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Managing Water in the West

Appraisal-Level Investigation Summary of Findings

Odessa Subarea Special Study
Columbia Basin Project, Washington

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Regional Office, Boise, Idaho
Upper Columbia Area Office,Yakima, Washington
Technical Service Center, Denver, Colorado

March 2008

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to 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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Columbia Basin Project, Washington

Prepared by
U.S. Department of Interior
Bureau of Reclamation

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Acronyms and Abbreviations

BC	benefit/cost
BiOp	biological opinion
BPA	Bonneville Power Administration
CBP	Columbia Basin Project
CCT	Confederated Tribes of the Colville Reservation
CFR	Comprehensive Facility Review
cfs	cubic feet per second
CNWR	Columbia National Wildlife Refuge
CRI MOU	Columbia River Initiative Memorandum of Understanding
DEIS	draft environmental impact statement
DPS	Definite Population Segments
ECBID	East Columbia Basin Irrigation District
Ecology	Washington Department of Ecology
ESA	Endangered Species Act
ESU	Evolutionarily Significant Units
FCCD	Franklin County Conservation District
FCRPS	Federal Columbia River Power System
FEIS	final environmental impact statement
ft/s	feet per second
FWCA	Fish and Wildlife Coordination Act
FWS	U.S Fish and Wildlife Service
GIS	Geographic Information System
gpm	gallons per minute
GWMA	Ground Water Management Area
H. Doc. No. 172	House Document No. 172, 79th Congress, 1st Session, Joint Report on Allocation and Repayment of the Costs of the Columbia Basin Project, Reclamation Report of October 30, 1944
HEP	Habitat Evaluation Procedures
Hyd-Sim	BPA hydrologic model
I-90	Interstate 90

KAF	thousand acre-feet
Lake Roosevelt	Franklin Delano Roosevelt Lake
MAF	million acre feet
NEPA	National Environmental Policy Act
NFFP	National Flood Frequency Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic Atmospheric Administration
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NTMB	neotropical migratory birds
Odessa Subarea	Odessa Groundwater Management Subarea
OM&R	operations, maintenance, and replacement
PASS	Project Alternative Solutions Study
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
Project	Columbia Basin Project
psi	pounds per square inch
Q-CBID	Quincy-Columbia Basin Irrigation District
Reclamation	Bureau of Reclamation
SCBID	South Columbia Basin Irrigation District
Secretary	Secretary of the Interior
State	State of Washington
Study	Odessa Subarea Special Study
TCP	Traditional Cultural Properties
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife

Executive Summary

The Odessa Subarea Special Study (Study) is investigating replacing groundwater currently used for irrigation in the Odessa Ground Water Management Subarea with surface water as part of continued phased development of the Columbia Basin Project (CBP). The aquifer is declining to such an extent that crop irrigation is at risk, and domestic, commercial, municipal, and industrial uses and water quality are also threatened. In response to the public's concern about the declining aquifer and associated economic and other effects, Congress has funded the Bureau of Reclamation (Reclamation) to investigate the problem. The State of Washington has partnered with Reclamation by providing funding and collaborating on various technical studies.

Potential Actions

Reclamation can only deliver water to lands authorized to receive CBP water. Up to 140,000 groundwater-irrigated acres in the Study area are eligible to receive CBP surface water.

To develop comprehensive alternatives, the Study divided actions into:

- **Water delivery alternatives.** Water delivery alternatives consist of infrastructure such as canals, pumping plants and laterals–and possible configurations of these facilities–to convey or deliver surface water to the groundwater-irrigated lands. These alternatives involve either building a new East High canal system or expanding or using the existing East Low Canal system or combinations.
- **Water supply options.** Water supply options consist of various storage facilities that could store the replacement surface water supply for use in the Odessa Subarea.

These alternatives can be combined in various configurations for full operational alternatives, which would include both water delivery and storage. Several water supply options may be needed to provide sufficient water supply for an alternative.

Water Delivery Alternatives

Four water delivery alternatives were examined:

- **Alternative A.** Construct a new East High canal system sized to 30 percent capacity of the original feasibility plan; siphons and tunnels sized to 100 percent capacity.
- **Alternative B.** Construct the northern portion of a new East High canal system sized to 15 percent of the capacity of the original feasibility plan; siphons and tunnels sized to 100 percent of that capacity. Enlarge the

existing East Low Canal sections south of Weber Branch Siphon (near Interstate 90 [I-90]) and construct a 2.3 mile extension east towards Connell, Washington.

- **Alternative C.** Enlarge the existing East Low Canal sections south of Weber Branch Siphon (near I-90).
- **Alternative D.** Construct distribution facilities to serve lands north of I-90. This alternative uses the existing East Low Canal configuration; however, the canal capacity only allows serving lands north of I-90.

Table S-1 shows the amount of water needed for each alternative and the number of acres that each alternative would supply. Chapter 3 describes the water delivery alternatives.

Table S-1. Appraisal-level alternatives and estimated water supply needs

Alternatives	Estimated Water Supply Needs* (acre-feet)	Potential Groundwater Acreage to be Supplied (acres)	Percent of Total Groundwater-Irrigated Acres in Study Area Supplied
A	515,300	140,000	100
B	453,200	127,300	91
C	216,800	70,100	60
D	125,900	48,000	40

*Alternative A uses entirely new conveyance infrastructure and will introduce new conveyance system losses. Alternative B uses less new conveyance infrastructure and relies more on existing conveyance infrastructure thus introducing less new conveyance system loss.

Water Supply Options

Reclamation would need to divert additional Columbia River water greater than current CBP diversions to provide a replacement water supply for groundwater irrigation in the Study area. Reclamation has a 1938 “withdrawal” which set aside water to irrigate the remaining authorized acres of the CBP. However, Reclamation would need to comply with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and other regulatory requirements and procedures before it could divert additional Columbia River water.

This Study assumed that water from the Columbia River would be diverted in a manner that would not affect flow objectives identified by the National Marine Fisheries Service (NMFS) to benefit salmon and steelhead listed under the ESA.

Figure S-1 presents a modeled analysis conducted by Reclamation, comparing the volume of Columbia River water above ESA flow objectives for the driest consecutive 10 years of record with the water demand required to provide a full replacement supply for all 140,000 groundwater-irrigated acres in the Study area.

Reclamation's analysis determined that Columbia River flows exceed these flow objectives in some fall and winter months, even in the driest years.

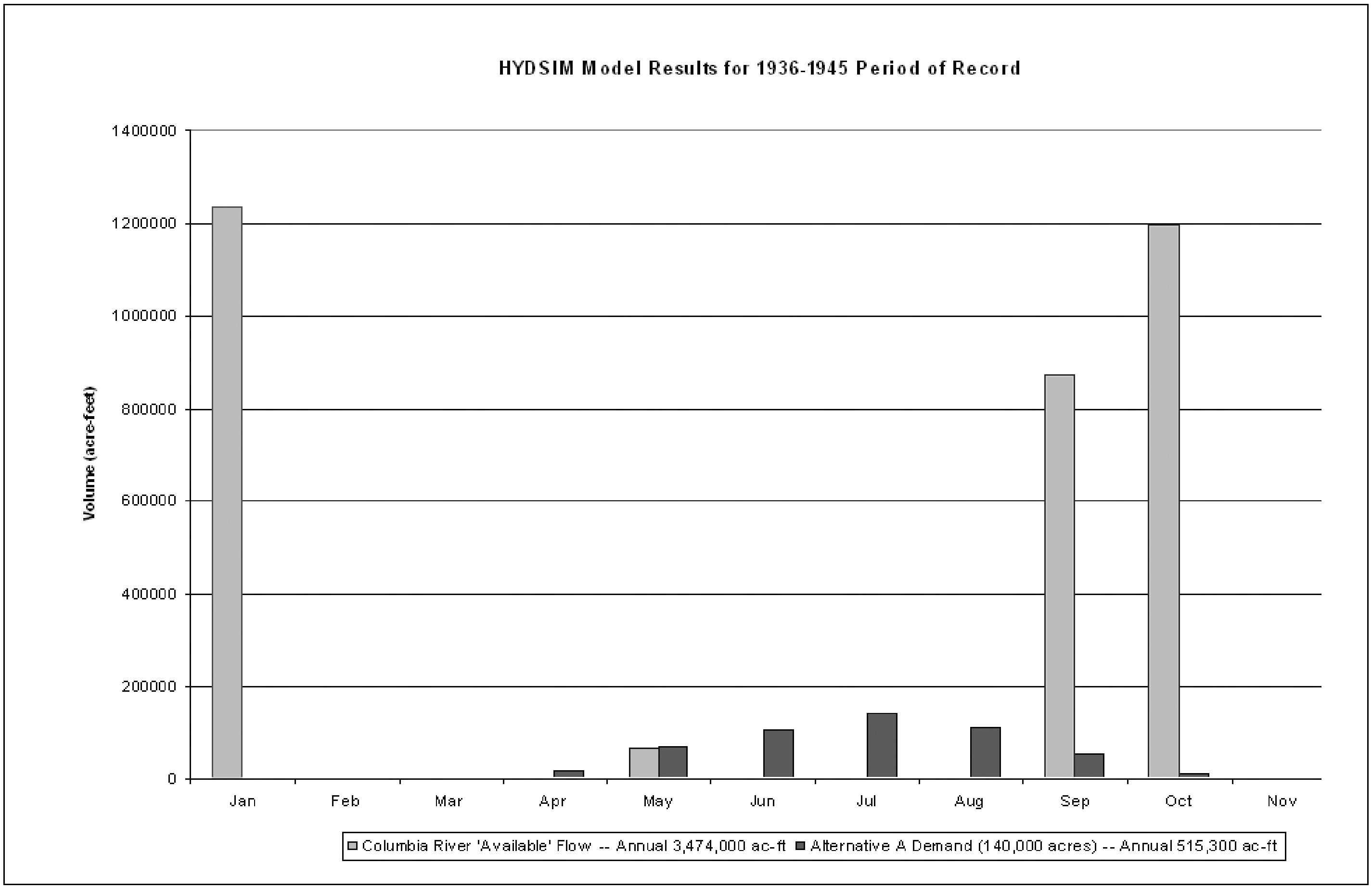

Figure S- 1. Volume of Columbia River water available for 1936-1945 (gray) compared to the volume required to replace all groundwater-irrigated acres in the Study area (black).

Reclamation's water diversion strategy is to divert water in the fall months, storing it for later use during the irrigation season. The replacement supply could be provided by operating existing CBP storage sites differently or constructing new storage. The appraisal-level investigation examined modifying operations at the following storage facilities:

- **Banks Lake drawdown.** Draw the existing lake to lower levels than current operations. Alternative A would require an additional 16 feet of draw down below current operation; Alternative D would require about 4 feet of additional draw down.
- **Banks Lake raise.** Raise the operational water surface of the reservoir by 2 feet. This may require raising the crest of the two dams forming Banks Lake to allow more storage.

- **Potholes reoperation.** Adjust the timing of water storage in the reservoir by feeding some water in the fall, rather than in the spring. This may require structural modifications to O'Sullivan Dam and acquisition of downstream right-of-way along Lower Crab Creek to provide for changes to downstream flood passage.

Another option for proving a replacement water supply would be to construct new storage facilities that could be filled in September and October for use in April through August. Potential reservoir sites examined included:

- **Dry Coulee reservoir.** The reservoir would have an active storage capacity of 481,000 acre-feet. The reservoir would be filled via a new inlet canal from the existing Main Canal at a location upstream of Summer Falls. An upper outlet would feed to the West Canal immediately upstream of the existing West Canal Siphon. A lower outlet would discharge into Crab Creek for reservoir evacuation.
- **Rocky Coulee reservoir:** The reservoir would have an active storage capacity of 126,000 acre-feet. Water would be pumped into the reservoir and then pumped back to the East Low Canal to serve downstream farmlands to the south.
- **Lower Crab Creek reservoir.** The reservoir would have an active storage capacity of either 472,000 acre-feet or 200,000 acre-feet. The reservoir would be filled from releases from Potholes Reservoir via Lower Crab Creek. Acquisition of right-of-way along Lower Crab Creek would be required to provide for increased flows downstream. Water would be returned to the Columbia River during the irrigation season to offset the upstream diversions at Grand Coulee Dam, which would supply the replacement water.

Table S-2 shows the amount of storage and groundwater acres served for each water supply option. Chapter 4 describes the water supply options.

Cost Estimates

Cost estimates were developed based on preliminary engineering designs and analysis, using limited available data and information. The designs were based on design data developed in previous Reclamation studies (completed between the 1960s and 1980s) supplemented with limited additional data. The design data collected for future studies may change future cost estimates significantly from those presented here. The cost estimate data presented here are preliminary and are not suitable for determining actual construction costs or requesting construction fund appropriations from the Congress. However, they are acceptable for making relative comparisons between the proposed water delivery alternatives and water supply options examined.

These cost estimates encompass field costs (direct cost of materials and services for construction of facilities) and noncontract costs (which include investigations, development of designs and specifications, construction engineering and supervision, and environmental compliance). Noncontract costs are calculated as 20 to 40 percent of the field costs.

Table S-2. Water supply options – active storage and groundwater-irrigated acres served

Alternative	Active Storage (acre-feet)	Groundwater Irrigated Acres Served		Comments
		Acres	Percent	
1) Banks Lake drawdown	50,000 for every 2-foot drop	Up to 140,000	100	No modifications to dams required. Depending on the extent of draw down, there could be environmental, cultural, and social impacts. Draw down up to 16 feet from baseline required for full replacement supply.
2) Banks Lake raise	50,000	16,700	12	Modification to embankments of both dams and to Grand Coulee Feeder Canal.
3) Potholes Reservoir reoperation	50,000	16,700	12	Structural modifications to O'Sullivan Dam,.
4) Dry Coulee reservoir	481,000	140,000	100	Two rockfill embankment dams proposed.
5) Rocky Coulee reservoir	126,000	46,900	34	Earthfill embankment dam proposed.
6) Lower Crab Creek reservoir	200,000	60,000	43	Rockfill embankment dam proposed; filled from releases from Potholes Reservoir via Lower Crab Creek.
	472,000	140,000	100	

A single field-cost estimate was developed for each water delivery alternative and water supply option, and then adjustment factors were developed to arrive at a range of most probable estimates (i.e., most probable low and the most probable high). Adjustments were based on level of confidence in the data. Chapter 5 provides additional information about developing cost estimates.

Figure S-2 shows the estimated construction cost range for the water delivery alternatives. These costs do not include the cost of providing a new water supply. Figure S-3 shows the estimated construction cost range for the water supply options. Banks Lake drawdown, as currently configured, does not have a construction aspect. This may change, depending on later findings. Figure S-4 shows a cost comparison per acre served for water delivery alternatives. The costs in Figure S-4 were calculated by combining water delivery alternatives and water supply options in workable configurations, calculating combined costs, and then calculating the cost per acre.

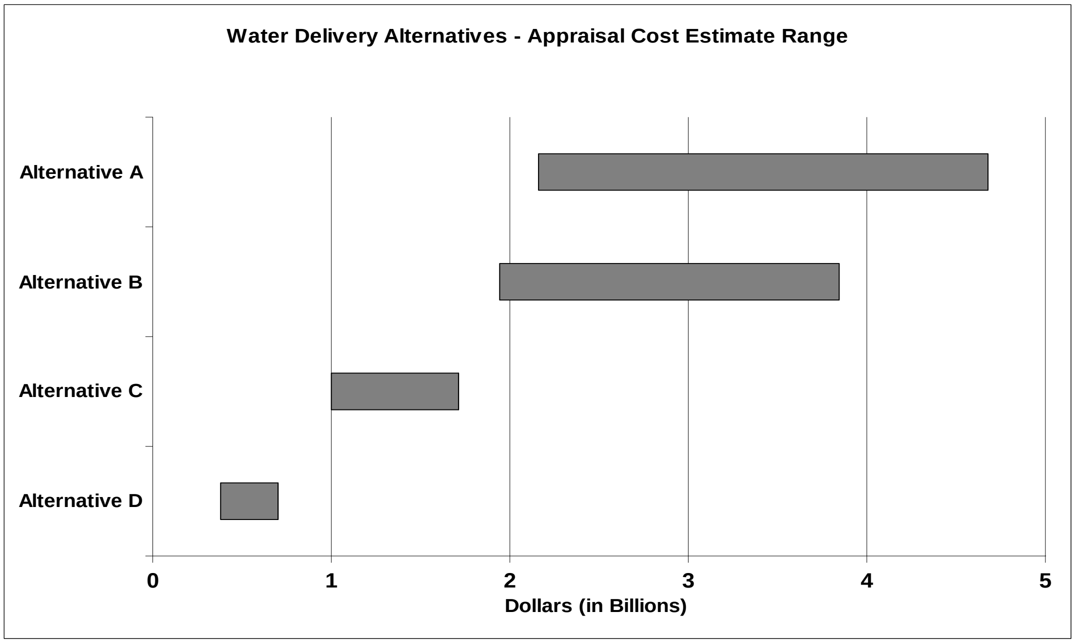

Figure S-2. Appraisal cost estimate range by water delivery alternative (in billions).

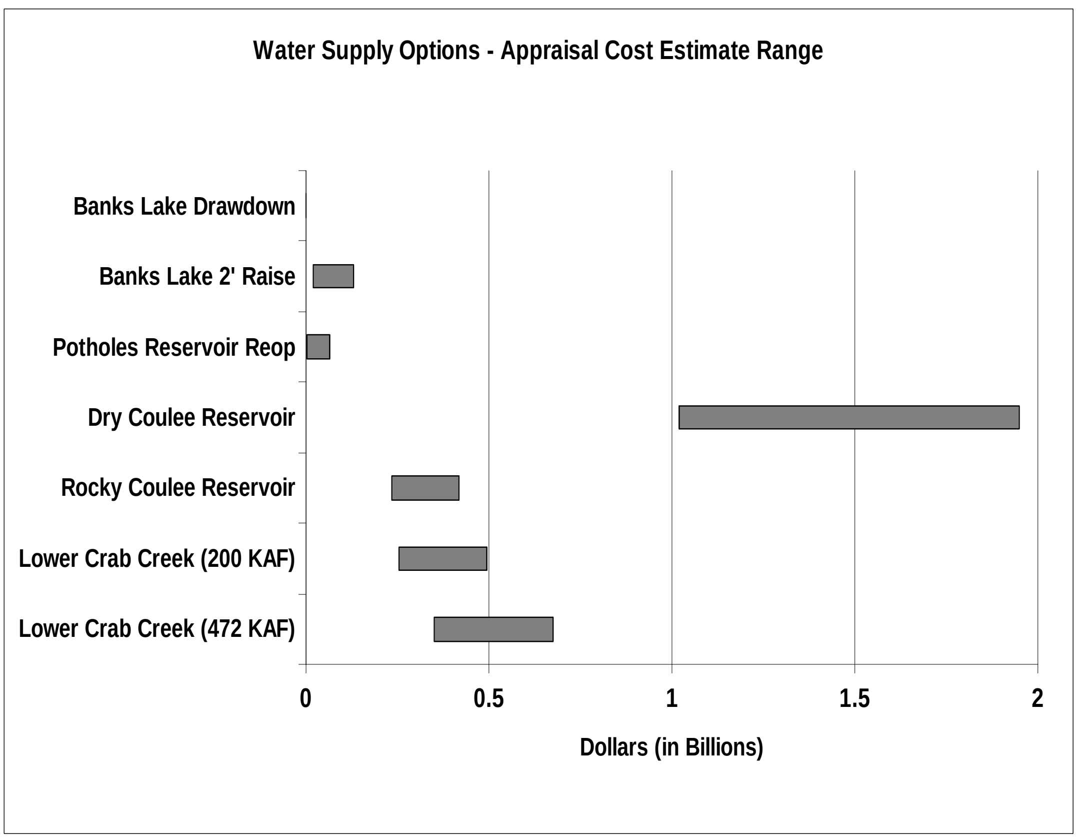

Figure S-3. Appraisal cost estimate range for each water supply option (in billions).

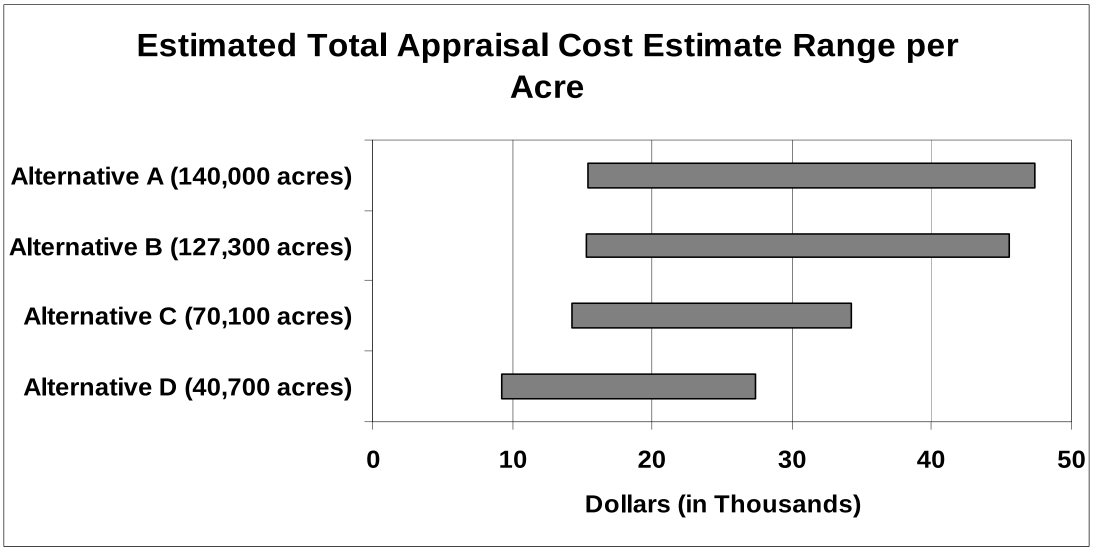

Figure S-4. Appraisal cost estimate range by acres served for water delivery alternative and water supply combinations.

The total combined cost of providing a replacement water supply to groundwater-irrigated lands will depend on which water supply option or options are combined with a water delivery alternative. Several water supply options may be needed to provide the replacement water supply required.

Findings and Recommendations

Reclamation reviewed the information developed during the appraisal-level investigation and considered public feedback to compare and evaluate the water delivery alternatives and water supply options. (See Chapter 6). The engineering investigation determined that all four water delivery alternatives and the six water supply options examined are technically feasible.

Reclamation has decided to initiate additional study of water delivery alternative B in the next Study phase. It was determined that this alternative balances maximizing use of existing CBP infrastructure, while providing a replacement supply to sufficient groundwater acres to benefit the aquifer. Further, initial cost estimates indicate that the costs per acre served are within the same general range as other alternatives examined, but they serve more acres.

Reclamation will continue to study operations modifications at Banks Lake, including a 2-foot operational raise, additional draw downs, and modifications at Potholes Reservoir as possible replacement water supply options. These three water supply options are the most cost effective because they use existing CBP storage facilities. Reclamation will also initiate additional studies of Rocky Coulee as a potential new storage site, as additional storage may be required to minimize the effects associated with modifications in existing facility operations (e.g., additional draw down of Banks Lake). Of the three potential storage sites examined, the Rocky Coulee location provides operational flexibility within the CBP and is less expensive to build.

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1.0 Introduction

The Bureau of Reclamation (Reclamation) is conducting the Odessa Subarea Special Study (Study) to investigate the continued phased development of the Columbia Basin Project (CBP) to replace groundwater currently used for irrigation in the Odessa Ground Water Management Subarea (Odessa Subarea) with CBP surface water. Reclamation has completed appraisal-level investigations of four water delivery alternatives and six water supply options that could provide a replacement surface water supply. The alternatives and options include constructing a new canal system or enlarging and expanding existing canals, as well as possibly constructing new storage facilities. The investigation examined the engineering viability, developed preliminary cost estimates, and identified potential environmental and social issues. This report documents the investigations.

1.1 Study Authority

The CBP is a multipurpose development in the central part of the state of Washington (State). The key structure, Grand Coulee Dam, is on the mainstem of the Columbia River about 90 miles west of Spokane, Washington. The Grand Coulee Dam Project was authorized for construction by the Act of August 30, 1935, and reauthorized and renamed in the Columbia Basin Project Act of March 10, 1943. Congress authorized the CBP to irrigate a total of 1,029,000 acres; about 671,000 acres are currently irrigated.

The 1943 Columbia Basin Project Act subjected the CBP to the requirements of the Reclamation Project Act of 1939. Section 9(a) of the 1939 Act gave authority to the Secretary of the Interior (Secretary) to approve a finding of feasibility and thereby authorize construction of a project upon submitting a report to the President and the Congress. The Secretary approved a plan of development for the Columbia Basin Project (Reclamation 1944), which was then transmitted as a joint report, known as House Document No. 172, to the President and to the House Irrigation and Reclamation Committee in 1945, thereby satisfying these requirements. (When the Secretary recommended a project to Congress, the feasibility report and Reclamation's Regional Director's report were customarily printed as a House Document.) The Odessa Subarea Special Study is conducted under the authority of this Act, as amended, and the Reclamation Act of 1939.

Congress authorized the continued irrigation development of the CBP using a phased development approach. House Document No. 172 anticipated about a 70-year period of incremental development to complete the CBP. Reclamation is authorized to implement additional phases as long as the Secretary finds it to be economically justified and financially feasible.

This Study is a special study investigating another developmental phase of the CBP. The Study will involve a feasibility-level analysis, as it is anticipated that the Office of Management and Budget and other decisionmakers may require this level of analysis before appropriations for new construction will be made. Further, this study approach will help the Secretary determine the financial and economic feasibility of a preferred alternative as stipulated in current contract provisions with CBP beneficiaries.

1.2 Purpose and Need

Groundwater in the Odessa Subarea is currently being depleted to such an extent that water must be pumped from great depths. Pumping depths are 750 feet in some areas, and well depths are as great as 2,100–2,400 feet. Well drilling well costs and pumping water from this depth have resulted in expensive power costs and water quality concerns such as high water temperatures and high sodium concentrations. The ability of farmers to irrigate their crops is at risk. Domestic, commercial, municipal, and industrial uses and water quality are also affected. Those irrigating with wells of lesser depth live with uncertainty about future well production (See Section 2.4.4, “Water-level Declines”).

Washington State University conducted a regional economic impact study assessing the effects of lost potato production and processing in Adams, Franklin, Grant, and Lincoln counties from continued aquifer decline. Assuming that all potato production and processing is lost from the region, the analysis estimated the regional economic impact would be a loss of about $630 million dollars annually in regional sales, a loss of 3,600 jobs, and a loss of $211 million in regional income (Bhattacharjee and Holland 2005).

