1989). An ingestion rate of 0.139 kg/day and body weight of 1.25 kg were used to convert the exposure concentrations to units of mg/kg-day (Piccirillo and Quesenberry 1980). A LOAEL of 111.2 mg/kg-day and a NOAEL of 33.36 mg/kg-day were calculated based on the results of this experiment.

Boron is rapidly accumulated in mallard tissues but also rapidly eliminated. Adult male mallards fed a diet of 1600 mg/kg boron accumulated equilibrium levels of boron in liver tissue and blood within 2 to 15 days. Once removed from the diet, the boron was completely cleared from the liver and blood within one day (Pendleton et al, 1995 as cited in USDI, 1998).

### Mammals

Weanling Sprague-Dawley rats were fed diets containing borax or boric acid at concentrations of 0, 117, 350 or 1,170 mg/kg as boron equivalents for two years. Reduced food consumption, suppressed growth, and atrophic testes were observed in rats fed diets containing boron at a concentration of 1,170 mg/kg. In a second study, rats were fed diets containing borax or boric acid at the above exposure concentrations for 14 weeks prior to their first breeding phase through production of three generations. No adverse effect on litter size, progeny weight, fertility indices or lactation indices were observed in rats fed 117 or 350 mg/kg. Rats exposed to boron at the highest exposure concentration were sterile (Weir and Fisher 1972). A body weight of 0.48 kg and ingestion rate of 0.034 kg/day were used to convert the exposure concentrations to units of mg/kg-day (USEPA 1988). A LOAEL of 82.9 mg/kg-day and a NOAEL of 24.8 mg/kg-day were calculated based on the ecological significance of the endpoint (growth and reproduction) and because the LOAEL is the lowest cited adverse effect level for mammals.

A two-year study with rats evaluated the effects of boron with doses of 0, 5.9, 18 and 59 mg/kg-day in the diet. No significant effects were seen in the 5.9 or 18 mg/kg-day doses (Weir & Fisher, 1972 as cited in WHO, 2003).

In some instances, animals avoid boron-contaminated drinking water; rats reject drinking water with boron concentrations as little as one mg/L (Dixon et al., 1976 as cited in USDI, 1998).

## 5.0 CALCIUM

**Birds**

Toxicity data for calcium were not found for avian species.

**Mammals**

An $LD_{50}$ of 1,940 mg/kg calcium chloride (oral exposure in mice) is reported in the Hazardous Substances Data Bank (HSDB) (Toxnet, 2016). This is converted to a calcium exposure of 700 mg/kg.

## 6.0 LITHIUM

**Birds**

Toxicity data for lithium were not found for avian species.

**Mammals**

Female rats were fed 0.028 kg/d dose with 500 and 100 mg/kg-d lithium carbonate during day 6-15 of gestation resulting in a NOAEL of 9.4 mg/kg and LOAEL of 18.8 mg/kg-bw. Lithium carbonate exposure of 100 mg/kg-d reduced the number of offspring and offspring weights. No adverse effects were observed at the 50 mg/kg level (Marathe & Thomas 1986).

Lithium has a modest acute toxicity in rodents ($LD_{50}$ values ranging from 526 to 840 mg/kg). However, lithium carbonate, administered at a dosage of 1 g/kg to protein-deficient rats for a month, induces lipid peroxidation (Tandon et al., 1998).

A prenatal developmental toxicity study was performed in rats (strain: Crl CD (SD)) according to Organization for Economic Cooperation and Development (OECD) Guideline 414 and EU method B.31. In this rat embryotoxicity study, lithium carbonate was administered to female rats at concentrations of 10, 30 or 90 mg/kg bw/day orally by gavage from the 6th to 19th day of pregnancy. Under these test conditions, the no-observed-effect level (NOEL) was 30 mg lithium carbonate/kg bw/day for the dams (maternal NOEL). At 90 mg lithium carbonate/kg bw/day, pilo-erection was noted in a few dams. Furthermore, slight but significant reductions were noted for the net weight change and the food intake. The NOEL for the fetuses was $\geq$90 mg lithium carbonate/kg bw/day. There was no test item-related increase in the incidence of fetal malformations, external/ internal, skeletal or soft tissue variations or skeletal retardations. The toxicokinetic analysis revealed a clear dose-related systemic exposure to lithium. In conclusion, no embryotoxic properties of the test item were noted during external/ internal, skeletal and soft tissue examinations. No test item-related increase was noted in the incidence of malformations, variations or retardations, not even at the materno-toxic dose level of 90 mg lithium carbonate/kg bw/day. The NOELs convert to NOAELs as follows: maternal toxicity = 5.64 mg lithium/kg bw/day and embryotoxicity = 16.91 mg lithium/kg bw/day (ECHA, 2016b).

A two generation reproduction toxicity study in rats with lithium carbonate was performed according to OECD Guideline No. 416 (2001). Lithium carbonate was dissolved in Milli-Q water and administered orally to Wistar rats at dose levels of 5, 15 and 45 mg/kg-day and the control group animals were administered Milli-Q water only. Each group consisted of 25 male and 25 female rats and were observed for clinical signs, behavior, physical abnormalities and changes in body weight, food and water consumption. The estrous cycle length and pattern was evaluated by vaginal smears examination for all females during two weeks prior to mating. After a minimum of 10 weeks of treatment, females were cohabitated with males in a 1:1 (one male to one female) ratio. The number, weight, survivability and mortality of pups were observed during the lactation period and physical signs of postnatal development were observed daily until the criterion was met. Vaginal opening and preputial separation were also observed in pups selected for the F1-generation. At the end of the experiment, animals were sacrificed and subjected to detailed necropsy and s specified organs were weighed. Andrological assessment like sperm motility was evaluated for all groups, whereas the sperm morphology, enumeration of homogenisation resistant testicular spermatids and caudaepididymal sperm counts were carried out only in control and high dose groups. Initial histopathological examination of parents was included gross lesions from control and high dose group animals. Based on the microscopic changes observed in the high dose, liver, kidneys and adrenals from males and liver, kidneys and thyroid from females of P generation and liver, kidneys and thyroid from males, liver and kidneys from females of F1 generation were considered as target organs and were examined in lower dose groups. The reproductive organs of non-pregnant females were also examined in the low and mid dose groups that included a quantitative evaluation of primordial and primary follicles in F1 females. In addition, ovarian follicle count was carried out for the control and high dose groups and all the not littered females of F1 generation suspected of reduced fertility. Histopathological examination of F1 and F2 weanlings included reproductive system and kidneys as well as all gross lesions or clinical signs.