Another study examined the regional economic impacts for Adams and Lincoln counties from possible agricultural production losses for other crops that might result with continued aquifer decline (Razack and Holland 2007). Two scenarios were examined. One scenario assumed a 10 percent reduction in agricultural production would occur with an estimated $20 million reduction in regional income and a 295 job loss for the two counties (Razack and Holland 2007). A second scenario assumed a 10 percent crop production loss combined with loss of the frozen potato processing product in the two counties would occur with an estimated $30 million loss of regional income and a 465 job loss for the two counties. If all deep well agricultural production were lost, an estimated 4650 jobs would be lost, equating to about 32 percent of total jobs in the two counties.

Action is needed to avoid significant economic loss to the region’s agricultural sector because of resource conditions associated with continued decline of the aquifers in the Odessa Subarea. The purpose of actions proposed in this report is to meet this need by replacing the current and increasingly unreliable groundwater supplies with a surface supply from the CBP as part of continued phased development of the CBP as authorized. An estimated 170,000 acres within the Odessa Subarea are now being irrigated with groundwater. An estimated 140,000 of these acres are within the Study area boundaries. See Section2.1, “Study Location.”

1.3 Study Background

As mentioned previously, the CBP is authorized to irrigate 1,029,000 acres; about 671,000 acres (approximately 65 percent of the acreage authorized by Congress) are currently irrigated. These lands, known as first half lands, were developed primarily in the 1950s and 1960s, with some acreages being added sporadically until 1985. Prior studies examined the merits of continuing the incremental development approach for the CBP. However, for various reasons, development did not occur.

The State issued irrigation groundwater permits in the 1960s and 1970s in the Odessa Subarea as a temporary measure until the CBP was developed to provide surface water to these lands. The aquifer has now declined to such an extent that the ability of farmers to irrigate their crops is at risk and domestic, commercial, municipal, and industrial uses and water quality are affected. Local constituents have advocated that Reclamation investigate CBP development to replace groundwater with CBP water as a possible solution for issues associated with the declining aquifer. In response to public concern about associated economic and other effects, Congress provided funding to Reclamation beginning in fiscal year 2005 to investigate opportunities to provide CBP water to replace groundwater use in the Odessa Subarea.

The State supports investigation of CBP development to provide a replacement for current groundwater irrigation. The State, Reclamation, and the CBP irrigation districts signed the Columbia River Initiative Memorandum of Understanding (CRI MOU) in December 2004, to promote a cooperative process for implementing activities to improve Columbia River water management and water management within the CBP. The Odessa Subarea Special Study implements Section 15 of the CRI MOU, which states in part that, "The parties will cooperate to explore opportunities for delivery of water to additional existing agricultural lands within the Odessa Subarea." The State provided a cost-share through an Intergovernmental Agreement between Washington Department of Ecology (Ecology) and Reclamation in December 2005 to fund this Study.

In February 2006, the State legislature passed the Columbia River Water Resource Management Act (HB 2860) that directs Ecology to aggressively pursue development of water benefiting both instream and out-of-stream uses through storage, conservation, and voluntary regional water management agreements. Reclamation's Odessa Subarea Special Study is one of several activities identified in the legislation. Additional Study background is located at: <http://www.usbr.gov/pn/programs/ucao_misc/Odessa/>.

1.4 Previous Study-Related Investigations

Reclamation began the Study in 2005. A *Plan of Study* (Reclamation 2006 [Odessa POS]) was first published that provided study background and purpose, described potential issues, outlined study steps and requirements, and identified required resources.

Reclamation completed a pre-appraisal-level investigation through a Project Alternative Solutions Study (PASS) late in 2006. The investigation is documented in a report entitled *Initial Alternative Development and Evaluation, Odessa Subarea Special Study* (Reclamation 2006 [PASS]).

The PASS was conducted with the assistance of two teams: the Objectives Team and the Technical Team. The Objectives Team was comprised of various stakeholders in the Study area including Federal and State agencies, local governments, Tribes, CBP irrigation districts, and groundwater irrigators. This team developed Study objectives that were used to rank alternative concepts, including:

- Replace all or a portion of current groundwater withdrawals within the Study area with CBP water.
- Maximize use of existing infrastructure.
- Retain the possibility of full CBP development in the future.
- Address Endangered Species Act (ESA) issues.

- Meet National Marine Fisheries Service (NMFS) seasonal flow objectives.
- Address the potential impact to shrub-steppe habitat for ESA-listed species.
- Provide environmental and recreational enhancements.
- Minimize potential delay in the Study schedule.
- Be developed in phases.

The Technical Team was comprised of engineers, a hydrogeologist, a watermaster, and irrigation district managers from Reclamation, Ecology, and the CBP irrigation districts. The Technical Team developed preliminary alternative concepts, suggested by the public and examined in previous investigations, and ranked them using the Study objectives developed by the Objectives Team. The Technical Team then recommended water delivery alternatives and water supply options for further study based on this evaluation. The PASS assumptions and recommendations helped guide the scope of the appraisal-level investigation described in this report.

1.5 Appraisal-Level Investigation Scope

This Study phase investigated alternatives for delivering water and options for storing a replacement water supply.

- **Water delivery alternatives.** These alternatives consist of possible infrastructure (such as canals, pumping plants, and laterals) and possible configurations of these facilities to convey or deliver surface water to the groundwater-irrigated lands.
- **Water supply options.** Water supply options consist of various existing or proposed storage facilities that could store the replacement surface water supply for use in the Odessa Subarea.

Four water delivery alternatives and six water supply options were considered to be viable enough to investigate at the appraisal-level. The information and assumptions developed during the PASS were reviewed and verified, or revised as appropriate. Refinements included identifying specific groundwater-irrigated land areas to receive a replacement surface water supply and calculating the number of groundwater-irrigated acres served and replacement water supply volumes for each alternative. This information is presented later in this report.

The appraisal-level investigation predominantly relied on existing data and included additional limited engineering, geologic, hydrologic, and hydrogeologic analyses to assess the technical feasibility of alternatives and options and to develop preliminary cost estimates to allow comparison among alternatives. Engineering designs and cost estimates are based on previous studies and limited design data, including investigations of the East High canal system conducted in the 1960s and 1970s, construction drawings and geology logs from previous investigations, and drawings from construction of existing CBP facilities such as the East Low Canal. Limited additional data were developed (e.g., hydrologic modeling to simulate operations to help determine the sizing of canals and pumping plants).

Reclamation, with the assistance of the U.S Fish and Wildlife Service (FWS), Washington Department of Fish and Wildlife (WDFW), and Confederated Tribes of the Colville Reservation conducted a preliminary inventory of potential environmental and cultural issues and concerns.

Much of this information was obtained from Geographic Information System (GIS) databases developed by State and Federal agencies. Many of these datasets are not complete or available for the entire Study area.

When the Study moves forward into feasibility-level investigation, extensive environmental surveys and analyses will be performed to verify the presence of resources and more accurately assess effects to cultural and historic resources, species, habitat, and other possible effects.

The information presented here is appropriate for an appraisal-level investigation to identify major constraints to implementing an alternative or issues that make an alternative infeasible or potentially cost prohibitive. Reclamation's appraisal-level analyses and activities summarized in this report include:

- **Geology studies.** Inventory at appraisal-level to assist engineering efforts
- **Hydrogeology studies.** A literature review of existing data and well measurement data
- **Hydrologic modeling.** Simulations of CBP operations, alternatives, and options
- **Cultural resource surveys.** Class 1 and Traditional Cultural Properties (TCPs)
- **Fish and Wildlife Coordination Act (FWCA) consultation.** Preliminary identification of possible fish and wildlife issues
- **Engineering studies.** Appraisal-level engineering designs and analyses to verify technical feasibility and estimate costs

2.0 Study Setting

The following section describes the general setting and resources located within the Study area.

2.1 Study Location

The CBP is in central Washington, east of the Cascade mountains. The CBP currently serves a total of about 671,000 acres in Grant, Lincoln, Adams, Walla Walla, and Franklin counties, with some northern facilities located in Douglas County.

The Odessa Subarea overlaps the CBP boundaries. The Washington legislature (WAC 173-128A) designated the Odessa Subarea in 1967 as a groundwater management area due to groundwater-level declines resulting from groundwater pumping. The Odessa Subarea covers about 2,000 square miles (639,600 acres) and has about 170,000 acres irrigated with groundwater. In Figure 1, the Odessa Subarea is outlined by a solid black line.

Reclamation can only deliver water to lands authorized to receive CBP water (i.e., lands determined to be irrigable and certified by the Secretary). Reclamation conducted a land classification survey in 1976 to identify irrigable lands (Reclamation 1976). This survey was certified by the Secretary. The tan shaded area on Figure 1 identifies lands certified as irrigable.

The Study area is defined by those lands both authorized to receive CBP water and within the Odessa Subarea. There are approximately 140,000 acres of groundwater-irrigated acres that are eligible to receive CBP water in the Study area, (shown by the green circles on Figure 1). These lands are in Adams, Grant, and a small portion of Franklin and Lincoln counties. Most of the eligible lands are within the East Columbia Basin Irrigation District (ECBID), with a few lands in the South Columbia Basin Irrigation District (SCBID).

2.2 Climate

The climate in the Study area is primarily arid, with an average of 7.4 inches of precipitation and 17.4 inches of annual snowfall at Ephrata, and 19.5 inches of precipitation and 18.0 inches of snowfall at Walla Walla (Washington State Climatologist 2006). Figure 2 shows the annual precipitation. Most precipitation occurs during the winter months, and the summers are hot and dry.

2.3 Geology

Numerous geologic investigations have been conducted in the Columbia River basin. and are documented in reports authored by Reclamation, U.S. Geological Survey (USGS), Washington Department of Natural Resources, and consultants for the U.S. Department of Energy's Hanford Reservation. This section summarizes relevant information from these sources.

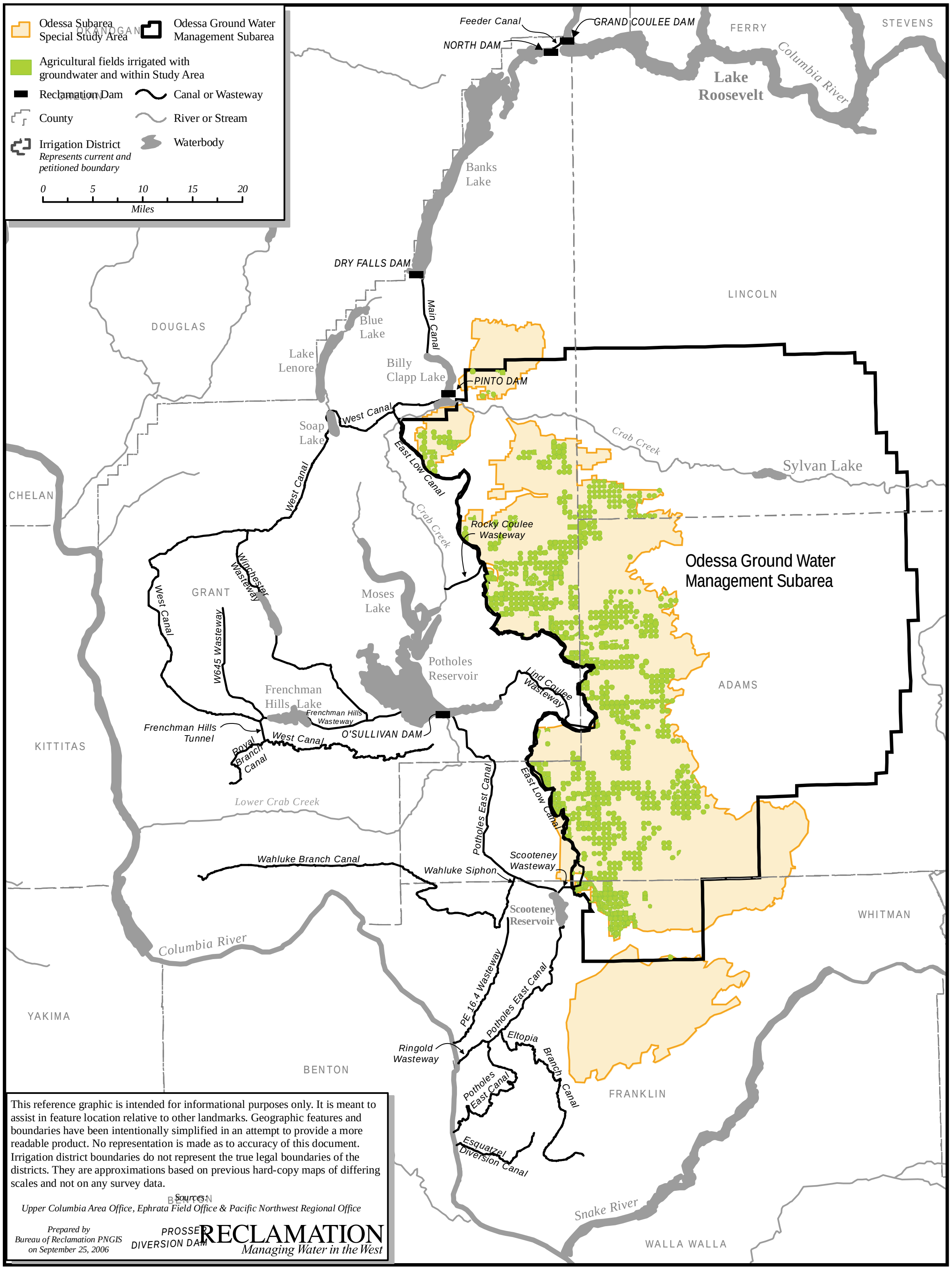

Figure 1. Study area boundaries.

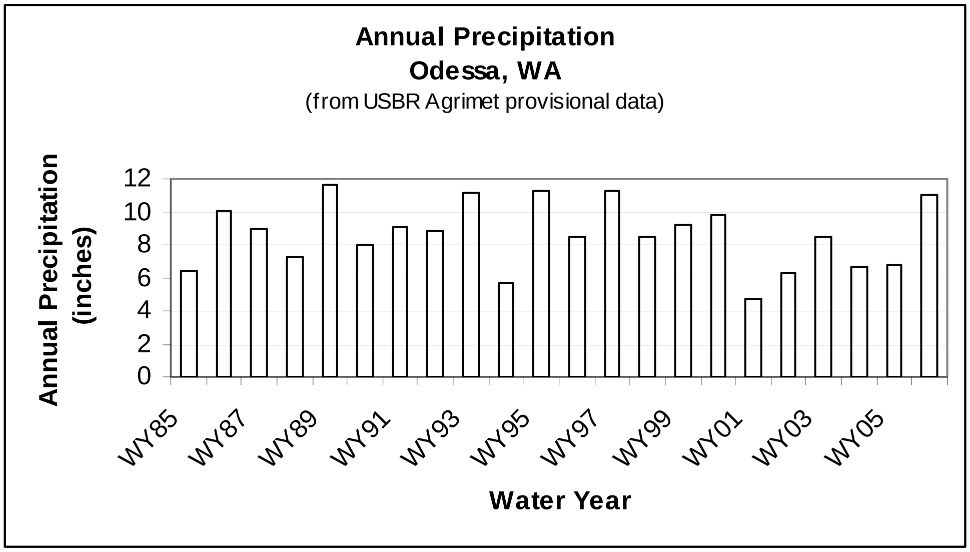

Figure 2. Annual precipitation measured at Reclamation's Odessa Agrimet station.

The Study area is in the northeast-central portion of the Columbia River Basalt Province. The Columbia River basin contains Miocene or Micoene-age (17 to 6 million years ago) basaltic flood lava that erupted from vents near the present boundary between Washington, Oregon, and Idaho. Individual flows were about 100 feet thick on average and covered hundreds to thousands of square miles. Extended time periods between eruptions allowed for the deposition and formation of sedimentary interbeds between basaltic flows. Late Pliocene-age fluvial and lacustrine sediments form the Ringold Formation, which overlies the basalt in the southern portion of the basin.

The history from the end of the Pliocene-age to the present is characterized by prolonged periods of loess and soil accumulation and periodic catastrophic flooding. A glacial ice dam impounded water in western Montana, forming Lake Missoula. The glacial dam failed repeatedly, releasing large amounts of water into the Columbia River drainage. Floodwater diverted by the Okanogan Ice Sheet flowed across the Columbia River Plateau, where it formed the region that Mr. J. Harlen Bretz named the "Channeled Scabland" (Baker and Nummedal 1978). High-velocity floodwater eroded the basaltic layers and formed the large, flat-bottomed channels in the Grand Coulee region north of the Odessa Subarea. Floodwaters also spilled over and eroded channels through the surface sediments and underlying basalt in the Odessa Subarea.

The Odessa Subarea is a loess-mantled upland dissected by flat-bottomed coulees with floors that merge with the Quincy Basin to the west. The Palouse Formation is loess that was not stripped away by the last major episode of flooding, which occurred between about 18,000 and 13,000 years ago (Baker and Nummedal 1978). The fluvial and lacustrine outburst flood deposits of the Channeled Scablands are more prevalent west of the Odessa area. The main valleys and coulees that dissect the Study area include the Upper Crab Creek, and Black Rock, Rocky, Weber, Lind, and Washtucna coulees.

2.3.1 Structure

The Palouse Subprovince is structurally simple and is the least deformed region in the Columbia River Plateau. With only minor faults and low-amplitude, long-wavelength folds, these structures alter an otherwise gently southwestward-dipping paleoslope (Reidel et al. 1989). The entire Columbia River Plateau was regionally tilted from an elevation of about 2,500 feet in the northeast to about 400 feet in the southwest near Pasco, Washington (Baker and Nummedal 1978). The Lind Coulee Flexure (anticline), south and southeast of Potholes Reservoir and O'Sullivan Dam, is one such feature identified in the area. In addition, the Lind Coulee Fault is a reverse fault that has been mapped along the north side of the Frenchman Hills in the lower reaches of Lind Coulee. The mapping shows that the fault cuts sediments that overlie Columbia River Basalt in several places (Reidel and Campbell 1989). Studies conducted for Reclamation show that Pleistocene loess is faulted and that still younger loess and flood deposits overlying the basalt are unfaulted. It appears that movement occurred on the fault during the Pleistocene, but the latest movement is older than the most recent catastrophic floods (Reidel and Campbell 1989).

2.3.2 Stratigraphy

The Odessa Subarea sediments include the Late Pliocene-age Ringold Formation, pleistocene-age loess of the Palouse Formation, Lake Missoula outburst flood deposits, and recent alluvial deposits and sand dunes. Bedrock units include the Grande Ronde and Wanapum Basalt Formations of the Columbia River Basalt Group. These geologic units are described in the *Appraisal Assessment of Geology at Potential Dam and Pumping Plant Sites, Odessa Subarea* (Reclamation 2007 [Geology]). Individual surface and bedrock units are described in Appendix A.

The Grande Ronde Basalt underlies the entire Study area and consists of as many as 131 individual flows (Tolan et al. 1987). In the Odessa Subarea, the Grande Ronde ranges from about 2,000 to 7,000 feet thick (Hansen et al. 1994). The extent and thickness of individual members within the Grande Ronde have not been mapped but are generally distinguished by their paleomagnetic properties (reversed or normal polarity relative to current conditions). Few sedimentary interbeds exist between Grande Ronde Basalt flows. However, the top of the Grande Ronde is distinguished in most places by a sedimentary interbed, locally called the Vantage. The Vantage interbed consists mainly of claystone, siltstone, and sandstone and is usually a confining unit. The Grande Ronde is exposed at the land surface at the northern margin of the Columbia River Plateau and where erosional features have removed the overlying units, such as in some of the deeper coulees and stream valleys.

The Wanapum Basalt overlies the Grande Ronde and ranges from about 200 to 800 feet thick in the Study area. The Wanapum generally contains about 33 individual basalt flows (Tolan et al. 1987) and has been subdivided into four members on the basis of petrology and magnetic polarity. The younger three members, Frenchman Springs, Roza, and Priest Rapids, are widespread on the plateau and found in the Study area.

Sedimentary interbeds between individual basalt flows are more common in the Wanapum than in the Grande Ronde, but these are relatively thin and not laterally extensive. Composition of the interbeds ranges from gravel to clay.

2.4 Groundwater

The aquifers underlying the Odessa Subarea are part of the larger Columbia River Plateau aquifer system. This aquifer system is the area's primary source of municipal, industrial, domestic, and irrigation water. Figure 3 shows the aquifer area.

Groundwater development began around 1950 and increased significantly in the 1960s and 1970s due to advances in drilling and pump technologies. In the Odessa Subarea, groundwater pumping increased from about 25,000 acre feet in 1963 to about 212,490 acre feet in 1984 and the number of large-capacity irrigation wells increased from 170 in 1963 to 618 in 1977 (Cline 1984). Initially, most of the wells were less than 1,000 feet deep and tapped the Wanapum Basalt aquifer. By 1977, many wells had been drilled deeper than 1,000 feet and tapped both the Wanapum and the underlying Grande Ronde Basalt aquifers.

The State legislature in 1967 designated the Odessa Subarea as a groundwater management area due to groundwater-level declines from groundwater pumping. The regulations require that three conditions be maintained within the management area:

- The rate of decline in groundwater level will be limited to no more than 30 feet in any three consecutive years (modified in 1975 to limit water-level declines to 10 feet per year).
- The total decline in groundwater level will be limited to no more than 300 feet below the static water level that existed in the spring of 1967.
- No new permits will be issued for groundwater withdrawals within the Odessa Subarea that would cause the limitations of conditions 1 and 2 above to be exceeded.

In 1998, a Groundwater Management Area (GWMA) was formed in response to water quality concerns. The GWMA initially included Franklin, Adams, and Grant counties. Lincoln County joined in 2005. Detailed stratigraphic mapping of sediments, water quality sampling, and agricultural water use studies have been conducted as part of the GWMA program (GWMA 2001). Figure 4 shows the locations of the GWMA, Odessa Subarea, and Reclamation's eligible Study area.

2.4.1 Groundwater Occurrence and Movement

An understanding of the geologic setting, the distribution and thickness of the geologic units, their hydrologic properties, and structural characteristics is important in determining the occurrence and movement of groundwater. See Section 2.3, "Geology," for a description of the geologic framework underlying the Study area.

Sedimentary materials that overlie the basalt host important aquifers in parts of the CBP. The Pliocene- to Holocene-aged sediments were deposited under fluvial, glaciofluvial, and eolian conditions. The aerial extent and thickness of these deposits vary greatly, with a maximum thickness of more than 200 feet in the Quincy Basin (Hansen 1994). The GWMA study defined and mapped three hydrostratigraphic units in the "suprabasalt sediments" (sediments that overlie the basalt) (Kennedy/Jenks and Franklin County Conservation District [FCCD] 2006). These include a coarse-grained Quaternary clastic unit, Quaternary loess, and the Miocene-Pliocene Ringold Formation. The Quaternary clastic unit includes sand dunes, alluvium, and cataclysmic flood deposits. These sediments are uncemented, have relatively high permeability, and

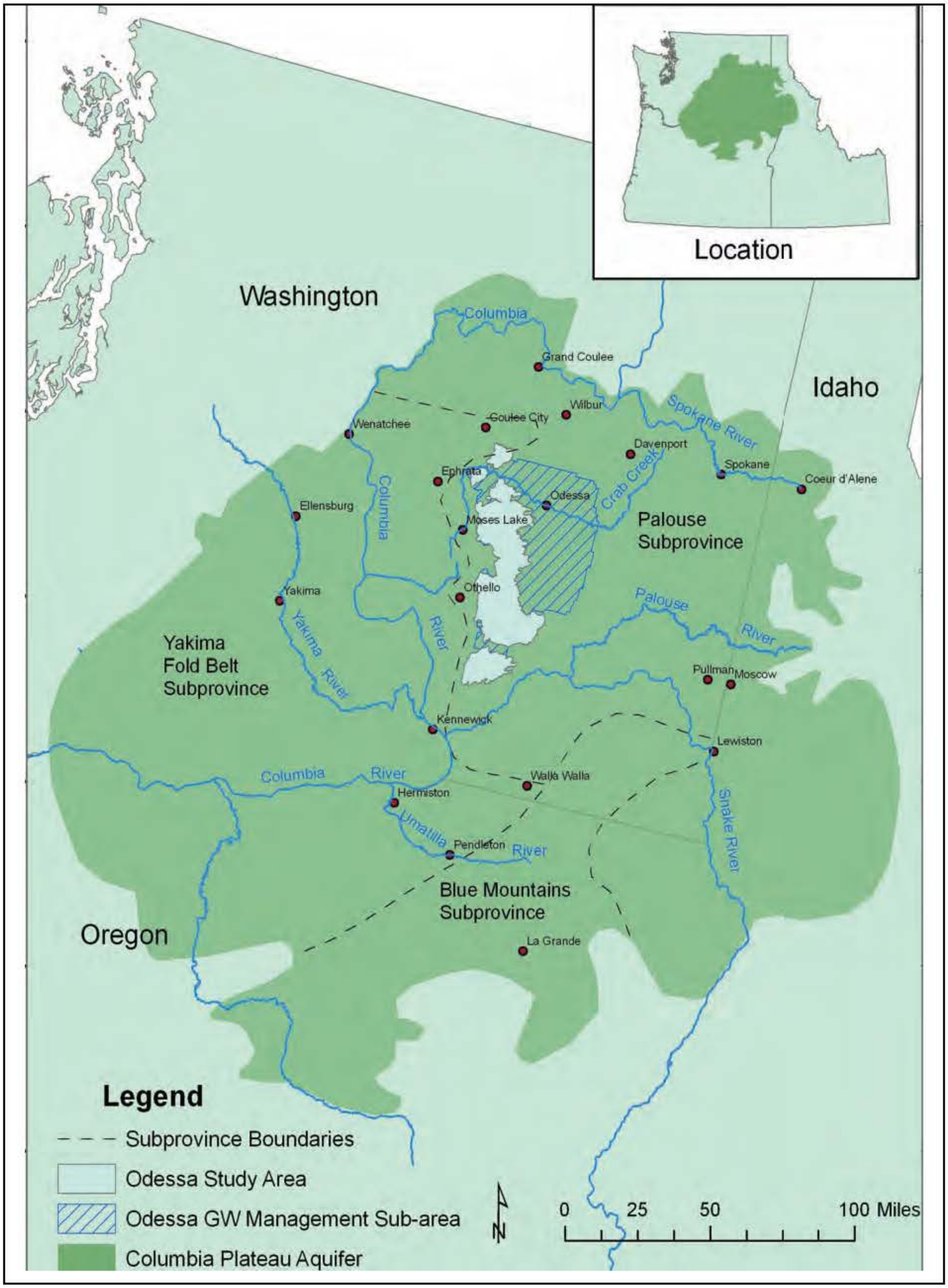

Figure 3. Aquifer location map.