At 5 mg/kg-day had no effects on general health, body weights, food and water intake, oestrus cyclicity, preciotal time, gestation length, pups survivability, mating, fertility, fecundity or sperm parameters in both generations nor treatment-related changes with regard to any absolute or relative organ weights including reproductive organs and other gross or microscopic findings of parents, offspring or weanlings in both the generations.

At 15 mg/kg-day, water intake increased significantly in males of both generations. No effects on general health, body weights, food intake, estrous cyclicity, pre-coital time, gestation length, pups survivability, mating, fertility, and fecundity or sperm parameters were observed in both the generations. No treatment-related changes in reproductive and other organ weights and gross findings of parents or weanlings were observed in both the generations.

At 45 mg/kg-day, treatment-related findings included increased body weights and net body weight gains in males of P generation, increased water intake in both P and F1 generations in males, and higher net body weight gains were observed in both P and F1 generations premating females. Treatment-related changes in reproductive organ weights and gross findings of parents or weanlings were not observed in either generation, nor any relevant treatment-related changes in oestrous cyclicity, pre-coital time, gestation length, pups survivability, mating, fertility, and fecundity or sperm parameters when dose response and historical control ranges were taken into account. Postmortem examination in P generation demonstrated a higher body weight in males, a significant increase in the absolute and relative liver weight in males and in the relative liver weight in females. In F1 generation, the terminal body weight was not affected. A significant increase in the absolute and relative liver weight was observed in males only.

Evaluation of pups showed that in both generations, the mean weight of male, female and total pups per litter at all the doses tested were unaffected by treatment and that there were no external abnormalities in live or dead pups in any of the groups. No treatment-related changes were observed in the survival data of pups up to lactation day 21 at all the doses tested. No relevant effects were seen for postnatal developmental observations in F1 and F2 pups. In view of the results observed, the NOAEL for systemic toxicity in parental rats is considered to be 15 mg/kg-day, the NOAEL for reproductive toxicity and fetal toxicity is considered to be 45 mg/kg-day as no clear substances related and biologically relevant effects on reproductive parameters were observed in the P, F1 and F2 generations. The calculated NOAEL values for lithium bromide were 35 mg/kg-day for parental systemic toxicity and 106 mg/kg-day for the reproductive and fetal toxicity in the F1 and F2 generation (ECHA, 2016a).

## 7.0 MAGNESIUM

**Birds**

A total of 150 white leghorn hens (65 weeks old) were divided such that 30 hens each were fed one of five diets for four weeks. The diets consisted of 0.15%, 0.36%, 0.53%, 0.76%, and 0.91% magnesium. Calcium levels were 3.5%. Eggs laid the last three days of weeks 1 and 4 were used to determine shell percentage. The results indicated a significant linear decrease in egg production with increasing dietary magnesium. A NOEC of 1,500 mg/kg and a LOEC of 3,600 mg/kg were determined. The resulting toxicity reference values were determined using the food ingestion rate (0.185 kg bw/day) and body weight of (1.8 kg) provided in the study and modifying factors (MF) of 10 to account for acute to chronic testing. Thus, the NOAEL is 28 mg/kg-d and the LOAEL is 67 mg/kg-day (Hess & Britton, 1997).

**Mammals**

An $LD_{50}$ of 2,800 mg/kg magnesium chloride (oral exposure in rats) is reported in HSDB (Toxnet, 2016). This is converted to a magnesium exposure of 714 mg/kg.

## 8.0 MANGANESE

**Birds**

Male Japanese quail were exposed to basal diets (56 mg/kg manganese) supplemented with 5,000 mg/kg manganese oxide for 75 days (Laskey and Edens 1985). No reduction in growth was observed, and aggressive behavior was reduced relative to control birds. Reduced aggressive behavior was not considered an adverse effect. The reported exposure concentration of 977 mg/kg-day was used as the NOAEL.

**Mammals**

Pregnant female Long-Evans rats were exposed to normal iron or low iron diets containing manganese oxide at concentrations of 50 (basal diet), 400, 1,100 and 3,550 mg/kg from day one of gestation through 224 days of age of the offspring. The offspring began feeding on the manganese-treated diets at 14 to 15 days of age. Mortality of all animals on the low-iron diet with 3,550 mg/kg manganese exceeded 90% by day 50; no mortality was observed in any other treatment group. At 90 to 100 days of age, non-littermate males and females from each dose group were caged for two weeks. Pregnancy percentage was significantly reduced in $F_1$ female rats receiving a normal-iron diet which contained manganese at a concentration of 3,550 mg/kg. Reproductive development (decreased testes weight, sperm count and testosterone concentration) was affected in males receiving the normal-iron diet and manganese at a concentration of 3,550 mg/kg. An ingestion rate of 0.031 kg/day and body weight of 0.41 kg (USEPA 1988) were used to convert the exposure concentration to units of mg/kg-day. A LOAEL of 268 mg/kg-day, and a NOAEL of 83 mg/kg-day were calculated (Laskey et al. 1982).

## 9.0 Potassium

**Birds**

Dein et al., (1997) reported evidence that high oral doses of potassium can be toxic to domestic duck species and that potassium may have a synergistic effect with sodium resulting in more rapid deaths of ducks on one playa lake (Laguna Tolston; potassium concentration = 35,900 ppm) vs another (Williams Sink; potassium concentration= 16,850 ppm). No specific benchmark for potassium exposure in birds was found

**Mammals**

An $LD_{50}$ of 383 mg/kg potassium chloride (oral exposure in mice) is reported in HSDB (Toxnet, 2016). This is converted to a potassium exposure of 201 mg/kg.

## 10.0 STRONTIUM

**Birds**

No avian toxicity studies were found for strontium.

**Mammals**

A three year study on rats dosed with 70, 147, and 263 mg/kg-day resulted in chronic NOAEL of 263 mg/kg-day; no adverse effects were observed for any strontium dosage level (Skoryna 1981).

Groups of eight rats each were given sodium fluoride (NaF) at a dose of 1.0 mg/kg-day, 0.2% strontium (Sr), or a combination of NaF (1.0 mg/kg-day) and of 0.20% Sr in drinking water for 8 weeks.  Body weights and water consumption were measured twice weekly to adjust the treatment to weight gain.  The length and diameter of tibiae and femurs were measured and concentrations of calcium (Ca), magnesium (Mg), and Sr in serum and bone ashes (tibia and femur) were also measured.  Data showed that low Sr doses of 168 mg/kg-day for eight weeks increased the number of bone forming sites and vertebral bone volume in rats, but did not have detectable adverse effects on the mineral profile, bone mineral chemistry or bone matrix mineralization. Thus, the low dose of 168 mg/kg-day could be interpreted as NOAEL in this study considering the other effects as beneficial ones (Grynpas et al., 1996 as cited in ECHA, 2016c).

## REFERENCES


Alemi, Manucher, 1999. Final Report. Evaporation Ponds. Technical Committee on Evaporation Ponds. San Joaquin Valley Drainage Implementation Program and The University of California Salinity/Drainage Program.

Arenal, C. and Ohlendorf, H., 2002. Technical Memorandum: Salinity Effects on Birds. CH2MHill. December 11, 2002.

Barnes, G.G., and T.D. Nudds, 1991. Salt Tolerance in American Black Ducks, Mallards, and Their F1-Hybrids. *The Auk* 108:89-98.

Bertram, B. M., 1997. Sodium chloride. *In* Kirk-Othmer encyclopedia of chemical technology, Vol. 22, 4th Edition. J. I. Kroschwitz and M. Howe-Grant (eds.). John Wiley and Sons, New York, New York, pp. 354–377.

Bollinger, T., P Mineau, ML Wickstrom, 2005. Toxicity of Sodium Chloride to House Sparrows (*Passer domesticus*). *Journal of Wildlife Diseases* 41(2): 363-370.

Borzelleca, J. F., L. W. Condie, Jr., and J. L. Egle, Jr., 1988. Short-term toxicity (one- and ten-day gavage) of barium chloride in male and female rats. *J. Am. Coll. Toxicol.* 7(5): 675-685.

Brownlee, L., P. Mineau, and A. Baril, 2000. Road Salts and Wildlife – an Assessment of the Risk. Environment Canada, Commercial Chemicals Evaluation Branch, Environmental Resource Group for Road Salts.

Dein, FJ; LA Baeten, CU Meteyer, MK Moore, MD Samuel, 1997. Investigation into Avian Mortality in the Playa Lakes Region of Southeastern New Mexico. US Geological Survey, Biological Resources Division, National Wildlife Health Center, National Wetlands Research Center.

Dickerson, K and P Ramirez, 1993. An Investigation of Trace Element Contamination at Bamforth National Wildlife Refuge. US Fish & Wildlife Service, Region 6. Contaminants Program. Report No. R6/707C/93.

Dolara, P. , 2014. Occurrence, exposure, effects, recommended intake and possible dietary use of selected trace compounds (aluminum, bismuth, cobalt, gold, lithium, nickel, silver); International Journal of Food Sciences and Nutrition, 65:8, 911-924.

ECHA (European Chemicals Agency), 2016a. Registration Dossier for Lithium. http://echa.europa.eu/registration-dossier/-/registered-dossier/14178/7/9/3

ECHA, 2016b. Registration Dossier for Lithium Bromide. http://echa.europa.eu/registration-dossier/-/registered-dossier/13642/7/9/2

ECHA, 2016c. Registration Dossier for Stronium Carbonate. http://echa.europa.eu/registration-dossier/-/registered-dossier/14362/7/9/3

Gordus, AG, HL Shivaprasad, and PK Swift, 2002. Salt Toxicosis in Ruddy Ducks that Winter on an Agricultural Evaporation Basin in California. *Journal of Wildlife Diseases* 38(1): 124-131.

Hampton, S. and J. Yamamoto, 2002. Assessment of Natural Resource Injuries to Birds at Searles Lake: 1998-2001. San Bernadino County, CA. California Department of Fish and Game.

Herin, RA, EA Fountain, DH Will, AC Skelly, 1979. Physiological and Behavioral Changes in Wild Waterfowl Exposed to Concentration Salt Water. Colorado State University, Department of Physiological and Biophysics.

Hermayer, KL, PE Stake, and RL Shippe, 1977. Evaluation of dietary zinc, cadmium, tin, lead bismuth and arsenic toxicity in hens. Poultry Science 56(5).

Hess, JB and WM Britton, 1997. Effects of Dietary Magnesium Excess in White Leghorn Hens. Poultry Science 76: 703-710

Jehl, JR, AE Henry, J St. Leger, 2012. Waterbird mortality in hypersaline environmental: the Wyoming trona ponds. *Hydrobiologia* 697: 23-29.

Johnson, D. Jr., A.L. Mehring, Jr. and H.W. Titus, 1960. Tolerance of chickens for barium. *Proc. Soc. Exp. Biol. Med.* 104: 436-438.

Laskey, J.W., G.L. Rehnberg, J.F. Hein and S.D. Carter, 1982. Effects of chronic manganese ($Mn_3O_4$) exposure on selected reproductive parameters in rats. *J. Toxicol. Environ. Health*. 9:677-687.

Laskey, J.W. and F.W. Edens, 1985. Effects of chronic high-level manganese exposure on male behavior in the Japanese Quail (*Coturnix coturnix japonica*). *Poult. Sci.* 64: 579-584.

Mahoney, SA and JR Jehl, Jr., 1985. Avoidance of Salt-loading by a Diving Bird at a Hypersaline and Alkaline Lake: Eared Grebe. *The Condor* 87: 389-397.

Marathe, M. R.,and G. P. Thomas, 1986. Embryotoxicity and teratogenicity of lithium carbonate in Wistar rat. *Toxicol. Lett*. 34: 115-120.