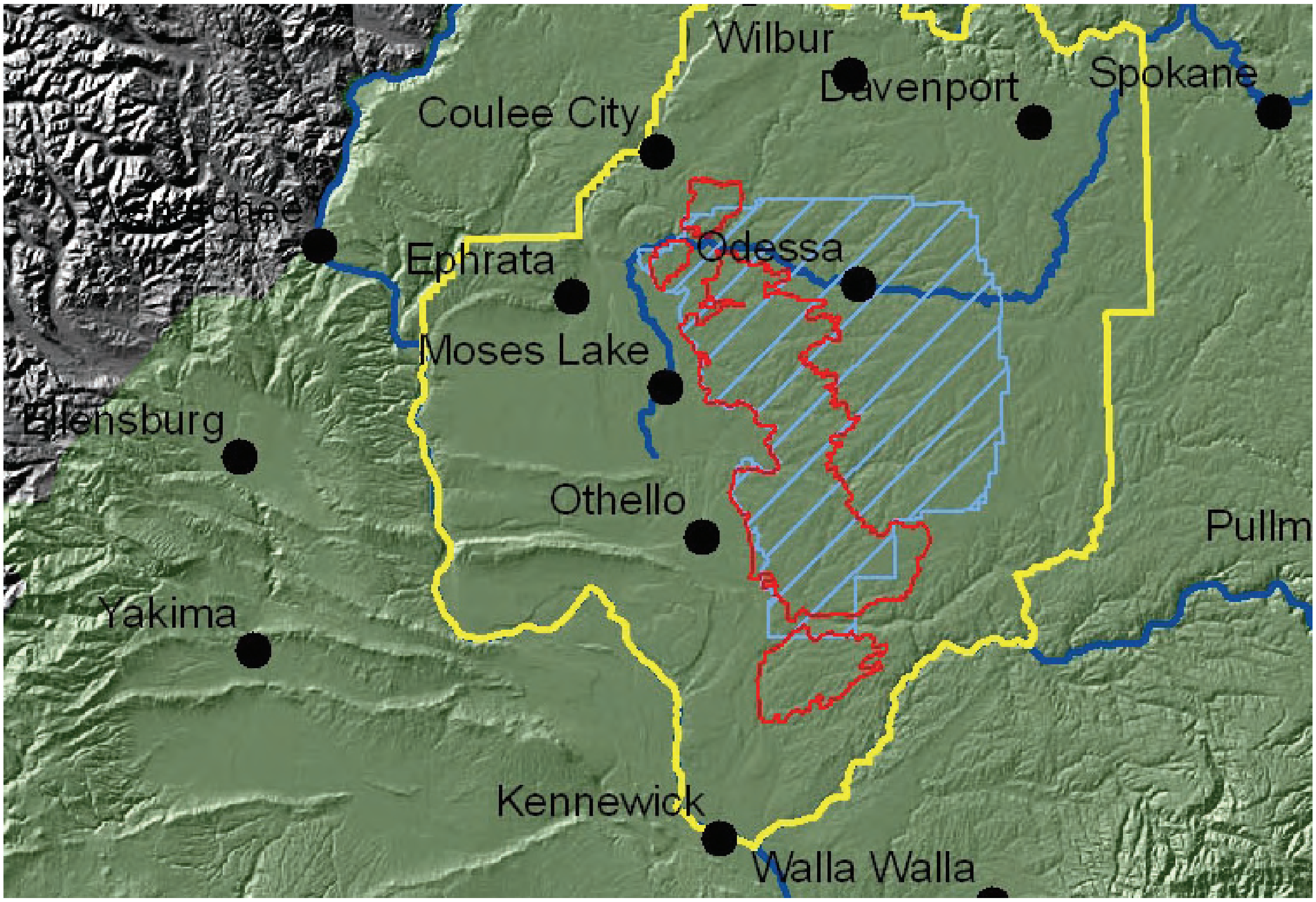

Figure 4. Boundaries of the Odessa Subarea (blue), GWMA (yellow), and Reclamation's eligible CBP area (red).

comprise shallow, unconfined aquifers. The Quaternary loess is generally confined to the upland areas, is fine grained, and does not typically serve as a productive aquifer. The Ringold Formation is highly variable. It generally origited deposits. The enates from rivers but also contains lake and variably-cemenxtent of the unit and lithology varies by location and depends on closeness to a stream or lake during deposition. Aquifers within the Ringold range from unconfined to locally confined.

The extent and continuity of the basalt units, as well as thickness and composition of the individual flows and their relation to overlying sediments, varies greatly, creating a complex and heterogeneous aquifer system. The regional dip of the basalt, approximately 5 degrees toward the southwest, influences regional groundwater flow direction. Internal structure and physical properties of the individual basalt flows have considerable influence on the local occurrence and movement of groundwater.

2.4.2 Hydraulic Properties

Hydraulic and storage properties of the basalts range over several orders of magnitude and demonstrate how variable these units are (Table 1). Groundwater moves most readily through the interflow zones (flow tops and bottoms), though these zones comprise only 5 to 10 percent of the thickness of an individual basalt flow (Whiteman et al. 1994). In the dense-flow interiors, lateral water movement is probably negligible, since the predominant fractures are usually near-vertical and are often filled with secondary mineralization. Vertical water movement, though diminished by fracture in-filling, does occur. Vertical water movement is sizeable when considered over the entire aquifer area, though it is relatively small compared to the volume of lateral movement through the interflow zones.

Table 1. Hydraulic and storage properties of the basalt units and overburden sedimentary unit.

Unit	Median and Range Hydraulic Conductivity (ft/day)	Range of Specific Yield (Sy) and Median and Range of Storage Coefficient (S) (dimensionless)
Overburden Sediments	240 (0.023-150,000) (871 sample points)	Sy = 0.0002-0.2
Wanapum Basalt	5.2 (0.007-5,244) (461 specific capacity tests)	S = 3.2 x 10-5 (1.8x10-6 – 9.9x10-5)
Grande Ronde	4.9 (0.005-2,522) (446 specific capacity tests)	S = 1.8x10-4 (6.0x10-6 – 1.1x10-3)

(Whiteman et al. 1994)

The effective porosity of the basalts varies considerably between the flow tops and the dense flow interiors. Samples from wells on the Hanford Reservation indicate a range of effective porosity in the flow tops of 1.6 to 41.6 percent (with a median of 14.45 percent). In contrast, the flow interiors have an effective porosity of 0.2 to 12.4 percent (with a median of 1.85 percent) (Whiteman et al. 1994). In the Study area, a large percentage of the irrigation wells are uncased through most of their depth, which allows for the continual draining of shallow aquifers into deeper aquifers through previously separated interflow zones, as shown in Figure 5. Ecology no longer allows this practice, but cascading wells within the Odessa Subarea continue to contribute to large-scale water-level declines in the upper aquifers.

In Figure 5, wells 4 and 5 were drilled to the same depth, but well 4 was only cased to the top of the bedrock, which leaves the well open to four different aquifers (shown in blue). This allows aquifers with a higher head to drain into deeper aquifers with a lower static head, thus draining the upper aquifers into the lower aquifers. The water level in these wells is a combined head level and can not be directly compared to wells that are cased or open to only one aquifer. These combined head levels within wells make comparing water-level trends through time difficult, which, in turn, makes it difficult to determine the current state of the aquifers.

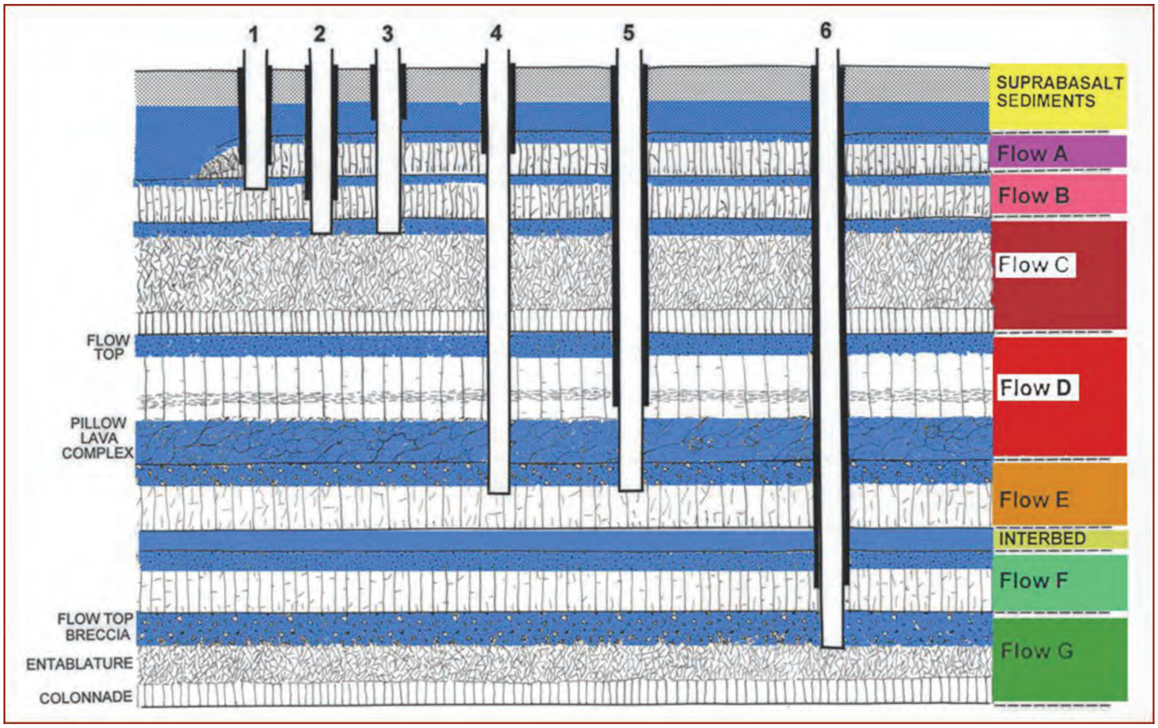

Figure 5. Cased and uncased wells tap different aquifers.

2.4.3 Recharge/Discharge

Precipitation and applied irrigation water are the primary sources of recharge to the aquifer system. Leakage from irrigation canals and rivers also contributes to recharge. Most of the groundwater in the deeper basalt aquifers moves laterally into the Study area from the north and northeast to replace the water pumped for irrigation or other uses. The water pumped from the Grande Ronde aquifer is estimated to be as much as 7,000 years old (Bhattacharjee and Holland 2005). The rate of groundwater recharge does not keep pace with current groundwater use; therefore, there are annual water-level declines. Additional information about water-level declines can be found in the following section of this report.

On the other hand, imported irrigation water from the CBP has raised groundwater levels more than 300 feet in the Quincy basin, where a thick layer of sediments (originally unsaturated prior to the CBP) acts as an underground storage reservoir.

Natural discharge from the aquifer system is primarily to rivers, secondarily to springs and seeps, and also by evapotranspiration. Within the Odessa Subarea, discharge is mainly due to pumping from large-capacity irrigation wells. Total groundwater pumping in the Odessa Subarea in 1984 was estimated at 212,490 acre-feet (Cline and Collins 1992). Based on the quantity of irrigated acreages, current use is estimated between 300,000 and 350,000 acre feet per year.

The spatial variability of recharge is important in determining the direction and movement of groundwater in the aquifer system. Water-level data show that regional flow generally follows the dip of the basalt, to the southwest, towards surface drainage features. Irrigation pumping in the Odessa Subarea has altered regional flow toward the water-level depression created in that area since the 1960s (Whiteman et al. 1994). Throughout most of the Columbia River Plateau, the vertical flow component is downward, except near discharge areas (Vaccaro 1999).

Seasonal water-level fluctuations are a result of precipitation and water use patterns. They vary due to depth of the aquifer and the degree of hydraulic connection with surface water processes. In general, shallower aquifers exhibit greater seasonal fluctuation than deeper aquifers. However, the deeper basalt units of the Study area show greater seasonal fluctuation than the shallower units due to seasonal pumping.

2.4.4 Water-Level Declines

When recharge and discharge from an aquifer system are equal, the system is in equilibrium and long-term aquifer storage is unchanged (water levels return to the same static level from year to year). When discharge exceeds recharge, water levels decline. Although the CBP has resulted in an overall increase in recharge to the groundwater system, most of the increase enters the overburden sediments and shallow basalts and results in increased leakage back to surface water bodies. Vertical flow to the deeper basalt units is impeded by the basalts themselves (i.e., by the rock characteristics and internal structure described in Section 2.3, “Geology”) and recharge from the CBP is minimal to the deep Wanapum and Grande Ronde basalts within the Study area. Pumpage in the Odessa Subarea has increased discharge from the aquifer system and resulted in significant water-level declines (Cline 1984 and Lane and Whiteman 1989).

Many of the wells within the Study area are uncased through multiple aquifers. Some wells only partially penetrate an aquifer. Many wells have been deepened as water levels have declined and may be pumping from a different aquifer than they were originally. All of these conditions make comparisons and interpretation of water-level data difficult. Wells that are open to both basalt units exhibit a composite water level, but the hydrograph pattern generally corresponds to that of wells that pump from the Grande Ronde alone (Cline 1984).

Figure 6 was compiled from information presented in Cline (1984) and illustrates the average water-level decline from spring 1968 to spring 1981 in wells that tap the combined Wanapum and Grande Ronde aquifers. By 1981, the water level had dropped more than 125 feet in an isolated area east of Othello and had dropped more than 100 feet in a relatively large area between Odessa and Moses Lake.

Ecology maintains a network of about 100 monitoring wells that are measured annually in late winter to provide data for managing the State groundwater management area. They have also produced hydrographs and maps of groundwater-level declines in the Odessa Subarea. Reclamation contracted with USGS to measure additional wells in and near the Study area during 2006. A total of 180 wells were measured. In 2007, Reclamation returned to about 20 of those wells.

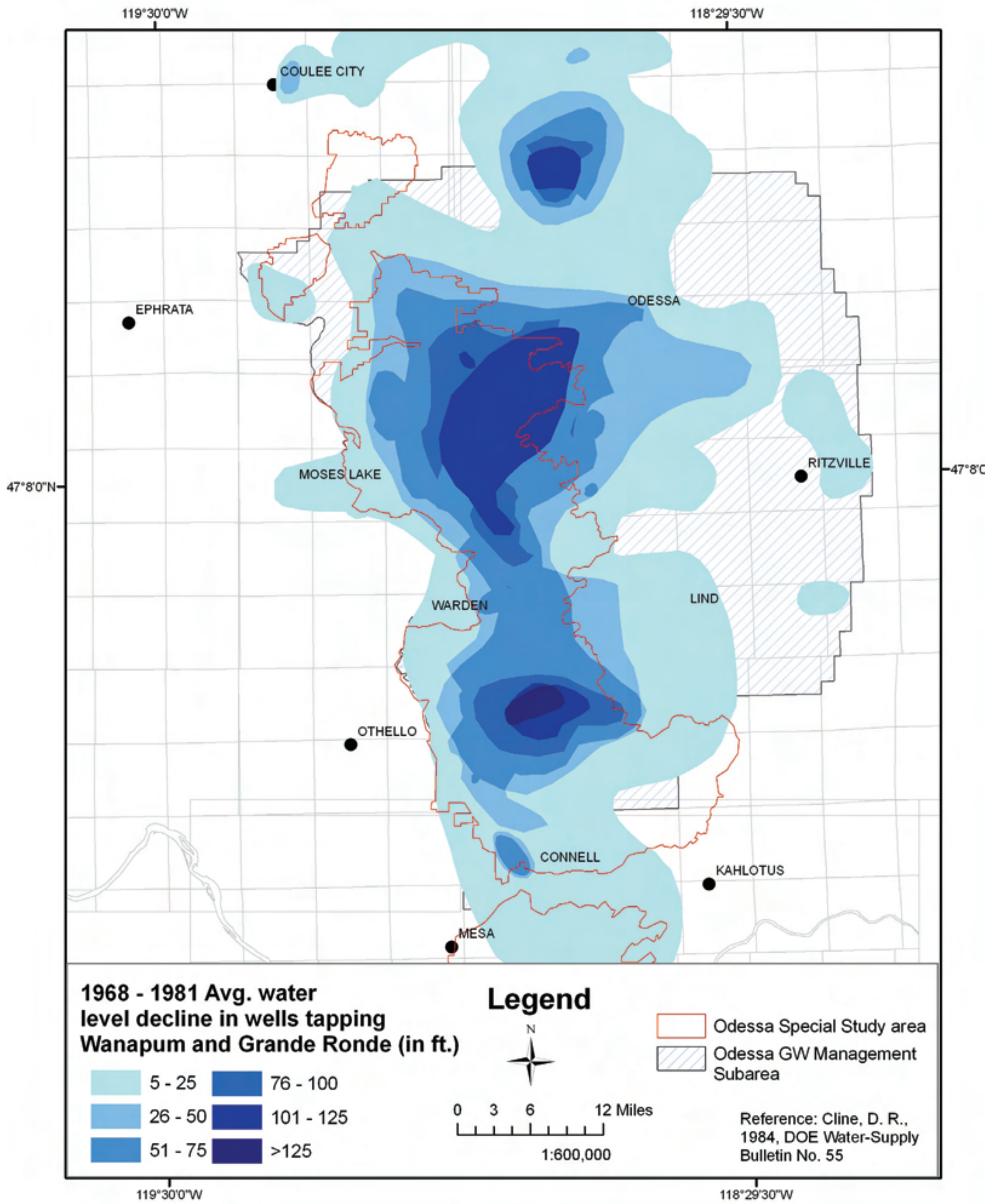

Figure 6. Water-level decline, 1968-1981, in wells tapping the Wanapum and Grande Ronde basalts (Cline 1984).

Water-level changes from the 1980s (or earliest available measurements) to the most current measurement were tabulated. Most of the wells have experienced water-level declines, some as much as an additional 200 feet. However, not all of the wells have had water-level declines. Some even exhibit a water-level rise (these are generally located along the eastern edge of the developed CBP and have benefited from the additional groundwater recharge of applied irrigation water).

Figure 7 shows declines in three measured wells from the 1970s through 2006. For example, two wells showed 175 feet of decline in 30 years, and another well showed a decline of 100 feet in 30 years. While not all wells have shown declines, the overall pattern of water-level decline remains similar to the initial pattern. The area of decline has spread and deepened over the past 25 years as wells have been drilled deeper. The pattern is influenced primarily by the location of the large capacity wells but is probably also affected by geologic structure and heterogeneities within the basalts. The replacement of groundwater by surface water for irrigation will allow groundwater levels to slowly recover in the Study area.

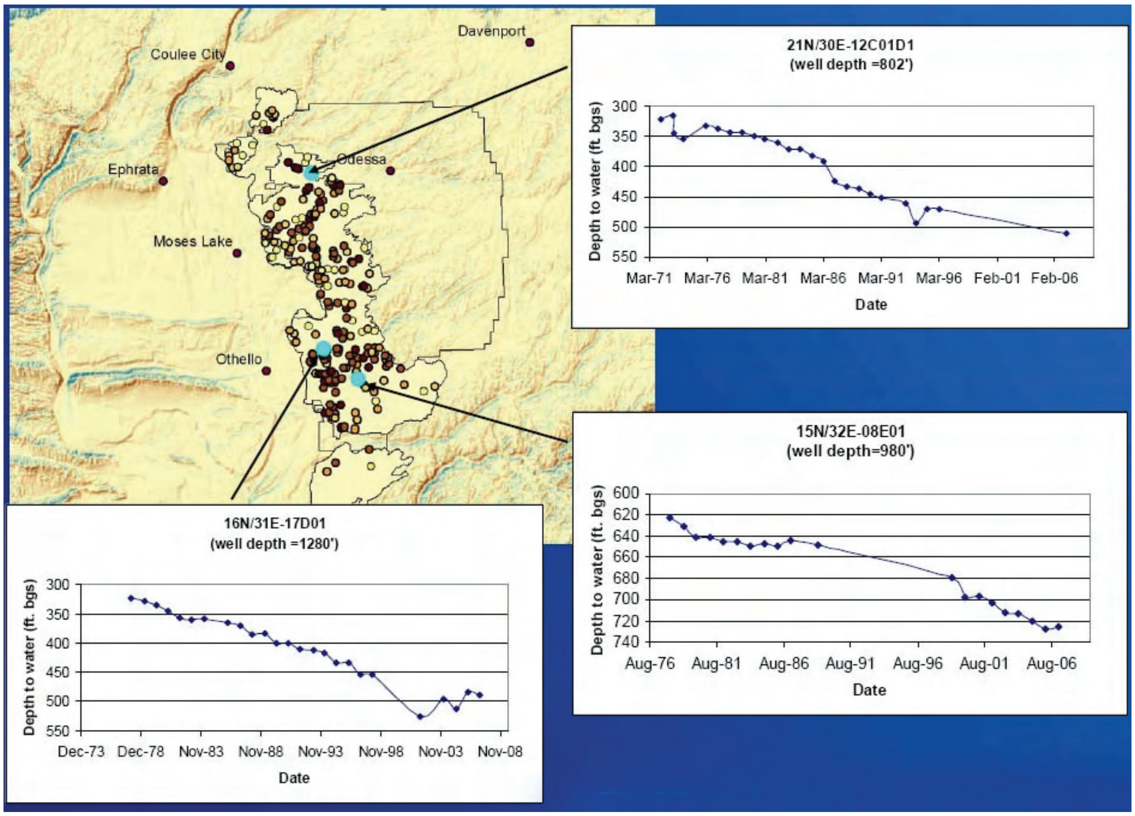

Figure 7. Well decline trends in wells in different locations and at different depths.

2.5 Surface Water

The Columbia River is one of the world's largest rivers, draining a basin that encompasses about 259,000 square miles in the northwestern United States and southwestern Canada. It is the 15th longest river in North America and carries the 6th largest volume of water. The Columbia River starts a 1,214 mile journey at Columbia Lake on the west slope of British Columbia's Rocky Mountains. It flows from Canada into the United States and becomes the border between Oregon and Washington. It empties into the Pacific Ocean near Astoria, Oregon. The Columbia River basin is bounded by the Rocky Mountains to the east and north, the Cascade Range on the west, and the Great Basin to the south.

Within the drainage are numerous subbasins formed by tributaries of the mainstem river, including the Kootenai, Flathead/Pend Oreille, Snake, and Willamette rivers.

The Columbia River is second only to the Missouri-Mississippi River system in the U.S. in runoff, with an average annual runoff at its mouth of about 198 million acre-feet. Most of the annual precipitation occurs in the winter, with the largest share falling in the mountains as snow. The snowpack is released in the spring and early summer, and about 60 percent of the natural runoff in the basin occurs during May through July. Within the CBP, major drainages to the Columbia River basin are predominantly coulees, which either have intermittent flows or are primarily dry. The primary natural inflow to the CBP is from the Crab Creek watershed with surface and subsurface components. Most of this natural water enters the CBP via surface flows from Upper Crab Creek and Rocky Ford Spring, and subsurface flows to Potholes Reservoir.

2.6 Water Resource Development and Management

The Columbia River system has been extensively developed for:

- **Flood control.** The Columbia River's flow varies widely, and the river is subject to severe floods. Controlling damaging floodwaters was one of the original purposes for many of the dams.
- **Electric power generation.** The hydroelectric dams on the Columbia River basin rivers are the foundation of the Northwest's power supply and have a maximum nameplate capacity of 22,500 megawatts.
- **Irrigation.** The construction of railroad systems and government land-grant acreages attracted farmers and investors in agriculture-related businesses. As in many parts of the West, agricultural and economic development in the Columbia River basin depend on the availability of water. The ability to store and distribute water from the Columbia River allowed farms to locate away from surface water bodies and to grow products that require a larger quantity of water. Six percent of the Columbia River basin's water (measured at its mouth; 9 percent of flows at The Dalles Dam) is diverted for agriculture.
- **Navigation.** Four Federal dams on the mainstem of the Columbia River have navigation locks for boats and barges.
- **Recreation.** The rivers and lakes in the Columbia River basin attract boaters, sport anglers, swimmers, hunters, hikers, and campers throughout the year.
- **Water supply and quality.** The Columbia River system supplies water to numerous municipalities and industries.

Figure 8 shows the 11 dams on the United States' portion of the mainstem of the Columbia River (Grand Coulee, Chief Joseph, Wells, Rocky Beach, Rock Island, Wanapum, Priest Rapids, McNary, John Day, The Dalles, and Bonneville dams) and 3 dams in the British Columbia, Canada's portion of the mainstem of the Columbia River (Mica, Revelstoke, and Keenleyside dams).

Figure 8. Major dams in the Columbia River basin.

2.6.1 Columbia Basin Project

The CBP is multipurpose, providing irrigation, power production, flood control, municipal water supply, recreation, and fish and wildlife benefits. The CBP includes 330 miles of main canals, 1,990 miles of smaller canals, and 3,500 miles of open drains and wasteways served by more than 240 pumping plants. Reclamation currently diverts about 2.7 million acre-feet of water from the Columbia River to irrigate about 671,000 acres. Up to 67 different crops are grown, with more than a half billion dollars of crop value each year; alfalfa, potatoes, apples, and vegetables are the major contributors.

Three irrigation districts receive CBP water: Quincy-Columbia Basin Irrigation District (Q-CBID), East Columbia Basin Irrigation District (ECBID), and South Columbia Basin Irrigation District, serving 247,122 acres, 152,000 acres, and 232,000 acres, respectively. Reclamation, along with these irrigation districts, operates and maintains the CBP. Transferred works are facilities owned by Reclamation but operated and maintained by an irrigation district or other entity. These include basic irrigation facilities such as canals, laterals, wasteways, and pumping plants. Reserved works, irrigation facilities that are operated by Reclamation, include Grand Coulee Dam and Powerplant and Pumping Plant, Banks Lake, Dry Falls Dam, Main Canal, Potholes Reservoir, and Potholes Canal headworks.

Principal Features

Irrigation works extend southward on the Columbia River Plateau 125 miles to the vicinity of Pasco, Washington, where the Snake and Columbia rivers join. Principal CBP features are listed below. Figure 9 provides a map of these features and Figure 10 shows the relative size of the Main Canal.

- **Grand Coulee Dam**. The largest concrete structure ever built raises the water surface 380 feet above the old riverbed. It is 5,673 feet long, 550 feet high, and contains about 12 million cubic yards of concrete. The spillway of the dam is capable of spilling 1 million cubic feet per second (cfs) with Lake Roosevelt at full pool (1290.0 feet above sea level).
- **Lake Roosevelt.** The reservoir behind the dam extends 151 miles northeast of the Canadian border and up the Spokane River, a tributary of the Columbia River, to within 37 miles of Spokane. The total storage capacity of the reservoir is about 9.4 million acre-feet, and the active capacity is about 5.2 million acre-feet.
- **Grand Coulee Powerplant Complex**. The total generating capacity for Grand Coulee (including the Grand Coulee Pump-Generating Plant) is 6.809 million kilowatts.
- **Relift Pumping Plants.** About 360,000 acres of the irrigable lands within the CBP are located at elevations higher than the gravity canals and laterals. Some of these high lands are being served by re-lift pumping plants.
- **Banks Lake (North and Dry Falls dams)**. Banks Lake, the equalizing reservoir, was created by building two rock-faced, earthfill dams at the north (North Dam) and south (Dry Falls Dam) ends of the Grand Coulee. This 27-mile-long reservoir, with an active storage capacity of 715,000 acre-feet, feeds Columbia River water into the Main Canal.

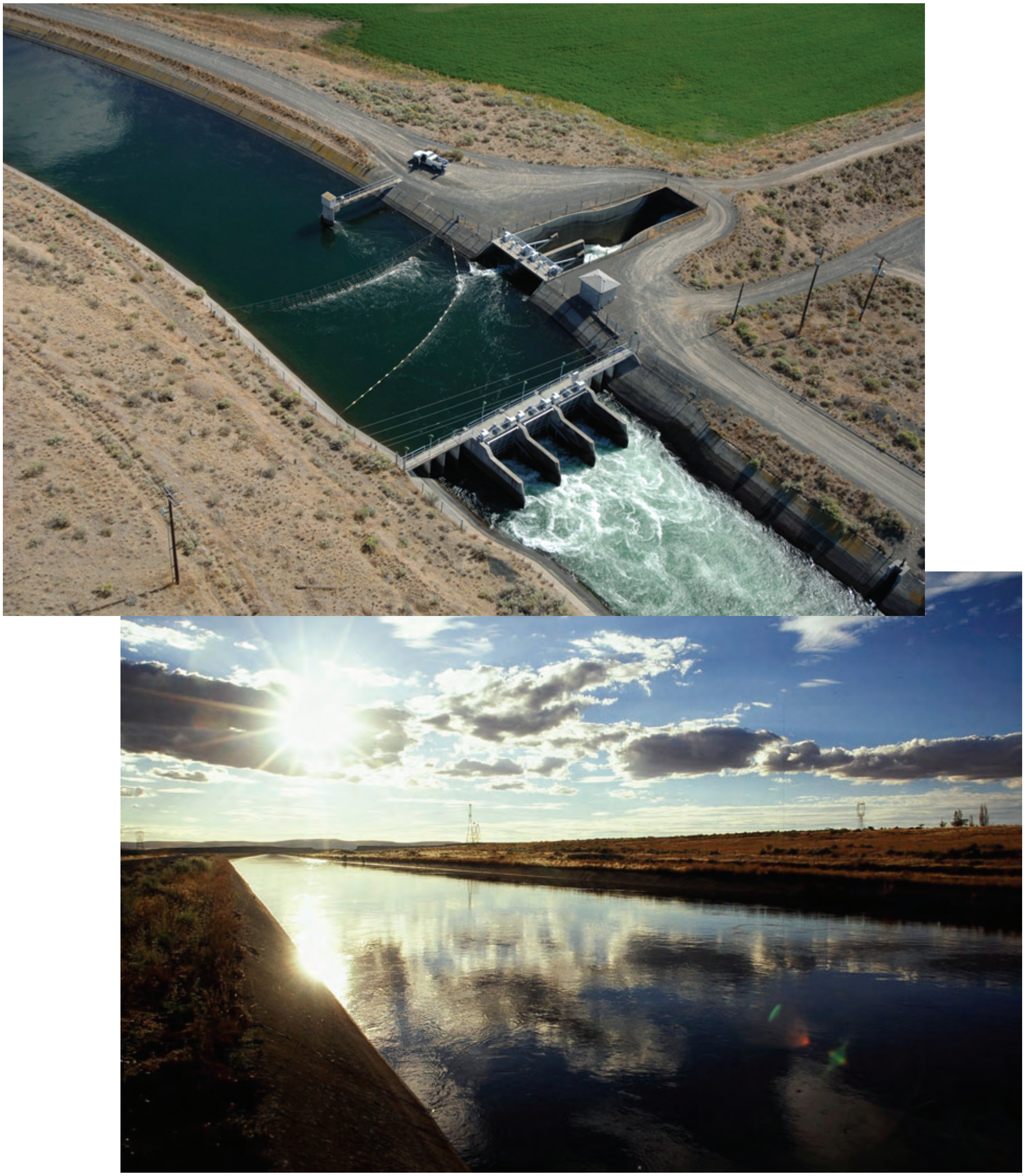

Figure 9. Top photo: Bifurcation of the Main Canal into the East Low Canal headworks (branches off to right) and West Canal (at the bottom of the photo). Bottom photo: Main Canal.

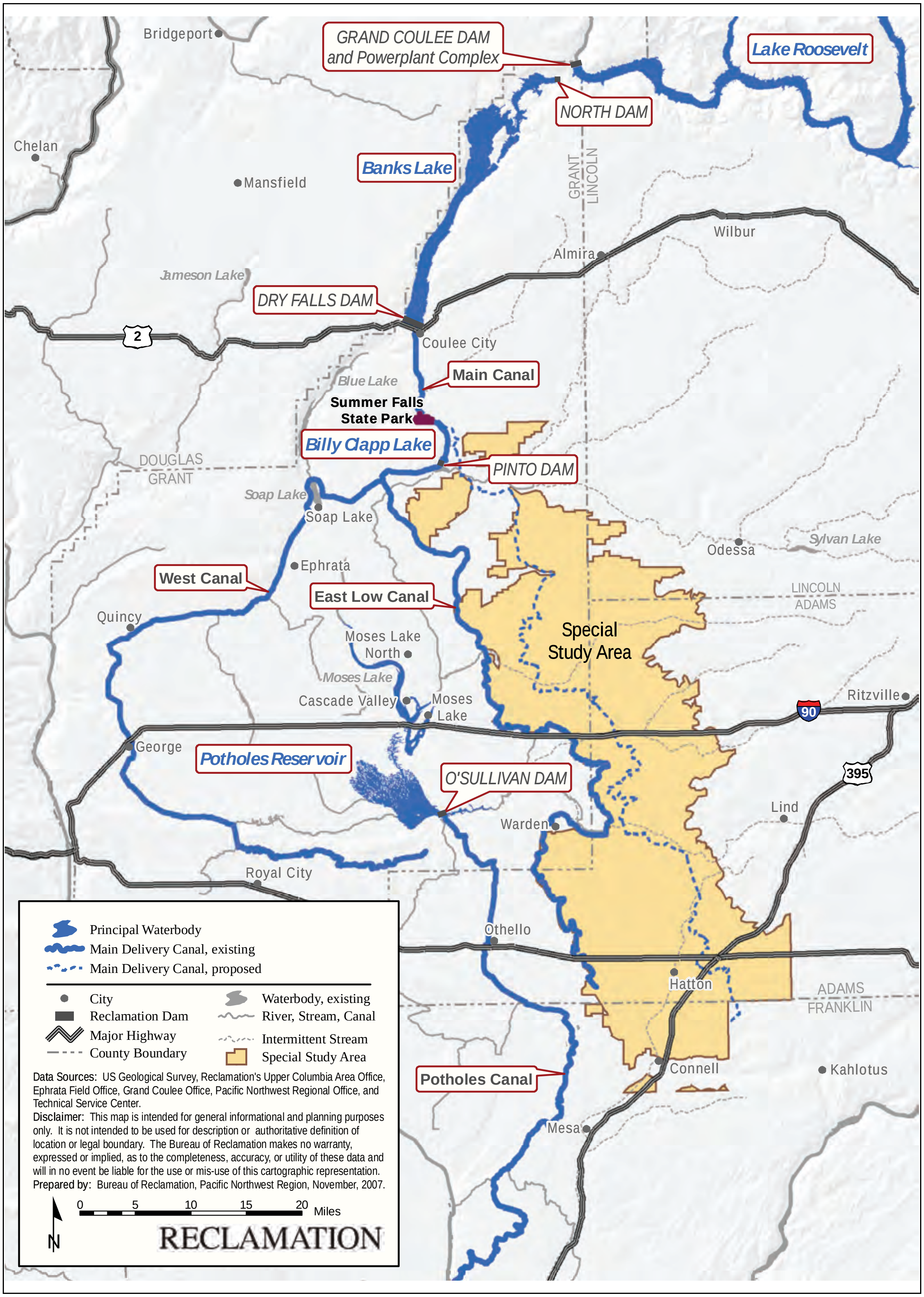

Figure 10. CBP features.

- **Main Canal**. The Main Canal begins at the headworks at Dry Falls Dam and consists of unlined and concrete-lined sections. Total length of the canal, including siphons, tunnels, and Billy Clapp Lake, is 18.4 miles. The first 1.8 miles from Dry Falls Dam to Bacon Siphon and Tunnel structures have a capacity of 19,300 cfs. Bacon Siphon and Tunnel structures consist of two siphons, each about 1,000 feet long, and two tunnels, each about 2 miles long, that carry the water to Billy Clapp Lake.
- **Billy Clapp Lake (Pinto Dam)**. Some 6 miles long, Billy Clapp Lake is a segment of the canal system.
- **West Canal**. The West Canal has an initial capacity of 5,100 cfs and is 82.2 miles long. It is one of two canals formed by the bifurcation of the Main Canal. The capacity of the canal is reduced progressively as water is diverted into lateral distribution systems built to serve the Q-CBID and the lands in the northwestern portion of the CBP.
- **East Low Canal.** The East Low Canal, 86 miles long and with an initial capacity of 4,500 cfs, also begins at the bifurcation of the Main Canal. The East Low Canal serves lands in the ECBID in the east portion of the CBP.
- **Potholes Reservoir (O'Sullivan Dam)**. One of the larger zoned earthfill dams in the United States, O’Sullivan Dam is on Crab Creek, about 15 miles south of Moses Lake. The 27,800-acre Potholes Reservoir formed by this dam collects return flows from all irrigation in the upper portion of the CBP for reuse in the southern portion. Active storage capacity of the reservoir is 332,200 acre-feet.
- **Potholes Canal**. The Potholes Canal, with a capacity of 3,900 cfs, begins at the headworks of O'Sullivan Dam and extends 62.4 miles to irrigate lands in the southwestern and south-central portions of the CBP for the SCBID. Some SCBID lands receive irrigation water pumped directly from the Columbia River.

Operational Overview

Grand Coulee Dam, the CBP’s key structure, forms Lake Roosevelt, which is on the mainstem of the Columbia River, about 90 miles west of Spokane, Washington. The Grand Coulee Pump-Generating Plant lifts irrigation water approximately 280 feet from Lake Roosevelt to Banks Lake, which serves as an equalizing reservoir for the irrigation system. The Main Canal transports flow southward from Banks Lake at Dry Falls Dam to the northern end of the irrigable area via Billy Clapp Lake, which is an equalizing reservoir within the Main Canal. The Main Canal splits into the East Low Canal and West Canal. These canals carry water to serve a large portion of the north and east portions of the CBP.

In the central part of the CBP, O’Sullivan Dam forms Potholes Reservoir, which receives return flows from the northern part of the CBP. The Potholes East Canal begins at O’Sullivan Dam and runs south to serve the southern part of the CBP area. Potholes Reservoir stores natural runoff from the Crab Creek watershed, which flows through Moses Lake.

During most years, runoff from Crab Creek is low and irrigation return flows and runoff flows into Potholes Reservoir are not sufficient to meet the annual irrigation demand that is supplied from the Potholes East Canal, requiring water to be diverted from Banks Lake to Potholes Reservoir. This water is called feed water.

2.6.2 Columbia River Water Supply

Reclamation will need to divert more water from the Columbia River than current CBP diversions to provide a replacement water supply. NMFS has identified seasonal flow objectives in the Columbia River primarily to aid downstream passage of juveniles and accommodate chum spawning and returning adult salmon and steelhead listed under the ESA. The current ESA flow objectives have been in place since the 1995 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp). This appraisal-level investigation assumed that water from the Columbia River would not be diverted unless flows exceeded these ESA flow objectives. In addition, the State has recently enacted a law that does not allow new Columbia River diversions in July and August without a replacement water supply.

To determine when water could be diverted from the Columbia River under these assumptions, Reclamation updated the hydrologic modeled analysis conducted during the PASS.

Reclamation’s model analysis is based on the output data from Bonneville Power Administration’s (BPA) Hyd-Sim model for the FCRPS. The BPA Hyd-Sim model includes all significant United States Federal and non-Federal dams and the major Canadian projects on the mainstem Columbia River and its major tributaries. The model is widely accepted as accurately simulating current operation of the Columbia River system.

The Hyd-Sim model for the FCRPS simulates Columbia River flows to determine what will happen to flows under different operating scenarios. The model includes the Columbia River seasonal ESA flow objectives, identified at Priest Rapids, McNary, and Bonneville dams. The model uses the current FCRPS system operating requirements for each project and historic hydrologic flow conditions. The model contains a data set of runoff from 1929 through 1998 to determine impacts to various resources and obligations (such as irrigation, flood control, power, instream flow, other contract obligations, project authorizations, and biological opinions). The model does not yet project changes to future water conditions due to climatic change.

To calculate when Columbia River flows exceed ESA flow objectives, Reclamation compared the Hyd-Sim model output and historic data to the ESA flow objectives on the Columbia River at Priest Rapids, McNary, and Bonneville dams. Reclamation then calculated the average monthly flow in excess of flow objectives as Columbia River water available for diversion to the CBP. Figure 11 shows the volume and time Columbia River flows exceed ESA flow objectives for the 1936-1945 period. These years represent the 10 consecutive driest years for the 1928-1998 period of record that data were available.

Reclamation’s analysis concluded that no water is available for diversion from the Columbia River the months of April through August. However, significant water is available for diversion when the canals are still operational during September and October, as well as January, December, and May.

2.7 Fish and Wildlife

This section summarizes the fish and wildlife resources, including habitat types, that occur in the Study area. This information was obtained through consultation with the FWS under the FWCA and through communications with the WDFW.

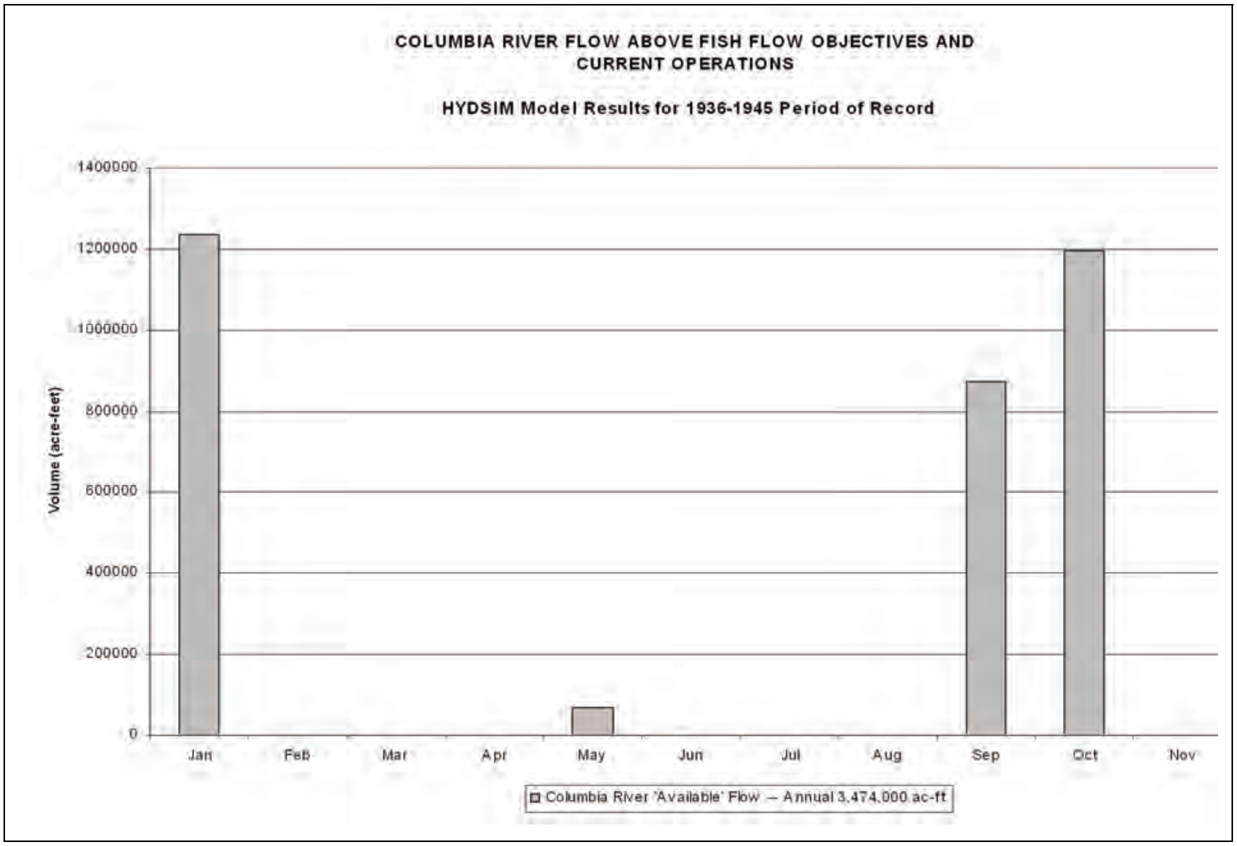

Figure 11. Average Columbia River monthly volume above ESA flow objectives for 1936-1945.

2.7.1 Habitat/Land Cover

Natural vegetation in the Study area and vicinity is characterized as the shrub-steppe vegetation zone with big sagebrush-bluebunch wheatgrass (*Artemesia tridentata-Agropyrona spicatum*) (Franklin and Dyrness 1988). This plant association is found in the driest portions of the Columbia River Plateau.

Vegetation within the central Columbia River Plateau is transitional to the ponderosa pine woodland of the eastern flank of the Cascade Mountain Range to the west, the grasslands of the Palouse region to the east, and the mixed conifer forests of northeastern Washington to the north and east. A variety of shrubs, grasses, and forbs may be present, depending on environmental conditions such as sediment depth, soil moisture, aspect, altitude, and slope.

Sagebrush (*Artemisia tridentata* and *Artemisia rigida*) and grasses are the dominant plants, with trees and shrubs limited to riparian areas. Hillslope soils are typically shallow and rocky, while valley bottom soils are often deep, silty, and gravelly.

Vegetation within a large portion of the region has changed dramatically as irrigation water provided by the CBP made the land suitable for irrigated crops.

Noxious weeds are a common problem in the Study area and generally invade and occupy sites that have been previously disturbed by fire, livestock grazing, motorized travel, and/or dispersed camping. A weed is usually defined as any plant species that is not native to the area (except for agricultural crops). Weeds typically interfere with maintaining healthy and diverse ecosystems. Consequently, weed control is an integral part of resource management, as non-natives can displace native plant species, are often of lower forage value to wildlife, and are difficult to extirpate once established. Other wildlife requisites, such as cover and nesting habitat, are also affected by the replacement of native plants by weedy species.

Non-native weedy plants often dominate disturbed area vegetation, including cheatgrass (*Bromus tectorum*), diffuse and spotted knapweed (*Centaurea diffusa* and *C. biebersteinii*, respectively), tumble mustard (*Sisymbrium* sp.), Canada thistle (*Cirsium arvense*), pepperweed (*Lepidium latifolium*), kochia (*Kochia scoparia*), dalmation toadflax (*Linaria dalmatica dalmatica*), Russian knapweed (*Acroptilon repens*), purple loosestrife (*Lythrum salicaria*), and Russian thistle (*Salsola kali*). Cheatgrass, the most common weed found in the Study area, has invaded many areas where native perennials have been overused and/or eliminated. There is little evidence that cheatgrass will relinquish a site once occupied due to its highly competitive ability.

Shrub-Steppe Habitat

Within the Study area, habitats that are not converted to cropland are typically shrub-steppe vegetation types. Daubenmire (1988) described shrub-steppe as vegetative communities consisting of one or more layers of perennial grass with a conspicuous but discontinuous overstory layer of shrubs. In the Crab Creek Subbasin, for instance, shrub-steppe also includes 'meadowsteppe' and 'steppe' habitats which may have a relatively low frequency of shrubs. The dominant shrubs include sagebrush, rabbitbrush (*Chrysothamnus spp*.), bitterbrush (*Purshia tridentata*), greasewood (*Sarcobatus spp*.), and spiny hopsage (*Grayia spinosa*). The dominant grasses include native bunchgrasses (*Poa*, S*tipa*, and *Agropyron spp*.) and non-native downy brome (*Bromus tectorum*). Dobler and Dixon (1996) reported 96 species of perennial plants on limited transects in the Columbia River basin. Undisturbed upland areas contain sagebrush, bitterbrush, greasewood, and rabbitbrush (KWA Ecological Sciences, Inc. 2004).

Current shrub-steppe conditions in the Columbia River basin are greatly altered from those existing prior to European-American entry into the area. The WDFW reports that over half of the total shrub-steppe land in Washington has already been lost to development (Vander Haegen et al. 2001 in WDFW 2007 [Letter]). Wooten (2003) also estimated that only 46.3 percent of previously existing shrub-steppe habitat remains. However, Wooten (2003) states that this is likely an overly optimistic estimate of remaining habitat. Ninety-eight percent of this loss is attributable to farmland development. Previously, Dobler and Dixon (1996) reported that from 62 percent (Lincoln County) to 76 percent (Adams County) of the shrub-steppe habitat within the CBP area has been lost. Dobler and Dixon (1996) reported that almost 60 percent of the remaining shrub-steppe habitat was privately owned (Table 2). Much of the

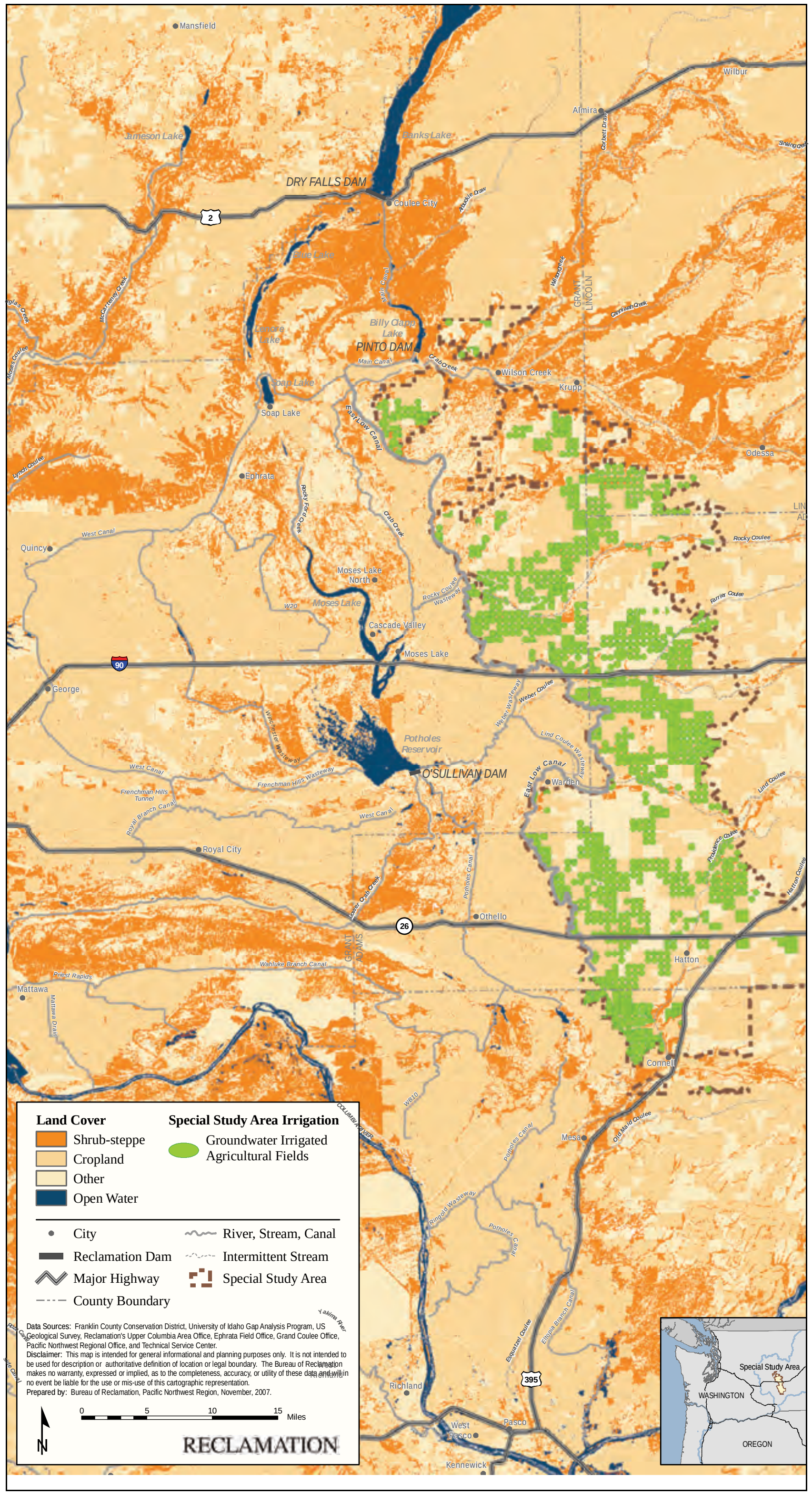

Figure 12. Land cover in the Study area and surrounding area, including shrub-steppe habitat (Davidson et al. 2007).

Table 2. Remaining acres of shrub-steppe habitat by county

County	Historical	Remaining	Percent Lost
Adams	1,187,399	279,758	76
Franklin	753,716	230,778	69
Grant	1,614,555	571,830	65
Lincoln	1,260,032	473,674	62

(Dobler and Dixon 1996)

confusion surrounding estimates of remaining shrub-steppe habitat may be from inconsistent use of terminology between documents. Figure 12 depicts shrub-steppe habitat in the Study area and surrounding areas, as well as other land cover based on a recent inventory.