Meneely, GR, RG Tucker, WJ Darby, and SH Auerbach, 1953. Chronic Sodium Chloride Toxicity in the Albino Rat. *Journal of Experimental Medicine* 98(1): 71-80.

Meteyer CU, RR Dubielzig, FJ Dein, LA Baeten, MIS Moore, JR Jehl, K Wesenberg, 1997. Sodium toxicity and pathology associated with exposure of waterfowl to hypersaline playa lakes of southeast New Mexico. *J. Vet Diagn Invest* 9: 269-280.

Mitcham, S.A., and G. Wobeser. 1988a. Toxic effects of natural saline waters on mallard ducklings. *Journal of Wildlife Diseas*es 24:45-50.

Mitcham, S.A., and G. Wobeser. 1988b. Effects of sodium and magnesium sulfate in drinking water on mallard ducklings. *Journal of Wildlife Diseases* 24:30-44.

Moorman, A.M., T.E. Moorman, G.A. Baldassarre, and D.M. Richard. 1991. Effects of saline water on growth and survival of mottled duck ducklings in Louisiana. *Journal of Wildlife Management* 55:471-476.

NAS (National Academy of Sciences), 1980. Mineral Tolerance of Domestic Animals. Committee on Animal Nutrition. Subcommittee on Mineral Toxicity in Animals. https://books.google.com/books?hl=en&lr=&id=gi4rAAAAYAAJ&oi=fnd&pg=PA1&dq=%22bismuth+toxicity%22+%22rodents%22&ots=t_-92O417A&sig=eYHM2650__6y-KiAL_aS0BIVPEw#v=onepage&q=%22bismuth%20toxicity%22%20%22rodents%22&f=false

Nelson, KJ and JC Reiten, 2007. Saline Seep Impacts on Hailstone and Halfbreed National Wildlife Refuges in South-Central Montana. US Fish & Wildlife Service, Region 6, Environmental Contaminants Program.

Nystrom, K.K.G., and O. Pehrsson. 1988. Salinity as a constraint affecting food and habitat choice of mussel-feeding diving ducks. *Ibis* 130:94-110.

Perry, H.M. Jr., S.J. Koop, Perry, E.F. and M.W. Erlanger, 1989. Hypertension and associated cardiovascular abnormalities induced by chronic barium feeding. *J. Toxicol. Environ. Health*. 28: 373-388.

Perry, H.M., E.F. Perry, M.N. Erlanger and S.J. Koop, 1983. Cardiovascular effects of chronic barium ingestion. In: *Proc. 17th Ann. Conf. Trace Substances in Environ. Health*, Vol. 17. U. of Missouri Press, Columbia, MO.

Piccirillo, V.J. and R.P. Quesenberry, 1980. Reproductive capacities of control mallard ducks (*Anas platyrhynchos*) during a one-generation reproduction study. J*. Environ. Path. Toxicol.* 4:133-139.

Ramirez, P., 1992. Trace Element Concentrations in Flue Gas Desulfurization Wastewater from the Jim Bridger Power Plant, Sweetwater County Wyoming. US Fish & Wildlife Service, Fish & Wildlife Enhancement, Cheyenne, WY.

Sample, BE, DM Opresko, GW Suter, 1996. *Toxicological Benchmarks for Wildlife*: 1996 Revision. ES/ER/TM-86/R3.

Sano, Y., H Satoh, M, Chiba, M. Okamoto, K. Serzawa, H. Nakashima, K. Omae, 2005. Ora Toxicity of Bismuth in Rat: Single and 28-day repeated Administration Studies. Journal of Occupational Health 47: 293-298.

Schroeder, H.A. and M. Mitchener, 1975. Life-term studies in rats: Effects of aluminum, barium, beryllium and tungsten. *Journal of Nutrition*. 105: 421-427.

Sladsky, KK, 2004. Investigation of Migratory Bird Mortality Associated with Exposure to Soda Ash Mine Tailings Water in Southwestern Wyoming. US Geological Survey, Biological Resources Division.

Skoryna, S. C., 1981. Effects of oral supplementation with stable strontium. *Can. Med. Assoc. J*. 125: 703-712

Smith, G.J. and V.P. Anders, 1989. Toxic effects of boron on mallard reproduction. *Environmental Toxicololgy & Chemistry* 8(10): 943-950.

Stolley, DS, ST Edmonds, and CU Meteyer, 2008. Mortality of Ducklings of the Black-bellied Whistling Duck (*Dendrocygna autumnalis*) During their Premier Swim in a Hypersaline Lake in South Texas. The Southwestern Naturalist 53(2): 230-235.

Swanson, G.A., V.A. Adomaitis, F.B. Lee, J.R. Serie, and J.A. Shoesmith. 1984. Limnological conditions influencing duckling use of saline lakes in south-central North Dakota. *Journal of Wildlife Management* 48:340-349.

Tandon A, Dhawan DK, Nagpaul JP., 1998. Effect of lithium on hepatic lipid peroxidation and antioxidative enzymes under different dietary protein regimens. J Appl Toxicol 18:187–190.

Tardiff, T.G., M. Robinson and N.S. Ulmer, 1980. Subchronic oral toxicity of $BaCl_2$ in rats. *J. Env. Path. Tox*. 4:267-275.

Thompson, LJ., 2012. *Veterinary Toxicology*. “Sodium chloride (salt). Academic Press. Pp.558-561.

USDI (United States Department of the Interior), 1998. Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment. National Irrigation Water Quality Program Information Report. No. 3. 198 p.

USEPA (United States Environmental Protection Agency), 2005. Ecological Soil Screening Level for Barium. https://rais.ornl.gov/documents/eco-ssl_barium.pdf

USEPA, 1993. Wildlife Exposure Factors Handbook, Section 3 Allometric Equations. EPA ORD EPA/600/R-93/187, December 1993.

USEPA, 1988. Recommendations for and documentation of biological values for use in risk assessment. EPA/600/6-87-008.

USEPA. 1986. Quality Criteria for Water 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA/440/5-86/001.

Weir, R. J., Jr., and R. S. Fisher, 1972. Toxicological studies on borax and boric acid. *Toxicol. Appl. Pharmacol.* 23: 351-364.