Many species depend upon native Columbia River basin habitats, such as shrub-steppe. WDFW is concerned about these dependant species such as pygmy rabbit (*Brachylagus idahoensis*), black and white-tailed jackrabbits (*Lepus californicus and L. townsendii*), Washington ground squirrels (*Spermophilus Washingtoni*), sagebrush lizard (*Sceloporus graciosus*), sage sparrow (*Amphispiza belli*), brewer's sparrow (*Spizella breweri*), grasshopper sparrow (*Ammodramus savannarum*), sage thrasher (*Oreoscoptes montanus*), and sharp-tail (*Tympanuchus phasianellus*) and sage grouse (*Centrocercus urophasianus*. Preserving large tracts of the native shrub-steppe habitat may be the best long-term method for protecting these species.

Riparian Habitat

Areas of streamside or riparian habitat are dispersed throughout the shrub-steppe habitat. Knutsen and Naef (1997) estimate between 50 and 90 percent of previously existing riparian areas on the Columbia River Plateau have been destroyed or drastically altered. The annual loss Statewide averages 2,034 acres per year (Knutsen and Naef 1997). In the Study area, large areas of riparian habitat are found along lower Crab Creek and around Banks Lake and Potholes Reservoir. Much of this habitat has been created as a result of irrigation development.

An estimated 85 percent of wildlife species found in Washington State use riparian habitats for all or significant portions of their life activities (Thomas et al. 1979 and Brown 1985 in Knutsen and Naef 1997). Andelman and Steele (1994 in Knutsen and Naef 1997) report that 67 of 118 neotropical migrants use riparian areas.

Riparian vegetation consists of willows (*Salix spp*.), rose (*Rosa spp*.), water birch (*Betula occidentalis*), black cottonwood (*Populus angustifolia*), aspen (*P. tremuloides*), hawthorn (*Crataegus douglasii*), and serviceberry (*Amelanchier alnifolia*). Undisturbed riparian areas in the Study area contain rose, birch (*Betula spp.*), black cottonwood (*Populus augustifolia*), aspen, serviceberry, and hawthorn (*Crataegus douglasii*).

Grasslands

Grasslands are uncommon in the Study area and are generally the early successional phase of shrub-steppe. Some grassland areas show evidence of recent fire and contain young shrubs. Grasslands are defined as those areas containing less than 5 percent shrub cover. Typical native grasslands contain bluebunch wheatgrass and needle-and-thread (*Stipa comata*). Cheatgrass is the dominant non-native grass. Many areas identified as grassland more closely resembles weedy fields with several dominant weedy forbs and relatively low plant diversity.

Cropland

Table 3 shows the total number of farms and amount of irrigated acreage for each county within the Study area. Note that the eligible groundwater-irrigated acres of the Study area are in portions of all of the counties listed in the table. Grant, Adams, and Franklin counties are economically driven by farm and crop-related industries, while Lincoln County's economy is more unspecialized (Rural Policy Research Institute 2005). Since 1964, the number of farms in Washington State, as a whole, has decreased, while the average farm size has increased (USDA 1998). All four counties have farms that average well above the mean size for the State. Most farm owners list farming as their primary occupation (USDA 1998).

Table 3. Farmland in the Study area

County	Total		Irrigated	
	Farms	Acres	Farms	Acres
Adams	628	1,096,447	294	148,018
Grant	1699	1,095,099	1409	446,183
Franklin	848	563,716	725	221,145
Lincoln	707	1,375,869	120	47,984

(USDA 1998)

Currently, approximately 35,600 acres of the CBP area are in potato production (Bhattacharjee and Holland 2005). Table 4 lists major crops by acreage for the four counties within the Study area, which includes lands both within and outside of the CBP boundaries. For reference, in 2000, the four counties listed produced almost 66 percent of the State's potato production, 65 percent of the hay production, and almost 40 percent of wheat production (Bhattacharjee and Holland 2005).

Table 4. Major agricultural crops by county (in acres)

Crop	County			
	Adams	**Grant**	**Franklin**	**Lincoln**
Corn	5,388	29,963	11,327	564
Wheat*	303,813	203,498	109,627	309,317
Barley	10,022	6,548	Not reported	102,415
Potatoes	27,914	44,263	35,770	771
Hay**	27,252	126,450	75,728	24,902
Vegetables	3,783	61,419	30,145	Not reported

(U.S. Census Bureau 2002)
*Includes dry-farmed (i.e., nonirrigated) wheat.
**Includes nonirrigated silage.

Cliffs and Rock Outcrops

Non-vegetated geologic formations such as cliffs, rock outcrops, and talus slopes also provide important habitat. Sensitive species such as ferruginous hawks (*Buteo regalis*; State Threatened, Federal Species of Concern), peregrine falcons (*Falco peregrinus*; State Sensitive, Federal Species of Concern), and golden eagles (*Aquila chrysaetos*; State Candidate), as well as bats nest on cliffs and rock faces. (Vander Haegen et al. 2001). Further, all of the Columbia River basin snake species and about half of the lizard species are associated with rocky features such as rock outcrops and talus slopes (Vander Haegen et al. 2001). Lastly, talus slopes provide refuge for small mammals and refuge for a variety of snakes including striped whipsnakes (*Masticophis taeniatus*, State Candidate) (Vander Haegen et al. 2001) that are likely to occur in the area.

Aquatic Habitat

The Columbia River basin has four major watersheds: Crab Creek, Douglas Creek, and Foster Creek that flow to the Columbia River, and the Palouse River that flows to the Snake River. Only Crab Creek is within the CBP area. Upper Crab Creek begins near Spokane and flows southwestward to Wilson Creek in Grant County, then on to Moses Lake. Crab Creek flows through Moses Lake into Potholes Reservoir. It reappears below Potholes Reservoir as a result of seepage and discharges from the irrigation canal system and flows westward, emptying into the Columbia River near Beverly.

Wasteways have seasonal and daily flood patterns not typical of native streams. Several coulees that had intermittent streams prior to the CBP now support perennial flow, and include Rocky, Lind, and Red Rock coulees. Flows in Crab Creek, below Stratford, are augmented with irrigation return flows.

2.7.2 Wildlife

Birds

More than 151 species of birds may be in the Study area. Appendix B lists typical bird species that occur in the Columbia River basin.

- **Raptors.** Excellent raptor nesting habitat in the basalt cliffs and other habitat diversity within the Study area have resulted in a high diversity of raptors using the Study area, including nesting peregrine falcons, prairie falcons (*Falco mexicanus*), and bald eagles (*Haliaeetus leucocephalus*). The bald eagle, although no longer listed under the ESA, is still federally protected under other laws and regulations.
- **Colonial-nesting birds.** Colonial-nesting birds may include great blue heron (*Ardea herodias*), black-crowned night-herons (*Nycticorax nycticorax*), California gulls (*Larus californicus*), ring-billed gulls (*Larus delawarensis*), caspian terns (*Sterna caspia*), Canada geese (*Branta canadensis*), mallards (*Anas platyrhyncos*), and western grebes (*Aechmophorous occidentalis*).
- **Waterfowl.** Waterfowl use primarily occurs during the breeding season, with the highest diversity of species throughout the field season in the various wetlands and ponds.
- **Shorebirds.** A diverse shorebird population is in the Study area; however, their numbers are low because there is little suitable habitat.
- **Neotropical migratory birds.** Neotropical migratory birds (NTMB) are species which breed in the United States and Canada and then migrate south to Mexico, Central or South America, or the Caribbean for winter. They do not include waterfowl, shorebirds, or herons and egrets, even though some species in these groups also winter south of the Mexico-United States border. There is widespread concern about the future of NTMB, since many of these species have experienced large population declines due to habitat destruction on the breeding grounds, wintering areas, and along migration routes. In addition to riparian and wetland habitats, which are important for two-thirds of the NTMB within the Study area, mesic shrub and shrub-steppe habitats are also important to several species. Sixty-six NTMB species may be within the Study area.
- **Other sensitive bird species.** Common loons (*Gavia immer*) were reported to have successfully bred at Banks Lake several years ago, and one loon in breeding plumage was observed in June 2002. Small numbers of American white pelicans (*Pelecanus erythrorhynchos*) were observed using the south portion of Banks Lake during spring and fall migrations.

Mammals

At least 34 species of mammals have been documented within the Study area. These range from large quadrupeds like elk (*Cervus elaphe*) and deer (*Odocoileus spp.*), to predators like coyotes (*Canis latrans*), to small rodents like ground squirrels (*Spermophilus spp. and Citellus spp*.). In addition, five bat species, which are Federal Species of Concern may occur: fringed myotis (*Myotis thysanodes*), long-eared myotis (*M. evotis*), pale Townsend's big-eared bat (*Plecotus* *townsendii pallescens*), small-footed myotis (*M. ciliolabrum*), and Yuma myotis (*M. yumanensis*). Appendix B lists mammals that may occur in the Study area.

Reptiles and Amphibians

Eleven species of amphibians and reptiles have been documented in the Banks Lake area, and more amphibian species may occur in the Study area. The only documented record of the Columbia spotted frog (*Rana luteiventris*), a Federal Species of Concern and a State Candidate species, was in the Banks Lake area in 1937. The only documented population of northern leopard frogs in eastern Washington occurs at Potholes Reservoir. Appendix B contains a list of potential reptiles and amphibians that occur within the Study area.

Game Species

Game species that may occur in the Study area include: chukar (*Alectoris chukar*), ring-necked pheasant (*Phasianus colchicus*), Rocky Mountain mule deer (*Odocoileus hemionus*), California quail (*Callipepla californica*), ducks, geese, gray partridge (*Perdix perdix*), mourning dove (*Zenaida macroura*), snipe (*Gallinago gallinago*), bobcat (*Lynx rufus*), cottontail (*Sylvilagus floridanus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*).

2.7.3 Fish

Many of the fish species present in Banks Lake originated from Lake Roosevelt on the Columbia River. With the exception of char, brown trout, and rainbow trout, all of the other fish present in pre-reservoir lakes or drafted from Roosevelt Lake were able to establish reproducing populations to various degrees.

Fish found in the Study area between 1973 and 1975 included: peamouth chub (*Mylochelius caurinus*), northern pikeminnow (*Ptychochelius oregonensis*), carp (*Cyprinus carpio*), longnose sucker (*Catostomus catostomus*), largescale sucker (*Catostomus macrocheilus*), bridgelip sucker (*Catostomus columbianus*), brown trout (*Salmo trutta*), mountain whitefish (*Prosopium williamsoni*), lake whitefish (*Coregonus clupeaformis*), brown bullhead (*Ictalurus nebulosis*), walleye (*Stizostedion vitreum*), bluegill sunfish (*Lepomis macrochirus*), and prickly sculpin (*Cottus asper*).

Additional species found in Banks Lake after 1975 and/or that are still present include yellow bullhead (*Ictalurus natalis*), white catfish (*Ictalurus catus*), channel catfish (*Ictalurus punctatus*), and smallmouth bass (*Micropterus dolomieui*). While the smallmouth bass were intentionally stocked, the others may have been illegally introduced.

The Washington Department of Fish and Game, through continuous introductions, developed substantial populations of rainbow trout. Rainbow trout (*Oncorhynchus mykiss*) were one of the three dominant sport fisheries in Banks Lake during the 1960s. These trout are currently stocked. Along with rainbow trout and perch (*Perca flavescens*), kokanee (*Oncorhynchus nerka*) came to dominate the catch in Banks Lake, during the 1960s and 1970s.

Irregular plants of kokanee have been made from the 1950s through the present. The kokanee fishery began to fail in the late 1970s, and anglers ceased to target kokanee in the mid-1980s. Large introductions of kokanee in the 1990s have failed to restore a successful kokanee fishery in Banks Lake. Since 1996, small numbers of kokanee are reared to a larger size in net pens at Electric City and Coulee City before planting to address predation and food availability problems.

Since its inception, Potholes Reservoir has been populated by warmwater gamefish species such as largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), pumpkinseed *(Lepomis gibbosis)*, black crappie (*Pomaxis nigromaculatus*), yellow perch, brown bullhead (*Ictalurus nebulosus*), and nongamefish such as largescale sucker (*Catostomus macrocheilus*), bridgelip sucker (*Catostomus columbianus*), longnose sucker (*Catostomus catostomus*), and common carp (*Cyprinus carpio)*. These species are believed to have been present in the backwaters of Crab Creek prior to reservoir impoundment and may have drifted down from Moses Lake. Lake whitefish and burbot (*Lota lota*) were also discovered in Potholes Reservoir and likely migrated from Banks Lake via irrigation canals from Billy Clapp and Moses Lakes (Fletcher 1997).

A lack of perennial flows limits the establishment of an effective fishery in most of middle Crab Creek. Trout fisheries are currently managed where perennial flows do exist. Rainbow trout, brown trout (*Salmo trutta*), eastern brook trout (*Salvelinus fontinalis*), and tiger trout (*Salmo trutta x Salvelinus fontinalis*) are stocked annually. The system is managed as a low-key trout fishery with Statewide rules and walk-in access. Angling success is sporadic, and stocking occurs on an “as available” basis. Willow and South Willow Lakes are stocked with rainbow trout when water levels permit. When adequate water is present, fingerling trout survival is sufficient to produce a good trout fishery. However, adequate water has been available less than 25 percent of the last 20 years. During lower water periods, these waters have been good warmwater fisheries, most notably for black crappie.

In the early 1970s, walleye and yellow bullhead entered the reservoir, most likely in the same way whitefish did. Smallmouth bass were released into Frenchman Hills Wasteway from 1958 to 1964 by the Washington Department of Game and the Richland Rod and Gun Club (Duff 1974) and are now a species of major importance to the fishery of Potholes Reservoir. Hatchery releases of rainbow trout, brown trout, and channel catfish also contribute to the fishery of this reservoir (Fletcher 1997).

Native fish present in Moses Lake include largescale sucker, longnose sucker, peamouth, and northern pikeminnow. Common carp, which have dominated the lake for the past 90 years, were first introduced to the lake when floodwaters breached the outlet of the lake connecting it to the Columbia River in 1904 (Groves 1951). Gamefish species present in the lake include black crappie, bluegill, yellow perch, pumpkinseed, walleye, largemouth bass, smallmouth bass, rainbow trout, and lake whitefish. Sixteen species of fish are known to currently occupy Moses Lake. Appendix B lists fish species that may occur in the Study area.

2.7.4 Species of Concern

Federally Listed Species

Table 5 lists federally ESA-listed and Candidate species that may occur within the Study area or whose habitat exists or historically existed in the Study area. Appendix C provides a description of these federally designated endangered, threatened, and candidate species.

Region 1, FWS, has also identified species of concern that may occur in the Study area (listed in Appendix C). Species of concern receive no legal protection and being on this list does not necessarily indicate that they would be proposed for listing as a threatened or endangered species. The list is meant to identify species which the FWS believes might be in need of concentrated conservation actions.

Table 5. Federally listed species that may occur in the Study area

Federal Endangered Species	Federal Threatened Species	Federal Candidate Species
• Pygmy rabbit (*Brachylagus idahoensis*)—Columbia River basin distinct population segment	• Ute ladies'-tresses (*Spiranthes diluvialis*) • Spalding's Catchfly (*Silene spaldingii*) • Bull trout (*Salvelinus confluentus*)—Columbia River distinct population segment	• Washington ground squirrel (*Spermophilus Washingtoni*) • White Bluffs bladderpod (*Lesquerella tuplashensis*) • Northern wormwood • (*Artemisia campestris ssp.* borealis var. *wormskioldii*)

NMFS has listed several Evolutionarily Significant Units (ESUs) and Definite Population Segments (DPSs) of salmon and steelhead, respectively, on the Columbia River. The Upper Columbia River steelhead DPS occurs in the lower end of Crab Creek near its confluence with the Columbia River.

State Species of Concern

The WDFW has identified species of concern that may occur within the area of proposed alternatives and options. Species of concern are summarized in Chapter 6.

2.8 Historic and Prehistoric Resources

Archaeological and Historical Services of Eastern Washington University conducted a high-level class I inventory of cultural resources for this Study (Ives 2007). This inventory identified previously recorded cultural resources within Reclamation managed lands and summarized previous cultural resources investigations within the Study area. Cultural resources investigations have been mainly limited to previous construction projects. These investigations, constituting less than 1 percent of the Study area, resulted in six prehistoric and nine historic cultural resource sites. One of the prehistoric sites has been determined eligible for listing in the National Register of Historic Places (NRHP), while another has been determined ineligible. The remaining prehistoric sites and all of the historic sites have not been assessed for eligibility.

2.8.1 Ethnographic and Historic Background

According to ethnographers Ray (1936) and Spier (1936), the Study area is within the Columbia River Plateau (Sinkayuse) peoples' traditional territory. The Columbia River forms the boundary between traditional Sinkayuse lands and their neighbors to the north and the west,

Table 6. Columbia River Salmon ESUs and DPSs Listed Under the ESA

ESU/DPS	ESA Listing Status	ESA Critical Habitat
Upper Columbia River spring-run Chinook salmon (*Oncorhynchus tshawytscha*)	Endangered 6/28/05 (70FR37160)	Designated 9/2/05 (70FR52630)
Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened 6/28/05 (70FR37160)	Designated
Columbia River chum salmon (*Oncorhynchus keta*)	Threatened 6/28/05 (70FR37160)	Designated 9/2/05 (70FR52630)
Lower Columbia River coho salmon (*Oncorhynchus kisutch*)	Threatened 6/28/05 (70FR37160)	Under development
Upper Columbia River steelhead (*Oncorhynchus mykiss*)	Endangered 6/13/07 (court decision)	Designated
Middle Columbia River steelhead (*Oncorhynchus mykiss*)	Threatened 1/5/06 (71FR834)	Designated 9/2/05 (70FR52630)
Lower Columbia River Steelhead (*Oncorhynchus mykiss*)	Threatened 1/5/06 (71FR834)	Designated 9/2/05 (70FR52630)

(NMFS 2007)

including the Wenatchee, Entiat, Chelan, Methow, Southern Okanogan, Nespelem, and Sanpoil peoples. These closely related Interior Salish speaking people are often grouped as the Middle Columbia Salish (Miller 1998:253 and Teit 1930).

Plateau peoples were hunters and gatherers who placed heavy emphasis on upland game animals, fish (including salmon and other species), root crops, and berries. The rocky hillslope soils within the Odessa Subarea are suitable habitat for a number of root crops such as bitterroot (*Lewisia rediviva Pursch*) and biscuit root (*Lomatium*), while the seasonally moist creekside flats were suitable for other root crops such as camas, valuable to native inhabitants of the central Columbia River Plateau. Some of the best camas gathering grounds in the central Columbia River Plateau included the area "across the flats east to Moses Lake and northeasterly to Wilson Creek" (Ellis and Fagan 2000:17). Native peoples circulated through their own and adjacent territories capitalizing on the changing food opportunities presented by the annual cycles of native plants and animals (Schuster 1998, Sprague 1998, and Stern 1998).

The Middle Columbia Salish—like other Native American peoples of the Columbia River Plateau—followed a seasonal subsistence round. Fishing at the large communal gathering sites on Crab Creek and major rivers in the region was the main activity during the summer months. A variety of large terrestrial game animals were hunted in the fall, including deer and elk. Winter was spent in the village sites, often near summer fishing stations, where the people subsisted largely on the preserved root crops and dried salmon and deer meat (Chalfant 1974 and Scheuerman 1982). The winter diet was supplemented by the continued hunting of deer and other large game animals, which occupied lower elevation landforms as the snow line dropped. Gathering roots and processing stored foods for consumption during the lean winter months began in the spring, as each crop became ready for harvest. Gathering root crops and berries continued into the summer months and many groups began their return to the communal fishing sites. The works of Chalfant (1974), Ellis and Fagan (2000), Miller (1998), and Ruby and Brown (1965) provide excellent overviews on other important aspects of life among the Sinkayuse, including social structure, material culture, and spiritual and world views.

Ethnographically recorded village sites associated with the Sinkayuse are generally along a segment of the Columbia River from Rock Island Creek south to Lower Crab Creek, near Vantage, Washington. Another cluster of villages occupy the uplands between Soap Lake and Moses Lake (Ellis and Fagan 2000). Of the named areas to the east of Moses Lake only one, Qatqowáus ("dip in the ground"), is within the Study area (Ray 1974:430).

Early Euro-American contact was made mainly by a small number of explorers, missionaries and traders, although indirect influences (e.g., trade goods, horses, and diseases) had already had a great impact on the traditional cultures of the Sinkayuse and other Native American groups within the region (Walker and Sprague 1998). It was not until the early 1870s that waves of settlers began to permanently encroach on the traditional lands and cultures of the local Indian groups. Scattered resistance was met with military force, and many of the native inhabitants were sequestered in reservations, leaving most of the desirable land for the Euro-American homesteaders.

The construction of the Connell Northern Railway (acquired by the Northern Pacific Railway in 1914) from Adrian to Connell through the region in 1910 sparked early development (Cheever 1949:108). However, stable farm economies did not exist in the central Columbia River Plateau area until the construction of the CBP irrigation canals.

2.8.2 Prehistoric Resources

Lands within the Study area comprise three very general environmental categories: (1) plain-like loess uplands, (2) hillslopes, and (3) flat seasonally dry coulees and sandy lowlands. Native inhabitants of the central Columbia River Plateau used each of these landscapes differently. The open uplands are likely little used other than as travel corridors to adjacent drainages or in pursuit of terrestrial game. The rocky slopes are likely root crop and stone tool gathering or resource caching locations for prehistoric inhabitants of the Study area. The sandy lowland flats, usually in proximity to a perennial water source, are likely locations for establishing residential sites. The ethnographic record for land use within the central Columbia River Plateau suggests that Study area, with the exception of lands adjacent to Crab Creek, were likely viewed as the hinterland by the prehistoric inhabitants of the area. Chatters (1980) indicated in his analysis that it is likely that there is less than one prehistoric site per thousand acres within the Pasco Basin and areas east of Moses Lake.

The class I inventory determined the potential for encountering additional, as yet unidentified cultural resources. The data sample from previous cultural resources investigations within the Study area is extremely limited, thus the inventory did not use these results to build a predictive model, as the size and scope of those investigations were limited. Lands within the Study area were ranked as high, moderate, or low probability for prehistoric sites. These rankings are based mainly on proximity to water, the underlying soils, or sediments and slope. The results of Chatters' (1980) survey of a large number of land parcels from a variety of topographical settings south and west of the Odessa Subarea documented that prehistoric activities:

- Are most densely concentrated within 1.6 kilometers (1.0 miles) of perennial water.
- Are concentrated in areas with rocky soils.

Previous investigations were placed within a model structure to assess the reliability of these factors.

2.8.3 Historic Resources

The historic pattern of land use depends less on natural factors, such as proximity to water and soil types, than the prehistoric pattern. While the loess uplands have a low probability for prehistoric sites, the fine-grained soils found in the uplands are suitable for some types of agriculture, such as dry (or groundwater-irrigated) farming and grazing, and are suitable for intensive use and habitation.

The historical record for land use within Study area indicates that the area supported only a few hearty pioneers until the arrival of transportation and irrigation features in the mid-twentieth century. While it would be difficult to predict the locations for cultural material associated with these early historical occupants, it is quite likely that these locations are few in number. Later historical structures and features associated with the CPB have been documented sporadically, which likely constitutes the largest historical cultural resources management activity task within the Study area.

Only two properties within the Study area are listed on the State's Heritage Register, and both are likely eligible for listing in the NRHP: the Sievers Brothers House, constructed between 1908 and 1910, and the Dr. Levi L. Sutton House, also constructed in the early twentieth century.

2.8.4 Traditional Cultural Properties

Traditional Cultural Properties (TCPs), like historic and archeological sites, are a class of historic resources potentially eligible for the NHRP. These resources derive significance by a historical link to, and the quality to sustain, a present-day community. Historic and archeological sites always have physical cultural evidence, such as artifacts or architectural elements, but TCPs may be represented by only a landform or landscape feature, culturally modified objects, or both. A TCP may relate to both native and non-native cultures and communities. Examples of places that fall under the TCP rubric are long-established hunting, fishing, or plant collecting locations, legendary sites, sacred sites, ancestral habitation sites, trails, as well as connections between these kinds of sites, among others.

The History & Archeology Program of the Confederated Tribes of the Colville Reservation (CCT) made an inventory-level investigation of the Study area in 2007. The investigation reviewed ethnographic records and oral histories housed in the CCT archives and a synthesis of published works, and interviewed Tribal members with knowledge of traditional use of the Study area. The inventory also included a field reconnaissance of the Study area. This process revealed that the Moses-Columbia people, and their contemporary descendants, are traditionally, but not exclusively, associated with the Study area.

Conversion of open, un-fenced, shrub-steppe vegetation to privately owned, agricultural lands over the past 100 years has restricted the land base available to Tribal members to follow traditional resource procurement or cultural practices. The restricted modern-day land base, the large expanse of the Study area, coupled with the declining numbers of Tribal members who have knowledge of use by previous generations, resulted in the TCP inventory identifying a very limited range of properties germane to the Study. As expected from available ethnographic literature, a variety of TCPs were noted adjacent to the western edges of the Study area in lands surrounding Moses Lake and Crab Creek.

Although no TCPs were identified within the boundaries of the Study area at a broad inventory level, additional, more focused, TCP inventory will occur for specific areas affected by alternatives proposed for study in the future. Coulees, prominent landforms, escarpments, and natural vegetation breaks are high probability landscape features deserving additional scrutiny.

3.0 Water Delivery Alternatives

The PASS Technical Team determined that four water delivery alternatives (Table 7) represented the best range of solutions for further study, based on the defined Study objectives and technical and engineering considerations. These four alternatives involve either constructing a new East High canal system or using and extending the East Low Canal (or a combination of these options). Each of these alternatives can serve a different proportion of the groundwater-irrigated area within the Study area. Table 7 summarizes the number of groundwater-irrigated acres for which each alternative would provide a replacement water supply.

Table 7. Water delivery alternatives—groundwater acres served

Water Delivery Alternative	Groundwater Acres Served	
	acres	percent
Alternative A. Construct a new East High canal system.	140,000	100
Alternative B. Construct north portion of a new East High canal system. Enlarge and extend the existing East Low Canal.	127,300	91
Alternative C. Enlarge the existing East Low Canal.	70,100	50
Alternative D. Use existing East Low Canal.	40,700	29

This section first describes the engineering assumptions and considerations that guided the development of the appraisal-level engineering designs and cost estimates. The four water delivery alternatives' components and proposed operational configurations are then described.

3.1 Assumptions and Considerations

Engineering designs were based on available design data obtained from previous Reclamation investigations involving development of the CBP and limited additional data development. Preliminary identification and sizing of required features were accomplished based on comparisons to similar features designed for other projects and professional judgment. Additional hydrologic modeling and geologic investigations were conducted to review and revise some PASS assumptions. Key engineering assumptions and considerations for this investigation are summarized in this section.

3.1.1 Previous Studies

Reclamation initially investigated construction of the East High canal system and other irrigation facilities to serve the remaining portions of the CBP between 1957 and 1964. Engineering feasibility-grade studies were performed beginning in the 1960s and continued into the1970s.

Reports developed during those studies were used to develop appraisal-level engineering designs and cost estimates for this Study, including:

- *Alternative Plans for Providing Irrigation Water to East High Canal Areas, Study No. 1* (Reclamation 1958) involved an analysis of alternate locations for the East High canal conveyance system between Banks Lake and Black Rock Coulee reservoir. The report recommended that the East High canal follow the alignment shown in the approved irrigation plan as presented in the report of 1943.
- *Alternative Plans for Providing Irrigation Water to East High Canal Areas, Study No. 2* (Reclamation 1960 [Main Report]) concluded that plans serving a larger area of 385,500 acres provided greater net benefits than the plans serving only the original 215,000 acres. The plan providing the greatest net benefit was recommended for a feasibility-grade examination as the plan of development for the East High canal area.
- *The CBP East High Investigations* (Reclamation 1968) was a feasibility-grade investigation to complete the CBP that compared benefits and costs with and without the East High canal system. The report examined the plans and facilities required for the presently irrigated acreage compared to development of a 710,000-acre Project and ultimate development of over 1,000,000 acres.
- *The CBP East High Plan Selection Study* (Reclamation 1970) examined irrigation distribution systems. The widespread use of sprinkler irrigation in the area was the primary reason for considering irrigation distribution systems other than an open lateral system.
- *The Columbia Basin Project, East High—East Low Extension, Initial Plan Formulation Study* (Reclamation 1972) re-analyzed the plan which was presented in the *East High Investigations Report* (Reclamation 1968) and presented a summary report indicating that neither a pressure pipe system nor a gravity pipe system could be incrementally justified over the open lateral system. The gravity pipe system had an extremely low incremental benefit/cost (BC) ratio. However, the pressure pipe system had a much better incremental BC ratio. Landowners in early 1972 indicated their overwhelming preference for project pressure with the understanding that they would assume additional costs connected with the system.
- *Continued Development of the Columbia Basin Project, Irrigation System Conceptual Designs and Cost Estimates, Study Area No. 1 and Study Areas N and Q* (CH2M Hill 1989) developed design concepts and cost estimates for irrigation field delivery systems.

3.1.2 Groundwater-Irrigated Acreage

Reclamation can only deliver water to lands authorized to receive CBP water. Previous estimates developed during the PASS determined that, of the 170,000 groundwater-irrigated acres in the Odessa Subarea, approximately 121,000 were eligible to receive CBP surface water. This estimate was based on a review of GIS data available at that time.

The number of groundwater-irrigated acres in the Study area was revised to 140,000 acres after a review during the appraisal-level investigation of additional GIS information and water rights information provided by Ecology. This revision accounts for a possible 15-percent margin of error in the GIS datasets and the fact that not all lands are irrigated in all years.

To identify these acres, Reclamation developed a detailed dataset for this appraisal-level analysis to show where the groundwater-irrigated acres are and to provide a basis for alternative design and hydrologic and design models. This dataset is based on a GIS dataset created for the GWMA by the FCCD. This dataset includes a distribution for all cultivated fields in Adams, Franklin, Grant, and a portion of Lincoln counties. It identifies whether a field is irrigated or dryland farmed, what type of irrigation system is used, and the crop type for the years 2000 through 2003. Reclamation also used information from Franklin County Conservation District that shows all of the irrigated land east of the East Low Canal that receives water from the CBP via water service contracts. The rest of the irrigated fields east of the East Low Canal are assumed to use groundwater.

Reclamation used the GIS data to identify eligible fields (fields within the area where Reclamation is authorized to deliver CBP water and that are also within the Odessa Subarea). The data were further sorted to eliminate non-irrigated fields and fields served by water service contracts. The remaining fields were checked using the 2003 National Agricultural Imagery Program aerial image and modified slightly to address inconsistencies.

Acres served by the water delivery alternatives were based on pivot-served area and not on field area. According to the GIS groundwater acreage data, there are approximately 130,000 acres served by center pivots in the East High canal area and about 10,000 acres served by center pivots south of the East Low Canal extension area near Connell, Washington. Individual groundwater pivots typically serve about 125 acres per 160-acre field.

3.1.3 Water Delivery Requirements/Demand

The water delivery requirement for alternatives is based on the amount of water needed for crops and canal and distribution losses. Reclamation used a hydrologic simulation model of the CBP for the appraisal-level analysis using RiverWare software (CBIP-RW model). The CBIP-RW model runs at a daily time step to simulate reservoirs, canal and lateral flows, farm deliveries, return flows, groundwater pumping, and natural flows within the CBP. Modeling results and assumptions are described here.

Crop Requirements

The farm sprinkler delivery requirement was assumed to be 3.00 acre-feet per acre on-the-farm delivery based on studies conducted during Reclamation's investigation of CBP development in the 1980s (Water Conservation Steering Committee 1987) The CBP irrigation district managers verified this number during this appraisal-level investigation. The 3.00 acre-feet per acre on-the-farm delivery is further based on crop distribution analysis. A crop distribution for the Study was estimated based on current cropping patterns for the ECBID (Table 8).

The *Washington State Irrigation Guide* (Natural Resources Conservation Service [NRCS] 2007) was used to provide monthly demands for the crop distribution. The crop irrigation requirements for Lind, Washington, were assumed to represent the Study area and are shown in Table 9.

Using the monthly distribution for the crop distribution in combination with the irrigation requirements for these crops, Reclamation determined a diversified irrigation requirement as shown in Table 10. An on-farm efficiency of 87 percent would be needed to meet this diversified crop irrigation requirement of 2.61 acre-feet per acre with an on-the-farm delivery of 3.00 acre-feet per acre.

Table 8. Crop distribution developed for appraisal-level investigation

Crop	Crop Distribution (percent)
Alfalfa, hay, mint, pasture (alfalfa)	34
Field Beans (dry beans)	2
Corn (field corn)	6
Early Potatoes (potato)	5
Late Potatoes (potato)	20
Small Grains and Seed Peas (winter wheat)	24
Miscellaneous (dry onion)	9
Total	100

Table 9. Crop irrigation requirement for Lind, Washington

	Irrigation Requirement (inches)								
Crop	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Annual**
Alfalfa	0	0	5.28	7.19	9.74	7.94	5.19	1.65	36.99
Dry beans	0	0	0	2.55	11.13	9.22	0.62	0	23.52
Field corn	0	0	0.69	3.48	10.06	9.7	5.42	0.21	29.56
Potato	0	0	0.69	3.69	11.03	9.68	4.49	0	29.58
Winter wheat	0.66	4.18	6.93	8.1	3.28	0.9	0.39	0.68	25.12
Dry onion	0	1.14	5.56	8	10.76	7.58	0.57	0	33.61

(NRCS 2007)

Table 10. Diversified crop irrigation requirement based on crop distribution and individual crop irrigation requirements for Lind, Washington

Month	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Annual
Diversified Irrigation Requirement (inches)	0.16	1.11	4.17	6.29	8.65	6.78	3.37	0.74	31.27
Diversified Irrigation Requirement (feet)	0.01	0.09	0.35	0.52	0.72	0.57	0.28	0.06	2.61
Adopted Distribution (percent)	0.5	3.5	13.3	20.1	27.7	21.7	10.8	2.4	100

Canal and Distribution Losses

The canal and spill losses predicted in this Study were based on recorded conveyance losses and waste from the *Water Supply, Use and Efficiency Report* (Montgomery 2003) for CBP's existing main canals and laterals. Main canal losses are estimated at about 10.5 percent, open lateral distribution system losses at about 19 percent, and pipe distribution system losses at about 3 percent, with losses compounded along the system. Pipe lateral loss and waste amounts are estimated to be zero loss for peaking. Open canal loss and waste amounts were estimated at approximately 13 percent for peaking.

Summary of Water Demands by Alternative

Each water delivery alternative serves a different percentage of the total 140,000 eligible acres. The amount of water needed for each alternative is based on the number of acres served and the water demands per acre. The water demands are based on the crop distribution, an annual on-farm allotment, and the main and lateral canal efficiencies described above.

All conveyance losses were assumed to return to the Potholes system or Esquatzel Coulee. Lining the East Low Canal for alternatives B and C would reduce return flows to the Potholes system. Reduced return flows would increase the volume of feed water needed to fill Potholes Reservoir; increased return flows would reduce the volume of feed water required. The CBIP-RW model was used to estimate the volume of additional Columbia River diversion required for each alternative, accounting for changes in return flows and the CBP operations.

Table 11 shows annual water requirements by alternative and canal. Each alternative's monthly water demand is summarized in Table 12. Table 12 further shows the amount of March-August volume that would be needed from storage during dry years, not accounting for changes to CBP operations. Dry-year Columbia River water supply calculations assume that no new water is available for diversion from March through August, so irrigation demands must be met from storage during these months. Based on this assumption, storage must provide 86.9 percent of full irrigation season demand in dry years. Columbia River diversions during September and October would meet the remaining irrigation demand and fill storage for use in next year's irrigation season.

Table 11. Estimated annual water requirements by canal

Water Delivery Alternative	Area Served (acres)	Annual Diversion Requirement	
		acre-feet per acre	acre-feet
A - East High canal system	140,000	3.68	515,300
B - East High canal system	61,900	4.05	250,900
B - East Low Canal	65,400	3.09	202,300
B - Total	127,300	NA	453,200
C - East Low Canal	70,100	3.09	216,800
D - East Low Canal	40,700	3.09	125,900

Table 12. Monthly water demand based on a crop distribution and irrigation requirements for Lind, Washington (in acre-feet)

Water Delivery Alternative	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual	Mar-Aug
A - East High canal system	2,600	18,200	68,800	103,700	142,600	111,800	55,500	12,100	515,300	447,700
B - East High canal system	1,300	8,900	33,500	50,500	69,400	54,400	27,000	5,900	250,900	218,000
B - East Low Canal	1,000	7,200	27,000	40,700	56,000	43,900	21,800	4,800	202,300	175,800
B - Total	2,300	16,000	60,500	91,200	125,400	98,300	48,800	10,700	453,200	393,700
C - East Low Canal	1,100	7,700	28,900	43,600	60,000	47,000	23,400	5,100	216,800	188,300
D - East Low Canal	600	4,500	16,800	25,300	34,800	27,300	13,600	3,000	125,900	109,300

The modeled assumptions used for each alternative are summarized in Table 13. The annual demand is developed from an assumed turnout allotment (on-the-farm delivery) of 3.0 acre-feet per acre divided by the conveyance efficiency multiplied by the number of acres served. Annual demands do not account for changes to current CBP operations from increased or reduced return flows associated with each alternative.

Table 13. Water demands as needed at the head of each alternative delivery system

Water Delivery Alternative	Number Acres Served	Annual Conveyance Efficiency (percent)	Annual Demand (acre-feet/acre)	Annual Demand (acre-feet)	Peak Conveyance Efficiency (percent)	Peak design flow (cfs)
A - East High canal system	140,000	81.5	3.68	515,300	88.6	2,290
B – East High canal system	61,900	74.0	4.05	250,900	84.6	1,060
B – East Low Canal	65,400	97.0	3.09	202,300	100	950
B – Total	127,300	NA	NA	453,200	NA	NA
C - East Low Canal	70,100	97.0	3.09	216,800	100	1,020
D - East Low Canal	40,700	97.0	3.09	125,900	100	590

3.1.4 Distribution Pipeline's Peak Flow Capacity

A design peak capacity of 3.25 acre-feet per acre to each farm turnout and transmission system was determined to be suitable for this Study. An instantaneous flow of 6.5 gallons per minute (gpm) per acre was calculated based on the anticipated crop distribution (Table 8), the Washington State Irrigation Guide for the Lind Area (Table 9), and the design peak capacity. The delivery rate does not account for losses in the canal system that occur before the water enters the closed pipeline system.

Table 14 shows the peak flow rate. A 5 percent design factor was applied to obtain the peak flow rate. The July peak design flow rate is 6.5 gpm per acre or 69 acres per cfs for diversified cropping in areas exceeding 5,000 acres and 9.48 gpm per acre or 47 acres per cfs for single crop in areas less than 1,000 acres.

3.1.5 Existing CBP Canal Availability and Capacity

The irrigation season is typically mid-March through late October. The existing canal system is only available to convey water between mid-March through mid-November because canal maintenance and freezing conditions occur outside of these months. The Potholes Canal above Soda Lake Check Structure, which could operate year-round, is an exception to this. The canal capacities assumed for the appraisal-level analysis are shown in Table 15. September and October available capacities are based on observed data from 1990 to 2005.

The East Low Canal was constructed in the 1950s, with most of its length unlined for a capacity of 4,300 cfs. The canal's capacity varies between 4,300 cfs and 3,650 cfs from the headworks to the Weber Branch Siphon.

Table 14. Peak flow rate

Crop Type	Farm Efficiency (percent)	Peak Flow Rate			Available for Monthly Crop Use (inches)
		inches/day	gpm/acre	acre/cfs	
Single crop	75	0.48	9.48	47	11.0
Diversified crop	85	0.33	6.50	69	8.6

Table 15. Primary CBP canal design and peak flow capacities

Canal	Canal Mile	Present Design Capacity (cfs)*	Current Peak Flow (cfs)**	Median Sep-Oct Flow (cfs)***	Available Sep-Oct Capacity (cfs)
Main Canal	0.2	13,000	8,500	3,800	9,200
East Low Canal	0.6	4,300	3,600	1,600	2,700
Potholes Canal	0.2	3,600	3,200	1,500	1,700
West Canal	0.2	4,800	4,800	2,200	2,600

* Design capacities have been modified to operational observed limits; original drawings may show higher capacities.
** 10 percent exceedance values from Reclamation gage data for 1990-2005, for June 20 to July 15.
*** 50 percent exceedance values from Reclamation gage data for 1990-2005, for September 1 to October 31.

The 42-mile section of the East Low Canal from the Weber Branch Siphon and south of I-90 to the Scooteney Wasteway was constructed to an initial capacity that was less than full capacity. Siphon transitions were constructed for dual pipe barrels; however, only single pipes were installed. The bridge crossings were constructed to span the ultimate canal size. This canal section's capacity varies between 1,700 cfs and 550 cfs and is presently operating at its current capacity.

Some of the alternatives propose to use the East Low Canal to carry additional water to provide the replacement water supply to lands located south of I-90. The East Low Canal capacity would need to be increased in this section in order to deliver the additional water. Canal capacity expansion would entail excavation of earthen materials, placing concrete lining, and installing siphon pipes at seven locations that vary between 14.67 feet and 13 feet in diameter. Pumping plants and pipeline distribution systems would be constructed along the East Low Canal.

3.1.6 East High Canal System Sizing

As discussed in Section 3.1.1., "Previous Studies," Reclamation examined an East High canal system sized to serve 385,500 acres during feasibility-grade investigations in the early 1970s

(Reclamation 1972). The 1972 Initial Plan Formulation design was used to develop East High canal system components and capacity for this appraisal-level investigation.

Alternative A is proposed to serve 140,000 acres using the East High canal system. The appraisal-level investigation assumed canals and pumping plants would be sized at 30 percent of the flow rate capacity of the original 1972 plan. Alternative B proposes to serve 61,900 acres north of I-90 using the northern portion of the East High canal system. The appraisal-level investigation assumed canals and pumping plants would be sized at 15 percent of the flow rate capacity of the original 1972 plan. For both alternatives, the siphons and tunnels were assumed to be at 100 percent of the original 1972 plan capacity.

3.1.7 Farm Delivery Concept

The primary water conveyance for the East High canal system would be canals and open laterals, including re-lift pumping plants, as required, along the primary conveyance system. Along the East Low Canal, pumping plants and re-lift pumping plants would lift the water approximately 225 feet into pump regulating tanks.

The system would provide at least 10 pounds per square inch (psi) (25 feet) to each turnout at the section boundary. Where topography does not provide sprinkler pressure between 65 psi (150 feet) and 80 psi (185 feet), small pump stations at each farm unit delivery would boost the pressure for on-farm sprinkler systems. The small pump stations (with pressure relief valves) would deliver water to the center of each approximate 160-acre unit at a pressure sufficient to provide 65 psi (150 feet) at the high point of the parcel. Where topography produces pressure in excess of 80 psi (185 feet), pressure reducing valves would be installed at the delivery to reduce the pressure to 65 psi (150 feet) at the high point of the parcel.

Peak farm delivery requirements (between 47 acres per cfs and 69 acres per cfs; Table 14) were used to size pipe distribution facilities. Laterals that serve less than 1,000 acres with a single crop were sized for 47 acres per cfs and diversified cropping patterns serving 5,000 acres or more were sized for 69 acres per cfs.

Velocities in the pipelines were limited to between 5.0 feet per second (ft/s) and 7.5 ft/s to minimize friction losses. Water allotments were based on an annual allotment of 3.00 acre-feet per acre for on-farm use with the water delivery system designed for the peak annual allocation of 3.25 acre-feet per acre.

Most of the farm unit fields are quarter section (nominal 140 acres irrigated field) size. The pipe lateral distribution system layout would deliver to each section of land that has groundwater-served fields. On-farm lateral extension piping and equipment would distribute to the quarter section fields. Each turnout would include a buried valve controlled by Reclamation to isolate the turnout from the lateral pipeline. Each East Low Canal pipeline distribution system would consist of a canal side pumping plant, an elevated pump operation tank, and a pipe lateral distribution layout. Re-lift pumping plants would be necessary when total elevation rise for land to be served exceeds approximately 200 feet.

3.1.8 Pumping Plant Considerations

Numerous pumping plants would be located along the conveyance system to pump water to higher elevation lands. Re-lift, or booster, pumps are located along laterals to provide additional pressure so that water can be pumped to the end of the lateral system. Pumping plant auxiliary systems would include systems for gravity drainage, fire suppression, compressed air, service water, heating and ventilating, and domestic water and sanitary waste, as well as a main pumping unit cooling water system when required. A number of electrical components are associated with pumping plants, including motors, switchyards, and substations.

The design concept also assumed that each pumping plant would have a sump waste oil skimmer and overhead traveling bridge crane, ultrasonic transducer-type flow meter, trash racks, and water-level measuring system.

3.1.9 Geologic Considerations

Information on overburden thickness, bedrock depths, and groundwater levels were compiled. The surface geology at the pumping plant sites is based on geologic mapping presented in a USGS report (Grolier and Bingham 1971 and 1978). Subsurface geology and groundwater levels are from water well reports obtained from Ecology and Reclamation test pit and soil profile data acquired during construction of the CBP.

Depth of Overburden

Appraisal-level geologic information (Reclamation 2007 [Geology]) indicates that the depth of overburden within the Study area ranges from 14 feet to 47 feet thick. Excavation depths for the pumping plants are estimated not to exceed 20 to 25 feet in depth, while excavation depths for the canals and pipelines are estimated not to exceed 10 to 20 feet in depth. Based on this information, Reclamation assumed that excavation operations would be within soil for most of the water delivery features. In a few instances, based on site visits, Reclamation assumed that excavation operations would occur in both soil and rock, which is reflected in the quantity estimates as appropriate.

The estimated depth of overburden for Black Rock Coulee dam (forming the re-regulation reservoir needed in alternatives A and B) is about 10 feet. Excavation quantities for Black Rock Coulee dam were not developed for this Study. Instead, Reclamation assumed that previously completed cost estimates for the development of the East High canal system that were indexed under this Study included appropriate excavation quantities for this dam site.

Excavation Dewatering Assumptions

Appraisal-level geologic information (Reclamation 2007 [Geology]) indicates that the depth to the top of groundwater within the Study area ranges from 45 feet to 274 feet below the existing ground surface. Excavation depths for the pumping plants are estimated not to exceed 20 to 25 feet in depth, while excavation depths for the canals and pipelines are estimated not to exceed 10 to 20 feet in depth. Based on this information, Reclamation assumed that excavation dewatering and unwatering quantities would not be significant and that the percentages for unlisted items incorporated into the field cost estimates would adequately cover these costs. During the feasibility design, this assumption would be revisited and the field cost estimates would be adjusted if needed.

The depth to groundwater of Black Rock Coulee dam (forming the re-regulating reservoir needed in alternatives A and B) is 45 feet. Excavation dewatering and unwatering for this dam are anticipated to be addressed in the unlisted items of the overall field cost estimates.

3.2 Alternative A: East High Canal System

Alternative A's configuration would provide a replacement water supply to 100 percent or 140,000 acres of the groundwater-irrigated land within the Study area, as indicated by the green shaded areas on Figure 13.

3.2.1 Proposed Operations

Alternative A would construct a new East High canal system. Major components include:

- East High canal intake structure
- East High canal
- Black Rock Branch canal
- Black Rock lateral
- Michigan Branch canal
- Black Rock Coulee re-regulating reservoir and dam
- Two major pumping plants and numerous smaller pumping plants
- Siphons and tunnels
- Wasteways
- Transmission lines and substations
- Piped distribution laterals

Figure 14 shows the proposed intake location for the East High canal. Figure 13 shows the main distribution features for alternative A. Table 16 summarizes the primary conveyance system features. The East High canal system was proposed in the original authorization for the CBP. As noted in Section 3.1.6, "East High Canal System Sizing," Reclamation conducted feasibility-grade studies in the 1960s and 1970s for an East High canal system that would irrigate about 385,000 acres. Evaluations and cost estimates for alternative A used the information from these previous feasibility studies; however, alternative A's facilities are sized at about 30 percent of the flow rate capacity of the original plans. This is the size needed to provide a replacement water supply to all of the groundwater-irrigated acres in the Study area. Siphons and tunnels were sized at 100-percent flow rate capacity.

The replacement water supply would be diverted into the East High canal through a new intake structure at the existing Main Canal above Summer Falls (Figure 14). Water would gravity flow into the East High canal for about 25 miles, and then would flow into a new Black Rock Coulee re-regulating reservoir. The re-regulating reservoir would be constructed in Black Rock Coulee, about 8 miles southeast from the town of Wilson Creek, Washington, and would regulate canals

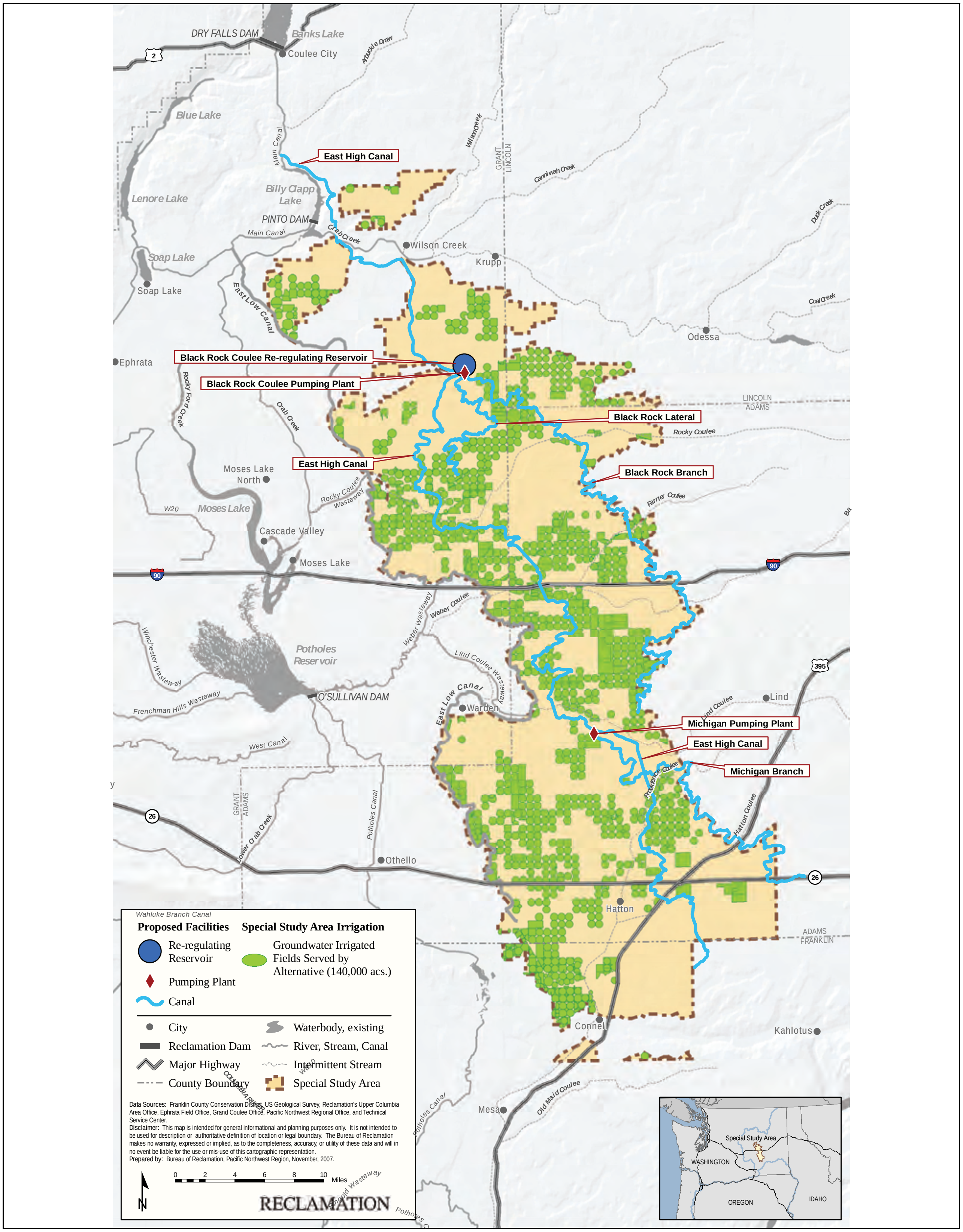

Figure 13. Alternative A.

and provide emergency water storage. It would have a storage capacity of about 4,800 acre-feet (600 acre-feet of this would be active storage, and a surface area of about 225 acres at full pool).