Windingstad, R.M., F.X. Kartch, and R.K. Stroud. 1987. Salt toxicosis in waterfowl in North Dakota. *Journal of Wildlife Diseases* 23:443-446.

Wobeser, G. and J. Howard, 1987. Mortality of Waterfowl and a Hypersaline Wetland as a Result of Salt Encrustation. *Journal of Wildlife Diseases* 23(1): 127-134.

World Health Organization, 2003. Boron in Drinking Water.
http://www.who.int/water_sanitation/health/dwq/wsh0304_54/en/index6.html

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| μmhos/cm | micro mhos per centimeter |
| g/kg | grams per kilogram |
| kg/d | kilograms per day |
| LOAEL | lowest-observed-adverse-effect level |
| $LC_{50}$ | lethal concentration for 50% of the test animals |
| $LD_{50}$ | lethal dose for 50% of the test animals |
| m | meter |
| mEq/L | milli-equivalents per liter |
| mg/kg | milligram per kilogram |
| mg/kg-day | milligram per kilogram (body weight) per day |
| mg/L | milligram per liter |
| mmol/L | millimoles per liter |
| NOEC | no-observed-effects concentration |
| NOEL | no-observed-effects level |
| NOAEL | no-observed-adverse-effects level |
| OECD | Organization for Economic Cooperation and Development |
| ppm | parts per million |
| TDS | Total dissolved solids |

# APPENDIX D

# APPENDIX D

# ECOLOGICAL DESCRIPTIONS OF PROPOSED SOLAR EVAPORATION POND SITES

Between May 11 and May 13, 2016, each of the three proposed evaporation pond sites (Paradox NW, BLM, and Landfill) and two of the alternate sites (Central and Hamilton Canyon) were visited by Amec Foster Wheeler biologists Reed Kraemer and Wanda Bruhns to observe and document the ecological conditions existing at each site and evaluate the potential loss of sensitive habitat at each site should it be converted to solar evaporation ponds. The following sections present the findings of these visits.

## PARADOX NW SITE

### Description

The Paradox NW Site is an approximate 351-acre site in the northwestern portion of the Paradox Valley. The site ranges in elevation from approximately 5,195 feet above mean sea level (amsl) in the northwest corner to approximately 5,090 feet amsl at the southern boundary. The site is mostly flat, although some hills are present in the southwest and northwest corners. The northern walls of the Paradox Valley are approximately 1.2 miles north of the site with large cliffs and exposed bedrock. The site is bisected by several ephemeral washes that converge near the southern boundary and flow southwest towards the Dolores River.

### Findings

Amec Foster Wheeler biologists Reed Kraemer and Wanda Bruhns (we) visited the Paradox NW Site the afternoon of May 11, 2016. Due to landowner restrictions, we were not able to access the site itself; however, we were able to walk its southern and western perimeters, which gave us a full view of the site. The habitat of the Paradox NW Site was predominantly *Inter-Mountain Basins Big Sagebrush Shrubland*, as described by the US Geological Survey's (USGS) Southwest Regional Gap Analysis Project (SWReGAP; USGS 2004). The majority of the site, particularly to the south, was dominated by big sagebrush (*Artemisia tridentata*) and four-wing saltbush (*Atriplex canescens*), interspersed by various shrubs, forbs, and annual grasses. Toward the northern portion of the site, the sagebrush gave way into annual grasslands, most likely dominated by cheatgrass (*Bromus tectorum*) and/or other annuals. Just south of the property boundary, a thicket of tamarisk (*Tamarix* sp.) was noted, which had been defoliated by the northern tamarisk beetle (*Diorhabda carinulata*). The ephemeral washes within the site did not contain riparian vegetation other than several scattered tamarisks.

The sagebrush habitat within the site is suitable for sensitive shrubland species such as Gunnison sage grouse (*Centrocercus minimus*), prairie dog (*Cynomys* spp.), longnose leopard lizard (*Gambelia wislizenii*), and midget faded rattlesnake (*Crotalus viridis concolor*). It should be noted however that the presence or absences of these species was not confirmed. Additionally, the nearby cliffs could provide suitable nesting habitat for golden eagle (*Aquila chrysaetos*) and American peregrine falcon (*Falco peregrines anatum*). During the site visit, we observed a variety of songbirds and raptors onsite, which included one sensitive species: Brewer's sparrow (*Spizella berweri*; Bureau of Land Management [BLM] Sensitive). We also noted an unidentified species of owl nesting in the tamarisk thicket just south of the site. We did not observe any sign of prairie dogs at the site, although the entire site was not searched. If prairie dogs are present on the site, the most suitable area would be within the open areas along the northern boundary. **Table 1** lists the plant and animal species that we observed during the site visit.

**Table 1. Species Observed within the Paradox NW Site**

| Common Name | Scientific Name | Status |
|---|---|---|
| | | |
| Ash-throated flycatcher | *Myiarchus cinerascens* | MBTA |
| Blue-gray gnatcatcher | *Polioptila caerulea* | MBTA |
| Black-billed magpie | *Pica hudsonia* | MBTA |
| Black-throated sparrow | *Amphispiza bilineata* | MBTA |
| Brewer's sparrow | *Spizella breweri* | MBTA; BLM Sensitive |
| Common raven | *Corvus corax* | MBTA |
| Northern harrier | *Circus cyaneus* | MBTA |
| Lark sparrow | *Chondestes grammacus* | MBTA |
| Loggerhead shrike | *Lanius ludovicianus* | MBTA |
| Owl sp. | N/A | MBTA |
| Yellow-rumped warbler | *Setophaga coronata* | MBTA |
| Vesper sparrow | *Pooecetes gramineus* | MBTA |
| | | |
| Cottontail | *Sylvilagus* sp. | N/A |
| | | |
| Sagebrush lizard | *Sceloporus graciosus* | N/A |
| Western whiptail | *Aspidoscelis tigris* | N/A |
| | | |
| Purple three-awn | *Aristida purpurea* | N/A |
| Big sagebrush | *Artemesia tridentada* | N/A |
| Four-wing saltbush | *Atriplex canescens* | N/A |
| Blue grama | *Bouteloua gracilis* | N/A |
| Cheatgrass | *Bromus tectorum* | List C State Noxious Weed* |
| Rose heath | *Chaetopappa ericoides* | N/A |
| Cryptantha | *Cryptantha* sp. | N/A |
| Broom snakeweed | *Gutierrezia sarothrae* | N/A |
| Wild barley | *Hordeum* sp. | N/A |
| Winterfat | *Krascheninnikovia lanata* | N/A |
| Whitest evening primrose | *Oenothera albicaulis* | N/A |
| Plains pricklypear | *Opuntia polyacantha* | N/A |
| Canaigre dock | *Rumex hymenosepalus* | N/A |
| Scarlet globemallow | *Sphaeralcea coccinea* | N/A |
| Desert princesplum | *Stanleya pinnata* | N/A |
| Tamarisk | *Tamarix* sp. | N/A |

BLM = Bureau of Land Management; N/A = Not Applicable; MBTA = Migratory Bird Treaty Act

*List C Species are species for which the Colorado State Commissioner, in consultation with the state noxious weed advisory committee, local governments, and other interested parties, will develop and implement state noxious weed management plans designed to support the efforts of local governing bodies to facilitate more effective integrated weed management on private and public lands. The goal of such plans will not be to stop the continued spread of these species but to provide additional education, research, and biological control resources to jurisdictions that choose to require management of List C species. (Colorado Department of Agriculture 2016)

<u>Photographs</u>


**Photo 1.** Paradox NW Site facing north from its southern boundary


**Photo 2.** Paradox NW Site facing northwest from near its southeastern corner

## LANDFILL SITE

Description

The Landfill Site is an approximate 351-acre site located 7.2 miles southeast of the Paradox Valley. The site ranges in elevation from approximately 6,350 amsl in the southern portion to approximately 6,140 feet amsl at the northern boundary. The site is relatively flat, sloping gradually towards the north. The site is situated on a plateau above the Paradox Valley that is characterized by slight rolling hills. The site is bisected by one ephemeral wash, which runs north through the center of the site and terminates into the San Miguel River near the town of Naturita.

Findings

We visited the Landfill Site the morning of May 12, 2016 and conducted a general pedestrian survey of the site. A 100% visual survey was not conducted for the site. The site was a mix of *Inter-Mountain Basins Big Sagebrush Shrubland, Colorado Plateau Pinyon-Juniper Shrubland,* and *Colorado Plateau Pinyon-Juniper Woodland* (USGS 2004). The central and southern portions of the site were dominated by nearly monotypic stands of big sagebrush with occasional four-wing saltbush and Utah juniper (*Juniperus osteosperma*). The ephemeral wash was often bounded by Utah juniper and/or twoneedle pinyon (*Pinus edulis*) and contained a higher variety of herbaceous plants such as sharpleaf twinpod (*Physaria acutifolia*) and peavine (*Lathyrus* sp.). The southern portion of the site contained pinyon-juniper woodlands with little-to-no undergrowth.

The sagebrush habitat within the site is suitable for sensitive shrubland species as described for the Paradox NW Site. The pinyon-juniper habitat in the southern portion of the site could also support sensitive woodland species or nesting raptors. During the site visit we detected two BLM Sensitive species of bird: Brewer's sparrow and pinyon jay (*Gymnorhinus cyanocephalus*). A raven (*Corvus corax*) was also found nesting near the center of the site in a juniper. We observed an abundance of elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) scat and tracks. We did not see any evidence of prairie dogs onsite, vegetation was likely too high for them to utilize the area and no burrows were seen. **Table 2** lists the plant and animal species that we observed during the site visit.

**Table 2. Species Observed within Landfill Site**

| Common Name | Scientific Name | Status |
|---|---|---|
| | | |
| Ash-throated flycatcher | *Myiarchus cinerascens* | MBTA |
| Black-throated gray warbler | *Setophaga nigrescens* | MBTA |
| Blue-gray gnatcatcher | *Polioptila caerulea* | MBTA |
| Brewer's sparrow | *Spizella breweri* | MBTA; BLM Sensitive |
| Chipping sparrow | *Spizella passerina* | MBTA |
| Common raven | *Corvus corax* | MBTA |
| Hairy woodpecker | *Leuconotopicus villosus* | MBTA |
| House finch | *Haemorhous mexicanus* | MBTA |
| Hummingbird spp. | N/A | MBTA |
| Juniper titmouse | *Baeolophus ridgwayi* | MBTA |
| Lark sparrow | *Chondestes grammacus* | MBTA |
| Pinyon jay | *Gymnorhinus cyanocephalus* | MBTA; BLM Sensitive |
| Red-breasted Nuthatch | *Sitta canadensis* | MBTA |
| Red-tailed hawk | *Buteo jamaicensis* | MBTA |
| Vesper sparrow | *Pooecetes gramineus* | MBTA |
| Western meadowlark | *Sturnella neglecta* | MBTA |
| Yellow-rumped warbler | *Setophaga coronata* | MBTA |
| | | |
| Elk (Sign only) | *Cervus canadensis* | N/A |
| Cottontail | *Sylvilagus* sp. | N/A |
| Mule deer (Sign only) | *Odocoileus hemionus* | N/A |
| | | |
| Western whiptail | *Aspidoscelis tigris* | N/A |
| | | |
| Big sagebrush | *Artemesia tridentada* | N/A |
| Four-wing saltbush | *Atriplex canescens* | N/A |
| Blue grama | *Bouteloua gracilis* | N/A |
| Indian paintbrush | *Castilleja* sp. | N/A |
| Limestone hawksbeard | *Crepis intermedia* | N/A |
| Cryptantha | *Cryptantha* sp. | N/A |
| Hedgehog cactus | *Echinocereus* sp. | N/A |
| Redstem stork's bill | *Erodium cicutarium* | N/A |
| Broom snakeweed | *Gutierrezia sarothrae* | N/A |
| Utah juniper | *Juniperus osteosperma* | N/A |
| Peavine | *Lathyrus* sp. | N/A |
| Horehound | *Marrubium vulgare* | N/A |
| Plains pricklypear | *Opuntia polyacantha* | N/A |
| Twoneedle pinyon | *Pinus edulis* | N/A |
| Sharpleaf twinpod | *Physaria acutifolia* | N/A |
| Canaigre dock | *Rumex hymenosepalus* | N/A |
| Wild mustard | *Sisymbrium* sp. | N/A |
| Yucca | *Yucca* sp. | N/A |

BLM = Bureau of Land Management; N/A = Not Applicable; MBTA = Migratory Bird Treaty Act

Photographs


**Photo 3.** Landfill Site facing south from near the center of the site


**Photo 4.** Wash on Landfill Site as facing north from the southern portion of the site. Note the pinyon-juniper woodland habitat.