The Black Rock Coulee re-regulating reservoir would serve two pumping plants and the continuation of the East High canal. A major pumping plant (Black Rock Coulee pumping plant) would pump water into the Black Rock Branch canal and the Black Rock lateral. A smaller pumping plant would pump water into a lateral located off the northeast side of the re-regulating reservoir. Water would also be gravity fed into a continuation of the East High canal.

Another major pumping plant, located on the East High canal south of I-90 and Lind Coulee, would pump water into the Michigan Branch canal. Canal side pumping plants would be located along the primary conveyance canals to lift water to higher elevations into the piped distribution laterals. Booster pumps would be located along the laterals to provide additional pressure to "boost" water to the end of the lateral system. The piped lateral system would be buried.

Figure 14. Existing Main Canal at Summer Falls Power Plant. The proposed East High canal intake structure would be located on the right side of the canal near the top of the photograph.

The East High canal system would include numerous miles of tunnels and siphons (Table 16). Tunnels would be constructed in areas where it is more cost effective to tunnel through the terrain as opposed to constructing additional miles of canal to go around the feature. Siphons would be constructed to go underneath coulees and streams.

3.2.2 Water Demands

The total annual water demand for alternative A was calculated using the annual diversion requirements and conveyance efficiencies. The annual efficiency for the proposed East High canal system was assumed to be 81.5 percent. The efficiency was developed by assuming East

High canal system seepage losses of 140 cfs and three spillways with losses at 30 cfs each. All lateral diversions from the system are assumed to be piped with a loss of 3 percent of the annual East High canal diversion.

Table 16. Alternative A: Primary conveyance system features

Component	Canals (miles)	Smaller Pumping Plants*	Canal Siphons	Tunnels	Lateral Pipe Distribution (acres served)
East High canal system	93.49	4	13 siphons/ 10.45 miles	3 tunnels/ 3.76 miles	75,508
Black Rock Branch canal	54.11	2	9 siphons/ 4.65 miles	1 tunnel/ 0.53 miles	39,636
Michigan Branch canal	42.99		3 siphons/ 1.45 miles	1 tunnel/ 0.34 miles	24,856
Total	190.59	6	25 siphons/ 16.55 miles	5 tunnels/ 4.63 miles	140,000

*Does not include two major pumping plants—one at Black Rock Coulee re-regulating reservoir and one on the Michigan Branch canal south of I-90.

The annual diversion requirement for the East High canal system would be 3.68 acre-feet per acre (3.00 acre-foot per acre on-the-farm delivery/0.815 efficiency). The East High canal system would have an annual water demand of 515,300 acre-feet (140,000 acres * 3.68 acre-feet per acre).

The peak design flow for the pipeline laterals is 69 acres per cfs. The peak efficiency of the East High canal system and its laterals is assumed to be 88.6 percent. The East High canal would have a peak design flow of 2,290 cfs (calculated as 140,000 acres/69 acres per cfs /0.886 efficiency).

3.2.3 Geologic Considerations for Black Rock Coulee Re-regulating Reservoir

The overburden properties and depth to bedrock are based on limited data from a single water well and surface geologic maps. The overburden is alluvium consisting mostly of silt and fine sand. The depth to bedrock in the bottom of the coulee is shallow, estimated at a depth of less than 10 feet based on a well located in the valley 2-3/4 miles downstream of the dam site. This location places the bedrock surface in the deepest section of the valley at approximately elevation 1409 feet. This elevation was used for the bedrock profiles at the dam site.

3.3 Alternative B: East High Canal System North of I-90 and East Low Canal Enlargement and Extension

Alternative B would provide a replacement water supply to about 91 percent of the groundwater-irrigated acres, or 127,300 acres (indicated by the green shaded areas on Figure 15).

3.3.1 Proposed Operations

This alternative would develop a new East High canal system north of I-90 and enlarge the capacity of the existing East Low Canal south from Weber Branch Siphon (near I-90) and extend it 2.3 miles east to near Connell, Washington. Table 17 summarizes the primary conveyance system features.

East High Canal System (North of I-90)

The new East High canal system would serve 61,900 acres located north of I-90, as indicated by the darker green shaded area on Figure 15. Major components of the East High canal system would include:

- East High canal intake structure
- East High canal
- Black Rock Branch canal
- Black Rock lateral
- Black Rock Coulee re-regulating reservoir and dam
- One major pumping plant and numerous smaller pumping plants
- Tunnels and siphons
- Wasteways
- Transmission lines and substations
- Piped distribution laterals

Evaluations and cost estimates for alternative B used the information from feasibility-grade studies conducted by Reclamation in the 1960s and 1970s, as described previously. Canals and pumping plants were sized at about 15 percent of the flow rate capacity of the original plan; siphons and tunnels were sized at 100-percent flow rate capacity.

Water would be diverted above Summer Falls from the Main Canal into a new East High canal intake structure. Water would gravity flow for 25 miles in the East High canal and then flow into the Black Rock Coulee re-regulating reservoir. A major pumping plant (Black Rock Coulee pumping plant) would pump water into the Black Rock Branch canal and Black Rock lateral. Water would be gravity fed from the Black Rock Coulee re-regulating reservoir to continue the East High canal for about 25 more miles. The Black Rock Coulee re-regulating reservoir would be the same as described under alternative A and would be sized to full capacity.

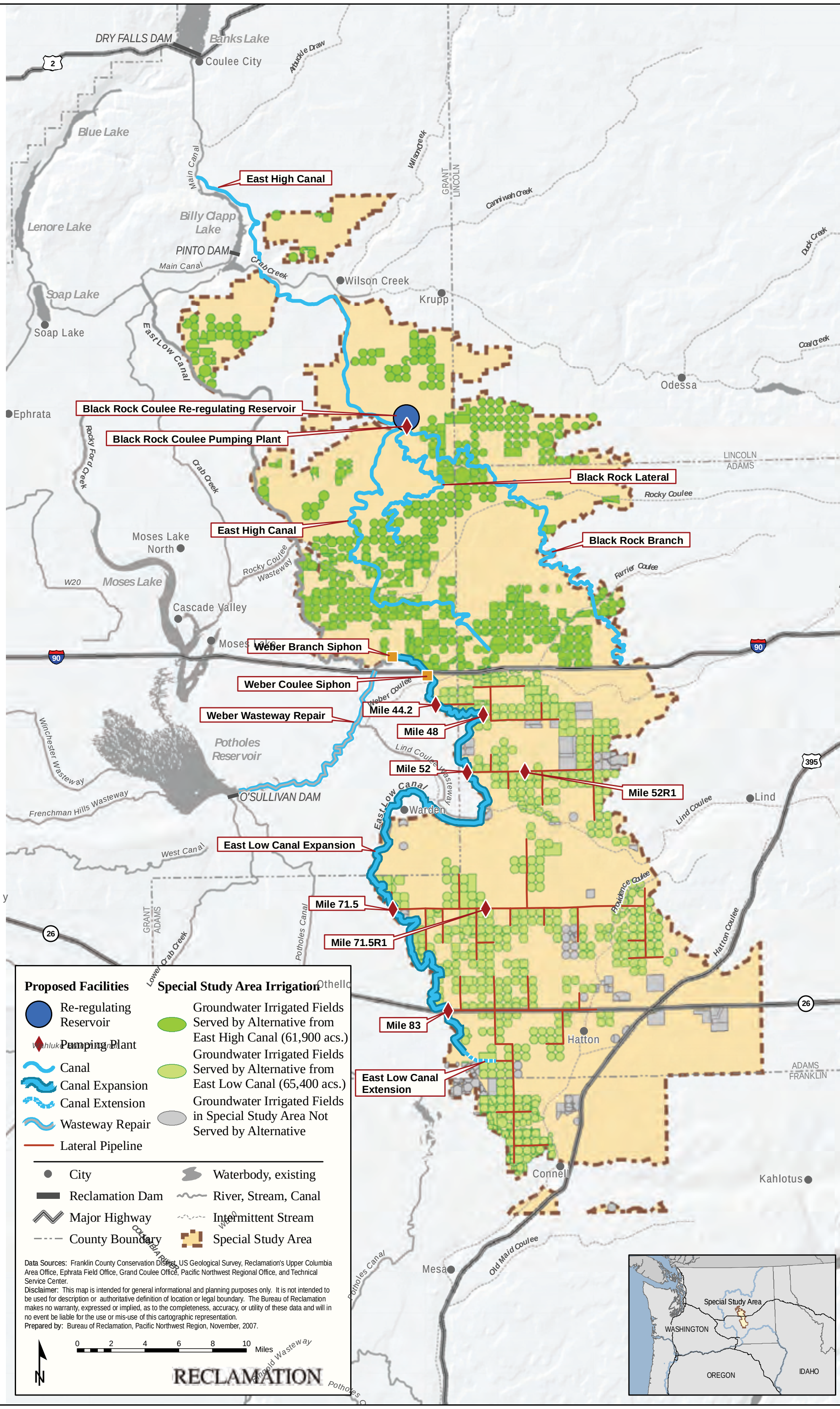

Figure 15. Alternative B.

East Low Canal (South of I-90)

The East Low Canal system enlargement would serve 65,400 acres located south of I-90, as indicated by the lighter green shaded areas on Figure 15. Major components of the East Low Canal system would include:

- East Low Canal enlargement from Weber Branch Siphon south; also includes enlargement of all siphons in this canal section
- East Low Canal extension for about 2.3 miles
- Weber Wasteway repair or replacement
- Transmission lines and substations
- Canal side and re-lift (booster) pumping plants
- Piped distribution laterals

This alternative would enlarge the capacity of about 54 miles of the existing East Low Canal beginning at the Weber Branch Siphon, located just north of I-90. The capacity of the Weber Branch and Weber Coulee siphons and other siphons along this southern section of the East Low Canal would also be enlarged. With the enlargement, the East Low Canal capacity would increase from its current maximum capacity of 1,700 cfs to 3,650 cfs at the Weber Branch Siphon and from 550 cfs to 2,375 cfs upstream of the Scootenay Wasteway. The East Low Canal would be extended for about 2.3 miles from Kansas Prairie Coulee east toward Connell.

Canal side pumping plants would be constructed on the East Low Canal to pump into a piped pressurized water distribution system to higher elevation lands. Re-lift or booster pumps would be located along the piped laterals to provide additional pressure to “boost” water to the end of the lateral system.

The Weber Wasteway has foundation problems and currently can not evacuate water for the full capacity of the East Low Canal. The appraisal-level investigation assumed that the Weber Wasteway would be repaired.

The East Low Canal prism would be lined with concrete from Weber Branch Siphon south to its end, which would reduce seepage by an estimated 150 cfs.

3.3.2 Water Demands

The annual water demand for alternative B was calculated using the annual diversion requirements and conveyance efficiencies. The new East High canal would have an assumed annual efficiency of 74.0 percent. The efficiency was developed by assuming East High canal system seepage losses of 100 cfsand two spillways at 30 cfseach. All lateral diversions from the East High canal system are assumed to be piped, with a loss of 3 percent of the annual East High canal diversion. The annual diversion requirement for the East High canal system is 4.05 acre-feet per acre (3.00 acre-feet per acre on-the-farm delivery/0.74 efficiency). The East High canal would have an estimated annual water demand of 250,900 acre-feet (61,900 acres * 4.05 acre-feet per acre).

Table 17. Alternative B: Primary conveyance system features

Component	Canals (miles)	Smaller Pumping Plants*	Canal Siphons	Tunnels	Lateral Pipe Distribution (acres)
North of I-90					
East High canal	50.32	2	7 siphons/ 6.14 miles	2 tunnels/ 0.78 miles	27,340
Black Rock Branch canal	41.00	2	3 siphons/ 1.17 miles	1 tunnel/ .53 miles	34,560
Total for East High canal system	104.43	4	10 siphons/ 7. 30 miles	3 tunnels/ 1.31 miles	61,900
South of I-90**					
East Low Canal	56.67	7	7 siphons/ 3.90 miles	0	65,400
Total	161.10	11	17 siphons/ 11.20 miles	3 tunnels/ 1.31 miles	127,300

*Does not include major pumping plant at Black Rock Coulee re-regulating reservoir.
**Enlargement of existing facilities.

New pipe laterals would be constructed to serve lands from the East Low Canal. These laterals were assumed to have an annual efficiency of 97.0 percent. The efficiency was developed by assuming pipeline lateral losses of 3 percent of the annual East Low Canal diversion. The annual new diversion requirement for the East Low Canal would be 3.09 acre-feet per acre (3.00 acre-feet per acre on-the-farm delivery/0.97 efficiency). The East Low Canal would have an additional annual demand of 202,300 acre-feet (65,400 acres * 3.09 acre-feet per acre).

This alternative proposes lining the enlarged section of the East Low Canal and the extension, which would save an estimated 150 cfs. Most of this water would have been captured by the Potholes system and would require increased Potholes feed volume to offset this amount. Water conserved from lining the East Low Canal and the potential need for additional Potholes feed water is not included in the total annual demand calculated.

The peak design flow for pipeline laterals is 69 acres per cfs. The peak efficiency for the East High canal and its laterals was assumed to be 84.6 percent. East High canal was assumed to have a peak design flow of 1,060 cfs (61,900 acres/69 acres per cfs/0.846 efficiency).

3.4 Alternative C: East Low Canal Enlargement

Alternative C would provide a replacement water supply to about 50 percent (70,100 acres) of the groundwater-irrigated land within the Study area, as indicated by the green shaded areas in Figure 16.

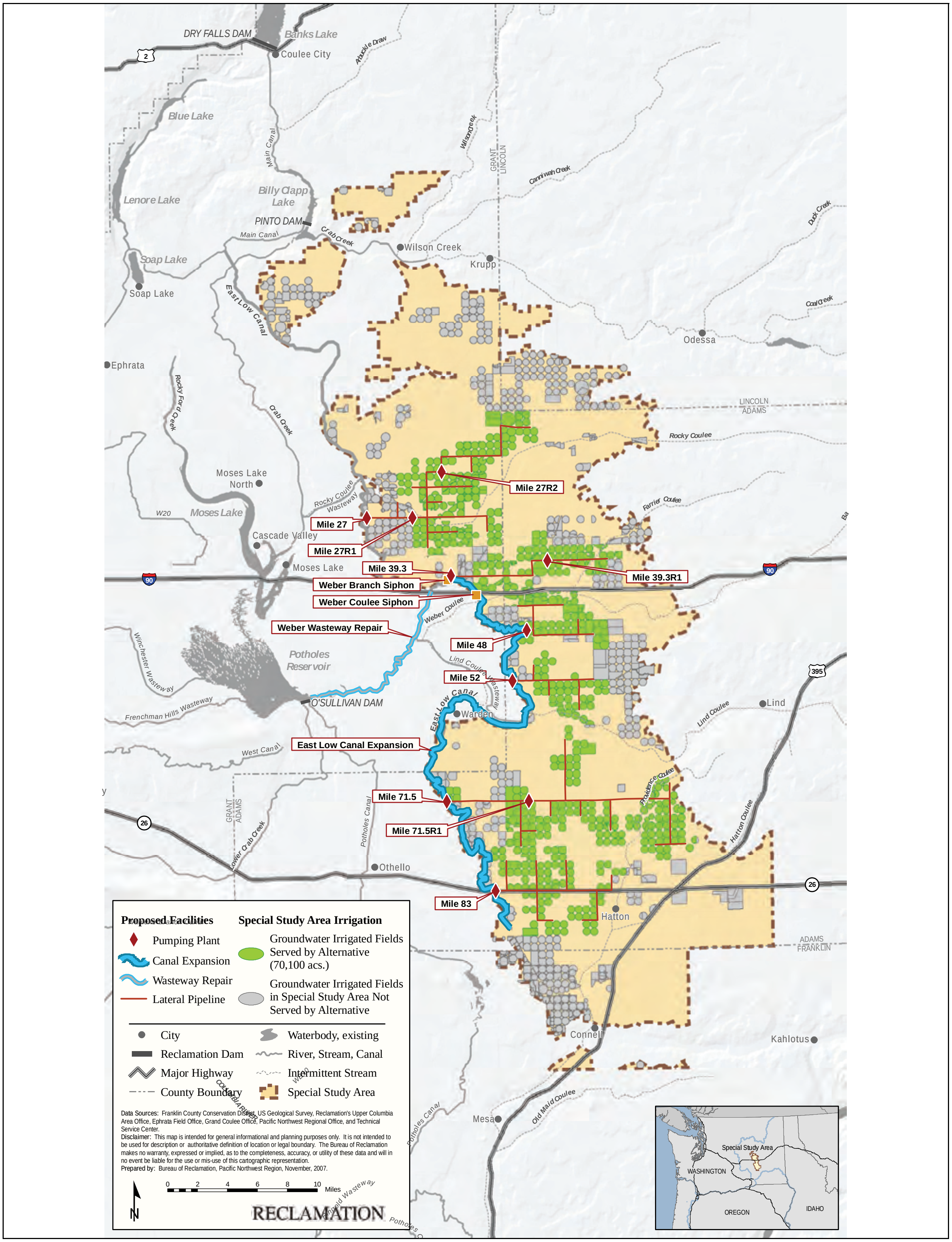

Figure 16. Alternative C.

3.4.1 Proposed Operations

Alternative C would enlarge a section of the existing East Low Canal. Major components include:

- East Low Canal enlargement from Weber Branch Siphon south;, includes enlargement of all siphons in this canal section)
- Weber Wasteway repair
- Canal side pumping plants and re-lift (booster) pumping plants
- Transmission lines and substations
- Piped distribution laterals

Figure 16 shows some of these facilities. Table 18 summarizes the primary conveyance features.

About 54 miles of the East Low Canal, beginning at the Weber Branch Siphon (located just north of I-90) and extending south, would be enlarged. Similar to alternative B, the Weber Branch and Weber Coulee siphons and five other siphons located along the East Low Canal to the south would be enlarged to allow additional water to be carried in the canal south of I-90. The East Low Canal prism for this section would be lined with concrete, which would reduce seepage by an estimated 150 cfs. The Weber Wasteway would be repaired.

Canal side pumping plants would be constructed along the East Low Canal, both north and south of I-90, to pump into a piped pressurized water distribution system to higher elevation lands. Re-lift or booster pumps would be located along the piped laterals to provide additional pressure to “boost” water to the end of the lateral system.

Similar to alternative B, alternative C proposes to enlarge the southern section of the East Low Canal to convey a replacement water supply. However, unlike alternative B, alternative C would distribute replacement water to lands located both north and south of I-90. This alternative focused on delivering replacement surface water to the areas experiencing the deepest aquifer declines.

3.4.2 Water Demands

The annual water demand for alternative C was calculated by using the annual diversion requirements and conveyance efficiencies. The pipe laterals that would serve the new lands were assumed to have an annual efficiency of 97.0 percent. The efficiency was developed by assuming pipeline lateral losses of 3 percent of the annual East Low Canal diversion. The annual new diversion requirement for the East Low Canal would be 3.09 acre-feet per acre (3.00 acre-feet per acre on-the-farm delivery/0.97 efficiency). The East Low Canal would have an additional annual demand of 216,800 acre-feet (70,100 acres * 3.09 acre-feet per acre).

This alternative proposes lining the East Low Canal, which would save an estimated 150 cfs. Most of this water would have been captured by the Potholes system so increased feed to Potholes Reservoir would be required to offset the conserved water. The water savings from lining the East Low Canal was not included in the total annual demand calculated.

The peak design flows for pipeline laterals is 69 acres/cfs. The peak lateral efficiency is assumed to be 100 percent. New laterals from the East Low Canal would have a peak design flow of 1,015 cfs (70,100 acres/69 acres/cfs).

Table 18. Alternative C: primary conveyance system features

	Smaller Pumping Plants	Canal*	Canal Siphons*	Tunnels	Lateral Pipe Distribution
Total	5	57 miles	7 siphons/3.09 miles	None	70,100 acres

*Enlargements of existing facilities.

3.5 Alternative D: Existing East Low Canal

Alternative D would provide replacement water for about 29 percent (40,700 acres) of the groundwater-irrigated lands within the Study area, as indicated by the green shaded areas in Figure 17. Major components include:

- Canal side pumping plants and re-lift (booster) pumping plants
- Weber Wasteway repair
- Transmission lines and substations
- Piped distribution laterals

3.5.1 Proposed Operations

Alternative D would use the existing East Low Canal capacity to deliver more water to concentrated areas of groundwater-irrigated lands that are close enough to the canal to make construction of distribution facilities economically viable. Because of constraints with the current size of the Weber Branch and Weber Branch Coulee siphons, replacement water could only be provided to lands adjacent to and near the East Low Canal north of I-90. A piped distribution system would be built to deliver a replacement water supply from the East Low Canal to lands north of I-90.

3.5.2 Water Demands

The annual water demand for alternative D was calculated using the annual diversion requirements and conveyance efficiencies. The annual efficiency for the pipe laterals to serve the new lands from the East Low Canal was assumed to be 97.0 percent. The efficiency was developed by assuming annual pipeline lateral losses of 3 percent of the annual East Low Canal diversion. The annual new diversion requirement for the East Low Canal was calculated at 3.09 acre-feet per acre (3.00 acre per acre on-the-farm delivery/0.97 efficiency). The East Low Canal would have an additional annual demand of 125,900 acre-feet (40,700 acres * 3.09 acre-feet per acre).

The peak design flows for pipeline laterals would be 69 acres/cfs. The peak lateral efficiency is assumed to be 100 percent. New laterals from the East Low Canal would have a peak design flow of 590 cfs (40,700 acres/69 acres/cfs).

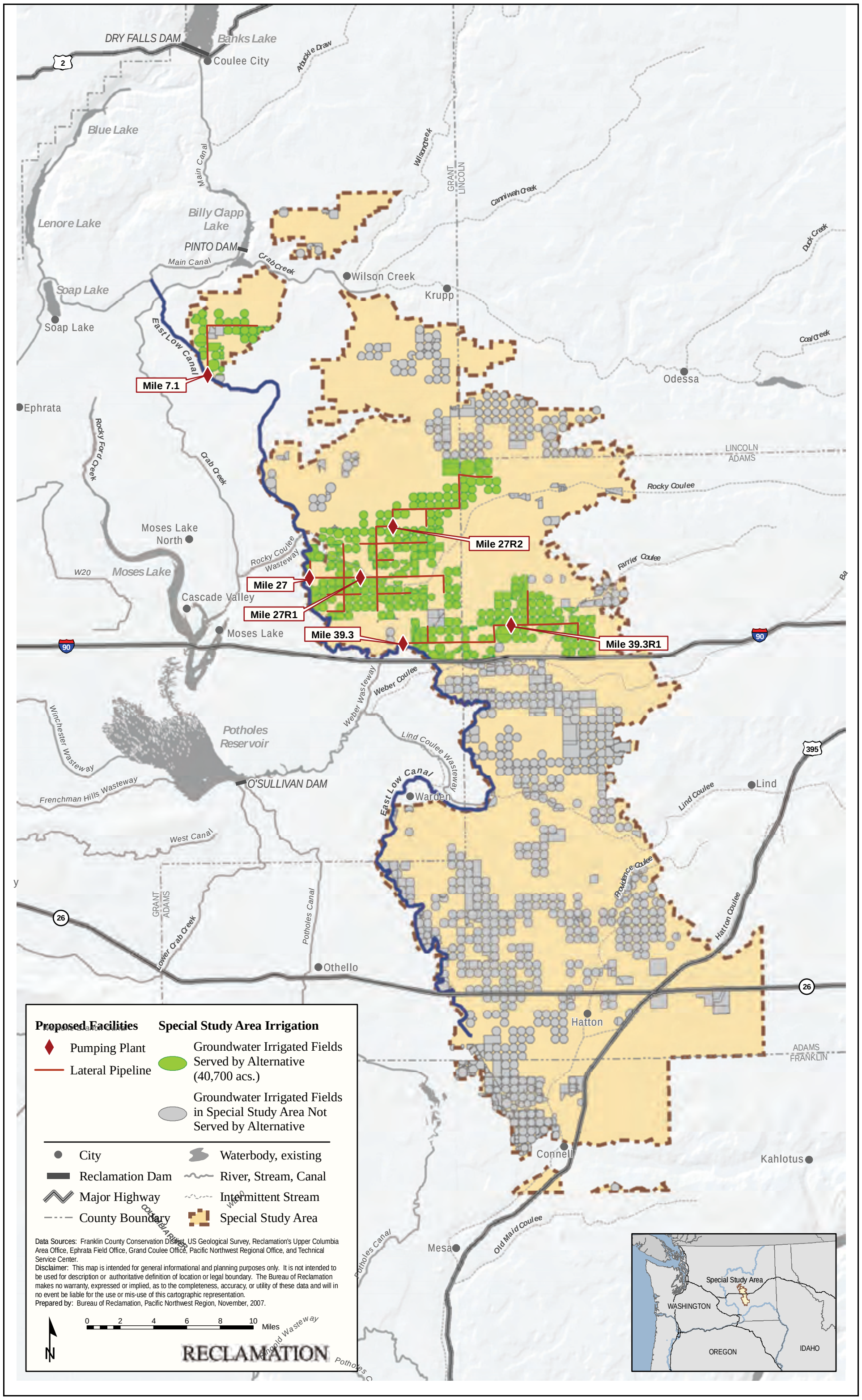

Figure 17. Alternative D.

4.0 Water Supply Options

Reclamation would need to make additional diversions from the Columbia River above current CBP diversions to provide surface water to replace current groundwater irrigation in the Study area. Table 19 shows the volume of new diversions required for each alternative.

Table 19. Columbia River diversions required for each water delivery alternative.

Water Delivery Alternative	Additional Columbia River Diversion* (acre-feet)
Alternative A – Construct East High canal system	515,300
Alternative B – Construct north portion of East High canal system. Enlarge and extend East Low Canal	453,200
Alternative C – Enlarge East Low Canal	216,800
Alternative D – Use existing East Low Canal	125,900

* Does not account for changes to current diversions if return flow changes are caused by the alternatives. This will be addressed in future studies.

4.1 Columbia River Diversion Strategy

Reclamation has a 1938 "withdrawal" in effect, which set aside water to irrigate the remaining authorized acres of the CBP. However, Reclamation would need to comply with NEPA regulations, consult under the ESA, and address other issues before it can divert additional water from the Columbia River. As discussed in Section 2.6.2, Columbia River Water Supply, this Study assumed that water from the Columbia River would not be diverted unless flows exceeded ESA flow objectives for anadromous fish that NMFS identified. Further, consistent with State water law, the investigation also assumed that no new diversions would occur in July and August without a replacement water supply. Reclamation conducted a modeled analysis using these assumptions to determine when water might be available for diversion.