## HAMILTON CANYON SITE

Description

The Hamilton Canyon Site is an approximate 350-acre site located 0.9 mile east of the Landfill Site. The site ranges in elevation from approximately 6,135 feet amsl in the southern portion to approximately 6,005 feet amsl in the northern portion. The site is relatively flat, sloping gradually towards the north. The site is similar in terrain to the Landfill site being situated near rolling hills. The site does not contain any water courses, but is situated between two ephemeral washes.

Findings

We visited the Hamilton Canyon Site the morning of May 12, 2016. Because the site was considered an “Alternative” rather than a “Proposed” site, our survey was brief and was conducted mainly from the central road. The site was a mix of *Inter-Mountain Basins Big Sagebrush Shrubland* and *Colorado Plateau Pinyon-Juniper Shrubland* (USGS 2004). The sagebrush shrublands on the site appeared more disturbed than those at the Landfill site. The vegetative makeup of these shrublands included big sagebrush, broom snakeweed, cheatgrass, and various bunchgrasses. We noted no sign of prairie dogs, although the entire site was not searched.

## Photographs


**Photo 9.** Hamilton Canyon Site facing northwest from the central road


**Photo 10.** Hamilton Canyon Site facing south across the central road

## CENTRAL SITE

Description

The Central site is an approximate 346-acre site located in the southeast portion of the Paradox Valley. The site is composed of two smaller parcels separated by approximately 200 feet. The northern parcel is linear in shape and runs parallel to the southern side of US Highway 90 (US 90). Elevation here ranges from approximately 5,230 to 5,425 feet amsl. The topography of the northern site is relatively flat near the highway, but hilly along its western and northern extents. The northern portion of this parcel is particularly hilly and eroded. The southern parcel is more rectangular in shape and ranges from 5,475 to 5,265 feet amsl. This parcel is hilly in its northern and southern reaches, but relatively flat near the center. Both parcels are drained by an ephemeral wash that runs northwesterly between them.

Findings

We visited the Central Site the afternoon of May 12, 2016 and the morning of May 13, and conducted a general pedestrian survey of the site. A 100% visual survey was not conducted for the site. The site was a mix of *Inter-Mountain Basins Big Sagebrush Shrubland, Invasive Grasslands,* and *Colorado Plateau Pinyon-Juniper Shrubland* (USGS 2004). The majority of the flat area on the northern parcel were dominated by fairly monotypic stands of big sagebrush, similar to portions of the Landfill Site. We noted that some of the sagebrush shrublands in the central portion of this parcel were graded or being actively cleared by bulldozer. These areas were highly deteriorated and had a higher density of broom snakeweed. Open patches within the site contained an annual shrubland dominated by cheatgrass and wooly plantain (*Plantago patagonica*), among other annual species. The hills in the northwestern portion of the site contained a high diversity of wildflowers including the endemic Paradox lupine *(Lupinus crassus*). Much of the southern parcel contained pinyon-juniper shrublands intermixed with sagebrush. During our visit, the entire site was actively being grazed, which may have contributed to us noting wildlife commonly associated with livestock, such as brown-headed cowbird (*Molothrus ater*).

The site could support shrubland species similar to the Landfill and Paradox NW Sites. In the flat portions along US 90 the site was highly disturbed by bulldozing and appeared to be of lower habitat quality than the Landfill and Northwest Paradox sites. Conversely, the hilly portions of the Central Site contained the highest diversity of plant species we observed at any site. Of particular interest in this area were large patches of Paradox lupine, a BLM Sensitive species, in the northern portion of the site. The southern parcel of the site contained pinyon-juniper habitat similar to that on the Landfill site, but with a higher diversity of species growing in the understory. We did not see any evidence of prairie dogs on the site. **Table 3** lists the plant and animal species that we observed during the site visit.

**Table 3. Species Observed within Central Site**

| Common Name | Scientific Name | Status |
|---|---|---|
| **Birds** | | |
| Ash-throated flycatcher | *Myiarchus cinerascens* | MBTA |
| Blue-gray gnatcatcher | *Polioptila caerulea* | MBTA |
| Brown-headed cowbird | *Molothrus ater* | MBTA |
| Black-throated sparrow | *Amphispiza bilineata* | MBTA |
| Common raven | *Corvus corax* | MBTA |
| House finch | *Haemorhous mexicanus* | MBTA |
| Lark sparrow | *Chondestes grammacus* | MBTA |
| Northern mockingbird | *Mimus polyglottos* | MBTA |
| Vesper sparrow | *Pooecetes gramineus* | MBTA |
| **Mammals** | | |
| Black-tailed jackrabbit | *Lepus californicus* | N/A |
| Elk (Sign only) | *Cervus canadensis* | N/A |
| Cottontail | *Sylvilagus* sp. | N/A |
| Mule deer (Sign only) | *Odocoileus hemionus* | N/A |
| **Reptiles** | | |
| Western whiptail | *Aspidoscelis tigris* | N/A |
| **Plants** | | |
| Indian ricegrass | *Achnatherum hymenoides* | N/A |
| Fragrant white sand verbena | *Abronia elliptica* | N/A |
| Purple three-awn | *Aristida purpurea* | N/A |
| Big sagebrush | *Artemesia tridentada* | N/A |
| Crescent milkvetch | *Astragalus amphioxys* | N/A |
| Milkvetch | *Astragalus* sp. | N/A |
| Four-wing saltbush | *Atriplex canescens* | N/A |
| Blue grama | *Bouteloua gracilis* | N/A |
| Cheatgrass | *Bromus tectorum* | List C State Noxious Weed* |
| Rose heath | *Chaetopappa ericoides* | N/A |
| Cryptantha | *Cryptantha* sp. | N/A |
| Tall mountain larkspur | *Delphinium scaposum* | N/A |
| Tansy mustard | *Descurainia sp.* | N/A |
| Mormon tea | *Ephedra sp.* | N/A |
| Redstem stork's bill | *Erodium cicutarium* | N/A |
| Wild barley | *Hordeum* sp. | N/A |
| Broom snakeweed | *Gutierrezia sarothrae* | N/A |
| Utah juniper | *Juniperus osteosperma* | N/A |
| Winterfat | *Krascheninnikovia lanata* | N/A |
| Flatspine stickseed | *Lappula redowskii* | N/A |
| Pepperweed | *Lepidium* sp. | N/A |
| Paradox lupine | *Lupinus crassus* | N/A; BLM Sensitive |
| Whitest evening primrose | *Oenothera albicaulis* | N/A |
| Crownleaf evening primrose | *Oenothera coronopifolia* | N/A |
| Plains pricklypear | *Opuntia polyacantha* | N/A |
| Mountain ball cactus | *Pediocactus simpsonii* | N/A |
| Twoneedle pinyon | *Pinus edulis* | N/A |
| Wooly plantain | *Plantago patagonica* | N/A |
| Twinpod | *Physaria* sp. | N/A |
| Canaigre dock | *Rumex hymenosepalus* | N/A |
| Russian thistle | *Salsoa* sp. | N/A |
| Smallflower fishhook cactus | *Sclerocactus parviflorus* | N/A |

**Table 3. Species Observed within Central Site**

| Common Name | Scientific Name | Status |
|---|---|---|
| Scarlet globemallow | *Sphaeralcea coccinea* | N/A |
| Small-leaf globemallow | *Sphaeralcea parvifolia* | N/A |
| Desert princesplum | *Stanleya pinnata* | N/A |
| Hoary Townsend daisy | Townsendia incana | N/A |
| Sixweeks fescue | *Vulpia octoflora* | N/A |
| Rough cocklebur | *Xanthium strumarium* | N/A |
| Yucca | *Yucca* sp. | N/A |

## Photographs


**Photo 5.** Hills in northern parcel of Central Site, as facing northeast towards its boundary

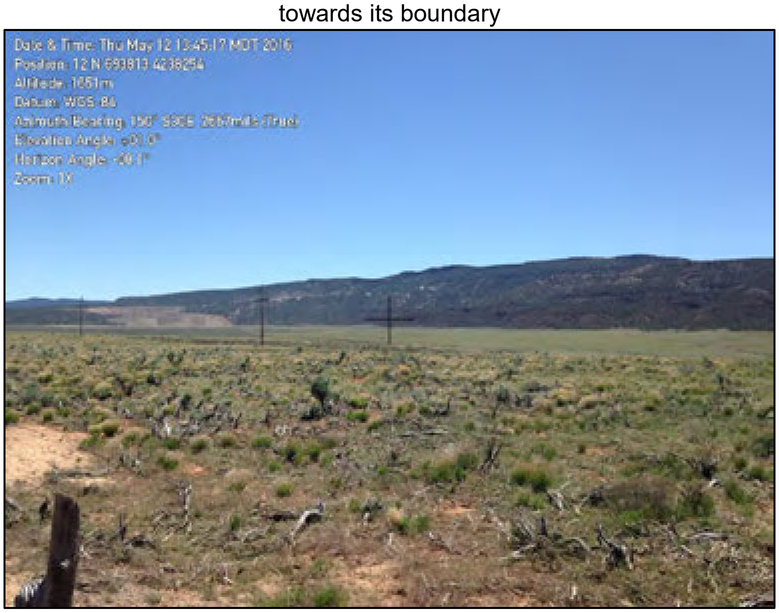


**Photo 6.** Upland area in northern parcel of Central Site, as facing southwest from US 90 near the center of the site. Note the disturbed sagebrush habitat.

**Photo 7.** Southern parcel of Central Site, as facing southwest from its northeastern corner. Note the pinyon-juniper shrublands

**Photo 8.** Example of patch of Paradox lupine in the northwestern portion of the site.

**BLM SITE**

<u>Description</u>

The BLM Site is an approximate 351-acre site located in the southeast portion of the Paradox Valley and 0.5 mile east of the Central Site. The site ranges in elevation from approximately 5,433 feet amsl in the southern portion to approximately 5,355 feet amsl in the northern portion. The site is relatively flat, sloping gradually towards the north. The site contains several ephemeral washes that flow northward and eventually converge into East Paradox Creek.

<u>Findings</u>

We visited the BLM Site the afternoon of May 13, 2016. Because at the time of the visit the site was considered an “Alternative” rather than a “Proposed” site, our survey was brief and was conducted mainly from the western boundary. The site was almost entirely composed of *Inter-Mountain Basins Big Sagebrush Shrubland* (USGS 2004). The shrublands were nearly monotypic stands of sagebrush, with little understory. The ephemeral washes contained no riparian vegetation. A cattle stockpond was constructed near the southern border of the site, by means of impounding a wash. The pond was likely too small to support fish species, but could support amphibians or attract local wildlife. We noted several small animal burrows on the site, likely those of a ground squirrel. We did not see any signs of prairie dogs, but the entire site was not searched.

<u>Photographs</u>


**Photo 11.** BLM Site facing southeast from its western boundary


**Photo 12.** Cattle stockpond in southern portion of BLM Site (visible in midground of photo, behind blue plastic troughs).

## REFERENCES


USGS. 2004. Provisional Digital Land Cover Map for the Southwestern United States. Version 1.0. RS/GIS Laboratory, College of Natural Resources, Utah State University. Available at http://earth.gis.usu.edu/swgap/landcover.html. Accessed May 20, 2016.

Colorado Department of Agriculture. 2016. Noxious Weed Species. Available at https://www.colorado.gov/pacific/agconservation/noxious-weed-species. Accessed May 20, 2016.