Figure 18 shows the results of the modeled analysis, comparing the volume of Columbia River water above ESA flow objectives for the driest consecutive 10 years of record (1936 to 1945) with the water demand to provide a full replacement supply for all 140,000 groundwater-irrigated acres in the Study area (water delivery alternative A). In the driest years, Columbia River water is not available for diversion in most months when required to meet the irrigation demands for Study area lands. However, even in drier years, significant water is available for diversion in September and October, when the canals are still operational. Based on these modeled results, Reclamation determined that additional Columbia River diversions would mainly need to occur in September and October, when canals are still operational, if ESA flow objectives were not to be affected.

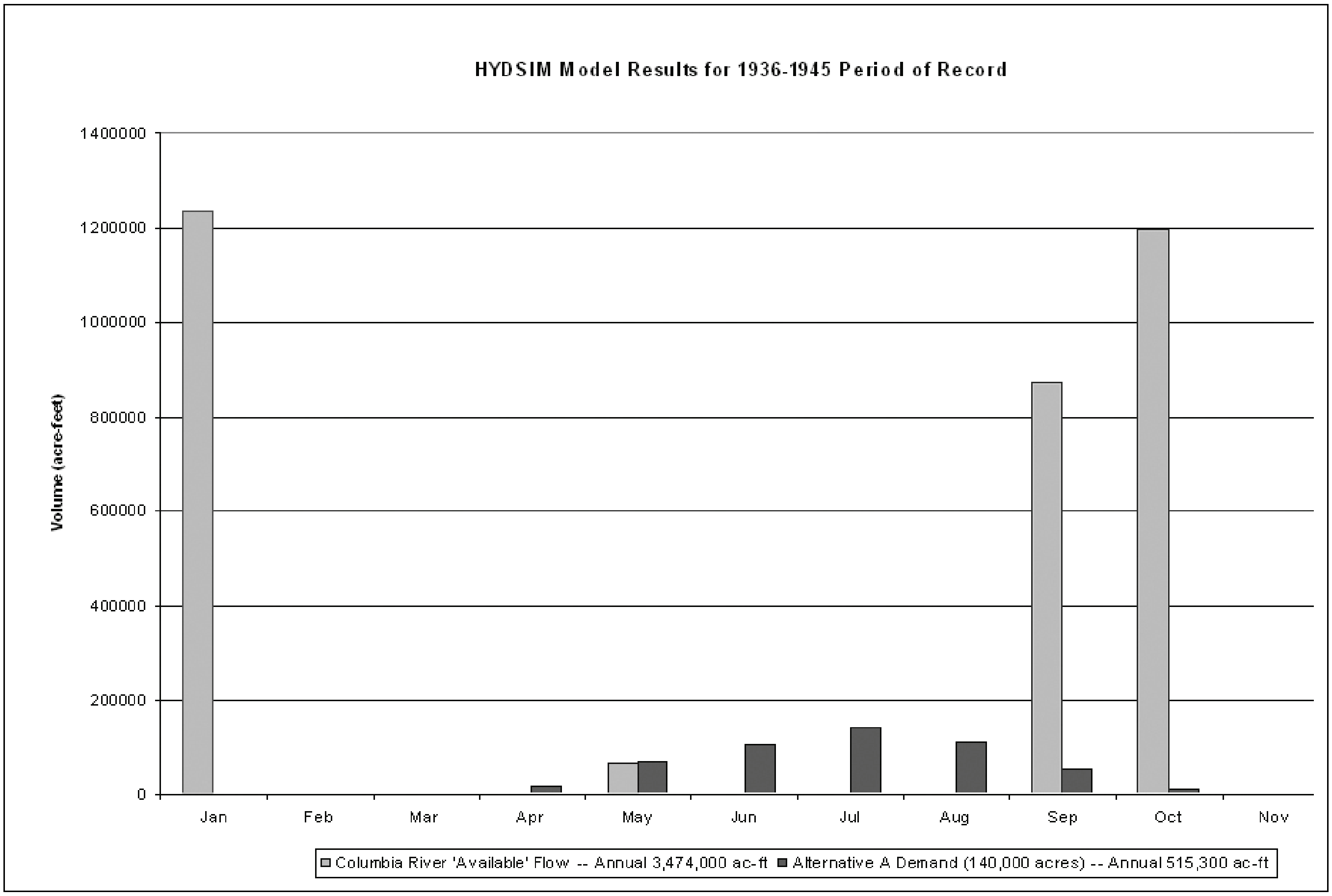

Figure 18. Volume of Columbia River water available (for 1936 to 1945 period) (gray) compared to the volume required to replace all groundwater-irrigated acres in the Study area (black).

4.2 Water Supply Options Examined

The PASS recommended a number of water supply options that would minimize potential effects to ESA flow objectives. Six were examined in this investigation. Several water supply options may be needed to provide sufficient replacement water for an alternative. Three options examined modifying operations at existing CBP storage facilities:

- **Banks Lake draw down**. Draw down Banks Lake to elevations lower than current operations. Drawdowns could range from an additional 4 to 16 feet, depending on the water delivery alternative selected.
- **Banks Lake operational raise**. Raise the operational water surface of the reservoir by 2 feet. This would require modifications to the two dam embankments forming Banks Lake and to the Grand Coulee Feeder Canal.
- **Potholes Reservoir reoperation**. Adjust the timing of water storage in the reservoir.

Three options examined constructing new storage reservoirs that would be filled in September and October and used in the irrigation season from mid-March through August when diversion water is not available from the Columbia River.

- **Dry Coulee reservoir**. Construct a new reservoir in Dry Coulee with an active storage capacity of 481,000 acre-feet.
- **Rocky Coulee reservoir and pumping plant**. Construct a new reservoir in Rocky Coulee, with an active storage capacity of 126,000 acre-feet, and a pumping plant.
- **Lower Crab Creek reservoir.** Construct a new reservoir in Lower Crab Creek. Two reservoir sizes were examined: one with active storage capacity of 472,000 acre-feet and the other with 200,000 acre-feet active storage capacity.

Figure 19 shows the locations of these water supply options. Table 20 shows the estimated volume of replacement water each option would provide. Reclamation estimated these quantities using various methods ranging from hydrologic modeling to approximations from preliminary storage capacity curves.

Table 20. Water supply options: active storage and groundwater-irrigated acres served

Water Supply Option	Active Storage (acre-feet)	Groundwater Acres Served	
		Acres	percent
Banks Lake drawdown	50,000 for every 2-foot drop*	Up to 140,000	100
Banks Lake raise	50,000	16,700	12
Potholes Reservoir reoperation	50,000	16,700	12
Dry Coulee reservoir	481,000	140,000	100
Rocky Coulee reservoir	126,000	46,900	34
Lower Crab Creek reservoir	472,000	140,000	100
	200,000	60,000	43

*Banks Lake has 715,000 acre-feet of active storage. Currently, 125,000 acre-feet of this is used to assist with Columbia River ESA fish flow objectives.

4.2.1 Water Supply Options Considered but Eliminated

The PASS study recommended other potential water supply options that were determined to not merit additional study early in the appraisal-level investigation. These water supply options and the rationale for not considering them further include:

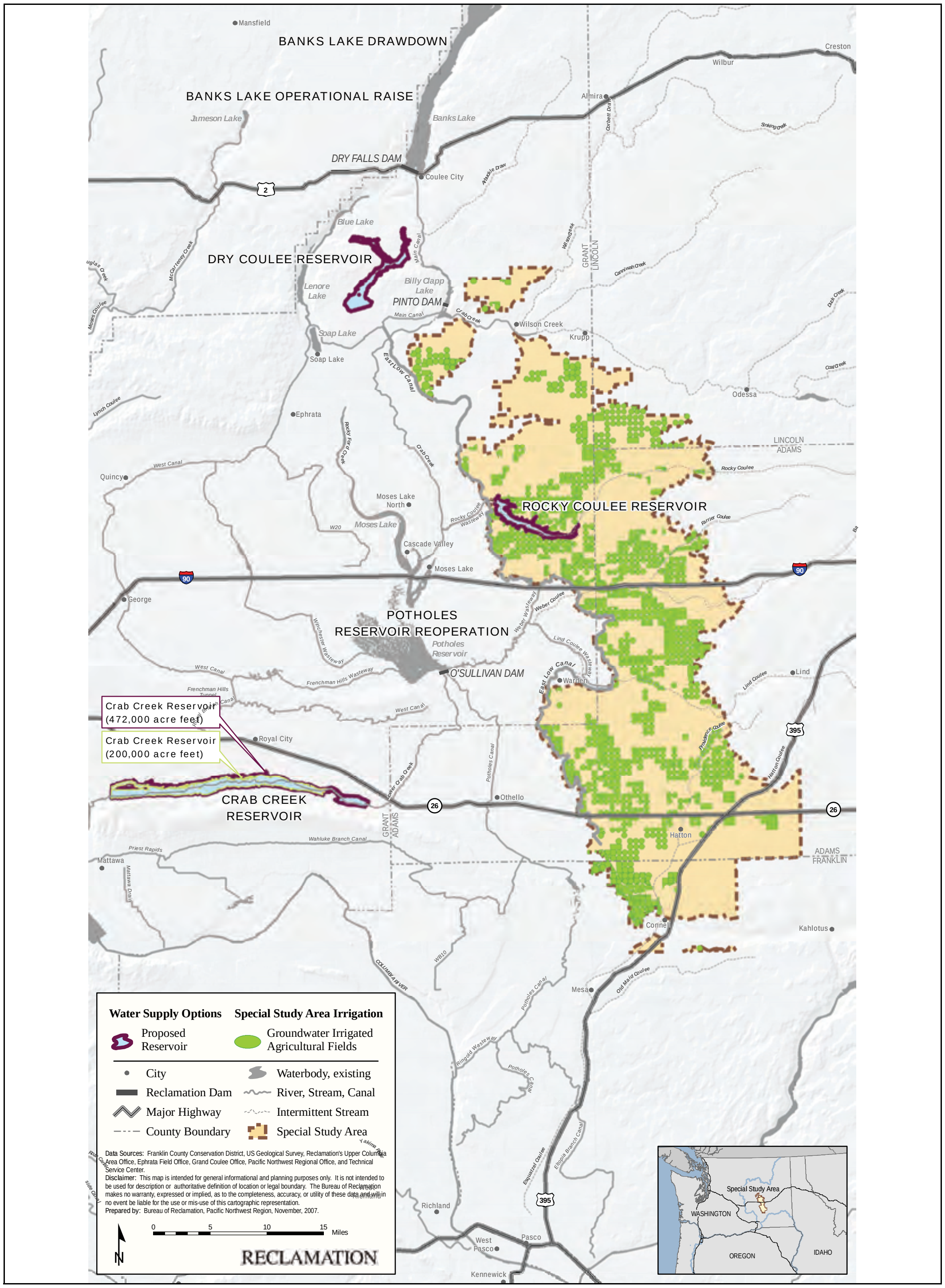

Figure 19. Location of the six water supply options investigated.

- **Proposed Lind Coulee reservoir**. Preliminary cost estimates developed during appraisal-level analyses determined that Lind Coulee was fairly costly and had a limited storage volume (about 75,000 acre-feet) compared to other proposed sites. In addition, the location of the proposed reservoir was not ideal from an operational perspective.
- **Proposed Black Rock Coulee reservoir**. This site is proposed for a re-regulating reservoir for canal regulation for the East High canal system for water delivery alternatives A and B. Reclamation did not assess its value as a water supply option in the appraisal-level investigations.
- **Water conservation through canal system efficiency improvements**. This option involves implementing canal system improvements to reduce or eliminate water loss due to leakage, inefficient system operations, etc. Reclamation and the CBP irrigation districts will continue to pursue canal system efficiency. However, it was determined that this alone could not provide the quantity of replacement water required for any of the alternatives. The smallest volume of water required is about 126,000 acre-feet to serve 40,700 acres under alternative D. Over the past 18 years, the ECBID has implemented 49 conveyance system water conservation projects that have yielded enough water to irrigate an additional 2,400 acres (Reclamation 2006 [PASS]). Further, the CBP operations include recapturing water and reusing it elsewhere in the CBP. The CBP diverts approximately 2.65 million acre feet (MAF) annually from the Columbia River at Grand Coulee Dam but delivers approximately 3.4 MAF to the lands it serves. Any water conserved within the CBP may affect water supply in another area of the CBP.

4.3 Operational Modifications at Existing Storage Facilities

Three water supply options considered operational modifications at existing storage facilities (either Banks Lake or Potholes Reservoir). Reclamation's dam safety guidelines require that any modification or change in operations must be risk neutral; that is, it must not increase the risk of failure above what currently exists at the facility.

Reclamation's dam safety program uses risk assessment as a primary tool to ensure that dams are operated in a manner that minimizes risk to downstream populations. Each Reclamation facility, as a minimum, has a risk analysis performed during the Comprehensive Facility Review, which is conducted every 6 years. In addition, a risk analysis is required before any dam is subjected to a modification of any of its features or if a potentially significant change is proposed in the operation of the reservoir (such as raising the operating level).

Reclamation conducted a preliminary risk analysis using existing data and without new exploration of the proposed operational modifications at Banks Lake and Potholes Reservoir. Reclamation reviewed risk analyses contained in the Comprehensive Facility Reviews for North and Dry Falls dams (Banks Lake) and O'Sullivan Dam (Potholes Reservoir) to determine if the proposed operational modifications would be "risk neutral" or if operations might increase risks. This preliminary analysis looked at three risk categories that a structure might be subjected under the proposed operational modifications:

- **Static failure risks.** Risks posed during normal operating conditions
- **Hydrologic risks.** Risks posed under flooding conditions

- **Seismic risks.** Risks posed during earthquakes

The preliminary risk analysis determined a structural response probability for each risk category. If Reclamation determined that the proposed operational modification may result in the possibility of risk above existing risks, then Reclamation proposed structural modifications to address these risks. Specific proposed modifications are discussed under the appropriate water supply option. Future feasibility studies of any operational modifications will continue to assess risk thresholds and will involve more detailed risk assessments.

4.3.1 Banks Lake Drawdown

This storage option involves withdrawing more water from Banks Lake to provide a replacement water supply, resulting in lower reservoir water levels than under current operations. There are no increased risks with this operation. This water supply option would not require any structural modifications to the dams. However, there would likely be effects to the resources and uses surrounding the reservoir, depending on the extent of the drawdown.

Current Operations

The water supply for the CBP is stored behind Grand Coulee Dam in Lake Roosevelt. Water from Lake Roosevelt is lifted to the Grand Coulee Feeder Canal, which flows 1.6 miles before entering Banks Lake (Figure 20). The Grand Coulee Feeder Canal has a capacity of 20,000 cfs. Since its construction in the early 1950s, Banks Lake has been operated and maintained to store and then deliver irrigation water to CBP lands. Reclamation operates the reservoir within established constraints on water surface elevation to meet contractual obligations, ensure public safety, and protect property. Water is delivered to CBP lands through the Main Canal, starting at Dry Falls Dam at the southern end of Banks Lake. Water is delivered into the Main Canal through a low-head powerplant or through an outlet works.

Banks Lake has an active storage volume of 715,000 acre-feet between elevations 1570 (full pool) and 1537 feet. From 1992 through 1999, the Banks Lake water surface elevation has fluctuated about 25 feet (elevation 1570 feet to 1545 feet). The lowest water surface elevation occurred in late 1994 and early 1995, when the reservoir was lowered to perform maintenance on constructed facilities and to reduce an infestation of Eurasian milfoil in the reservoir area. In September 1993, the water surface elevation was lowered 5 feet, to about elevation 1565 feet, for canal gates maintenance. Operational recommendations by Columbia River managers in April 1995 and August 1998 left Banks Lake near water surface elevation 1565 feet for short (i.e., month-long) periods. Except for these periods, the water surface elevation of Banks Lake fluctuated in a narrow 2-foot range, from about elevation 1570 feet to elevation 1568 feet, between 1992 and 1999.

Since 2000, Banks Lake is drafted 5 feet every August, to elevation 1565 feet, to provide water in the Columbia River for summer fish flow augmentation.

Proposed Operational Modifications

The Banks Lake drawdown option would use Banks Lake storage during the months when additional diversions from the Columbia River could not occur because flows above ESA flow objectives are not available. Hydrologic simulations of CBP operations, using the CBIP-RW

Figure 20. Top left photo: Grand Coulee Feeder Canal with Lake Roosevelt in background and Banks Lake in the foreground. Top right photo: Banks Lake and North Dam, one of two dams forming Banks Lake. Bottom right photo: Dry Falls Dam, one of two dams forming Banks Lake. Bottom left photo: Main Canal Headworks and Power Plant at Dry Falls Dam.

model, estimated the extent of draw down needed for each alternative using the 1929 to 2005 period of record. This simulation incorporates the 5-foot draw down that currently occurs in August. In all scenarios, refill to full pool for Banks Lake (1570 feet) would occur during September and October, assuming normal pumping capacity is available at Grand Coulee Dam.

Figure 21 shows the extent of draw down that would be needed to provide a full replacement supply for each of the water delivery alternatives compared to the current (baseline) operation.

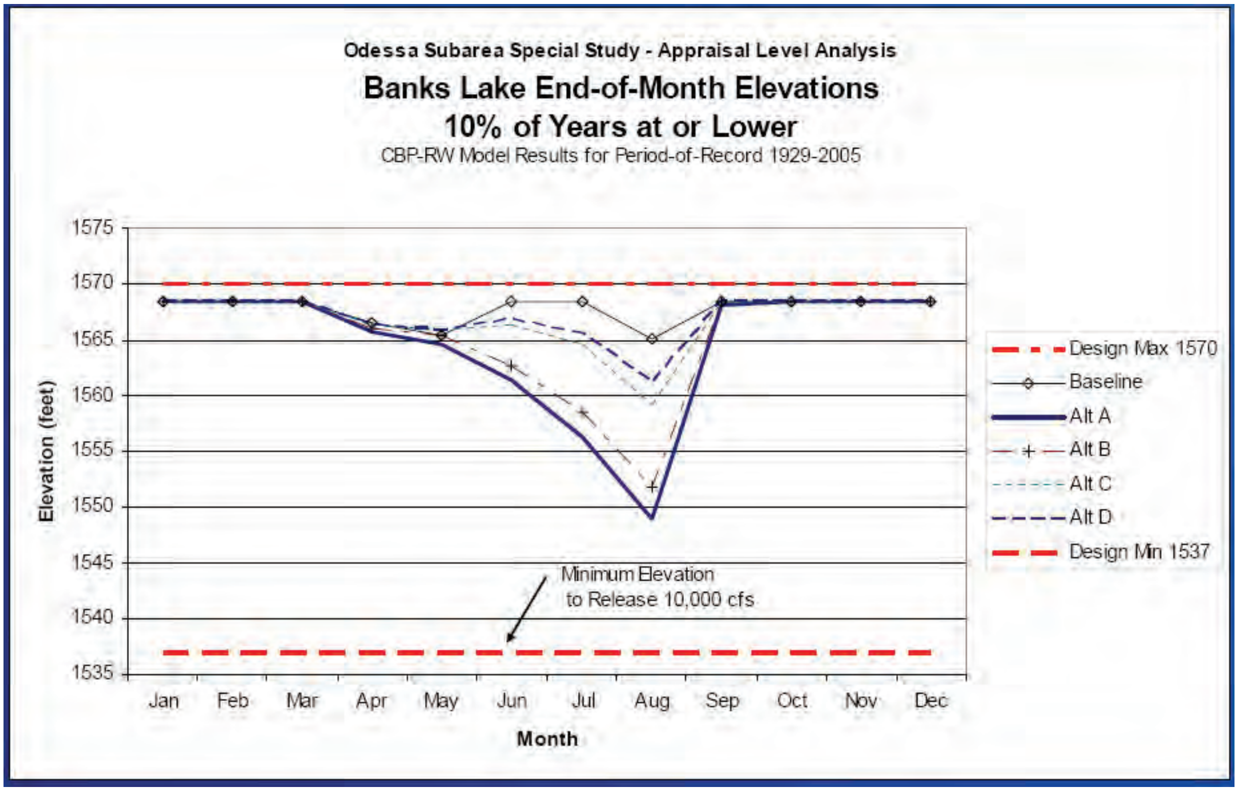

Figure 21. Modeled Banks Lake end-of-month elevations for current (baseline) operations and for alternatives A, B, C, and D (period of record 1929-2005).

The extent of draw down for each of the water delivery alternatives would be:

- Alternative A - Draw down to elevation 1549 feet (16 feet below current operations)
- Alternative B - Draw down to 1551 feet (13 feet below current operations)
- Alternative C - Draw down to 1559 feet (a little over 5 feet below current operations)
- Alternative D - Draw down to 1562 feet (almost 4 feet below current operations)

Elevation 1537 feet is the minimum water surface elevation at which the Banks Lake Headworks can release 10,000 cfs (the current maximum demand rate) into the Main Canal. If the water surface level drops below 1537 feet, releases from Banks Lake would be less than 10,000 cfs.

4.3.2 Banks Lake Raise

This option would fill Banks Lake above its current full pool elevation by as much as two feet. Raising the reservoir water surface could minimize the extent of draw down required and impacts associated with proposed increased withdrawals from Banks Lake to provide the replacement water supply. This operational modification may require structural modifications.

Current Operations

See description in Section 4.3.1, "Banks Lake Drawdown."

Proposed Operational Modifications

This water supply option investigated raising the maximum water surface elevation stored behind North Dam and Dry Falls Dam by an additional 2 feet, from elevation 1570 feet to elevation 1572 feet. Each additional foot of elevation equates to about 25,000 acre-feet of water stored—enough to provide a replacement supply to about 8,350 acres. Dry Falls Dam and North Dam each have approximately 10 feet of potentially useable freeboard (the portion of the dam above the normal reservoir levels) that extends above the full pool elevation of 1570 feet. Operating the reservoir within this potentially useable freeboard would require a Reclamation Safety of Dams review.

Potential Structural Modifications

Reclamation conducted a preliminary risk analysist to determine the potential risks associated with the proposed operational changes at Banks Lake. Based on this initial analysis, it may be necessary to raise the crest of Dry Falls and North dams by 2 feet and make modifications to the dam embankments to ensure that both dams would meet current Safety of Dams criteria for Reclamation dams. In addition, the height of the reinforced concrete lining of the Grand Coulee Feeder Canal may need to be increased by 2 feet to ensure that its structural integrity is not compromised by the proposed water surface elevation increase. This proposed structural modification would ensure that all structures at Banks Lake would maintain the same amount of freeboard that exists under the current reservoir operations.

Reclamation considered a series of design options and selected those with the most benefit for the least cost. Proposed modifications at Dry Falls and North dams include building a 2-foot crest raise, using conventional earthwork materials, and procedures and excavating a crackstopper trench through the dam crest that would be backfilled with sand and gravel filter material. The crackstopper trench and filter would serve to mitigate any increased potential for internal erosion failure mechanisms in the upper portion of the dams. Adding a vertical filter would effectively ensure that an internal erosion failure mode would not occur in the upper 15 feet of the embankments.

More detailed risk analyses, including risk reduction analyses, would be required in future design studies to verify the adequacy of these proposed modification measures. Impacts to highways, parks, other shoreline features, other infrastructure, the riparian environment, and the communities of Coulee City and Electric City would also need detailed review.

4.3.3 Potholes Reservoir Reoperation

This option proposes to adjust when feed water would be delivered to Potholes Reservoir. The shift in timing would result in additional capacity in the East Low Canal so that a replacement water supply could be delivered to groundwater-irrigated lands. This operational modification may require structural modifications.

Current Operations

O'Sullivan Dam and Potholes Reservoir lie immediately downstream of Moses Lake in the Lower Crab Creek basin. Irrigation water for the southern part of the CBP is distributed via the Potholes Canal, which begins at O'Sullivan Dam. At present, the Potholes Canal system serves approximately 204,000 acres, requiring up to 990,000 acre-feet of water annually from Potholes Reservoir.

The reservoir's main water supply is operational waste and irrigation return flow from northern CBP lands irrigated from the East Low and West Canals. Reservoir inflows originate from Moses Lake through the Crab Creek channel on the north side, from the Lind Coulee Wasteway on the east side, and from the Winchester and Frenchman Hills Wasteways on the west side. Current runoff and return flow volumes are not enough to supply the required irrigation water to the Potholes Canal system. Feed water is diverted from Banks Lake to Potholes Reservoir to meet the Potholes Canal system water supply shortfall. Potholes Reservoir requires up to 350,000 acre-feet of feed annually. Three feed routes currently deliver water into Potholes Reservoir:

- The primary route is through the East Low Canal to Rocky Coulee Wasteway, then into Upper Crab Creek, Moses Lake, and into Potholes Reservoir.
- A secondary route is from the East Low Canal to Lind Coulee Wasteway, which flows directly to Potholes Reservoir.
- The other secondary route spills water from the West Canal to the Frenchman Hills Wasteway, which also flows directly to Potholes Reservoir.

The existing feed routes would be used only in the spring and fall during the irrigation season when unused canal and wasteway capacity is available because of low irrigation demand. The existing feed routes are further limited by the need to leave space within the wasteways for emergency evacuation.

Fall feed is limited by the need to leave storage space in Potholes Reservoir to capture incoming return flows and to limit the spill of spring runoff from Upper Crab Creek into Lower Crab Creek. Reclamation has rights to pass floodwater down Lower Crab Creek to the extent that the flood releases do not exceed flows that might naturally occur without the CBP. The additional flow that could be spilled from Potholes Reservoir down Lower Crab Creek has been judged to be 50 to 100 cfs, depending on the time of year and other flows in the channel. Currently, Potholes Reservoir is operated to fill by June 1 (elevation 1046.5 feet) and then drafted until fall. Feed water is delivered in the spring to meet the fill target. Beginning on September 1, the baseline operation targets an end-of-season 1030.5 elevation. Historical end-of-month elevations for Potholes Reservoir are shown in Figure 22.

Proposed Operational Modifications

An estimated 50,000 acre-feet of water could be made available to replace groundwater use in the Study area by delivering that volume of feed water to Potholes Reservoir earlier in the fall season and holding it in the reservoir through the winter so that less feed water would be needed in the spring. Potholes Reservoir is filled around June 1 to ensure a full supply for the southern part of the CBP. Currently, about 260,000 acre-feet of feed is taken from the Columbia River during the April-May period to meet this full pool target date. Reclamation is proposing to shift some or all of this spring feed and deliver it in the September-October period, when Columbia

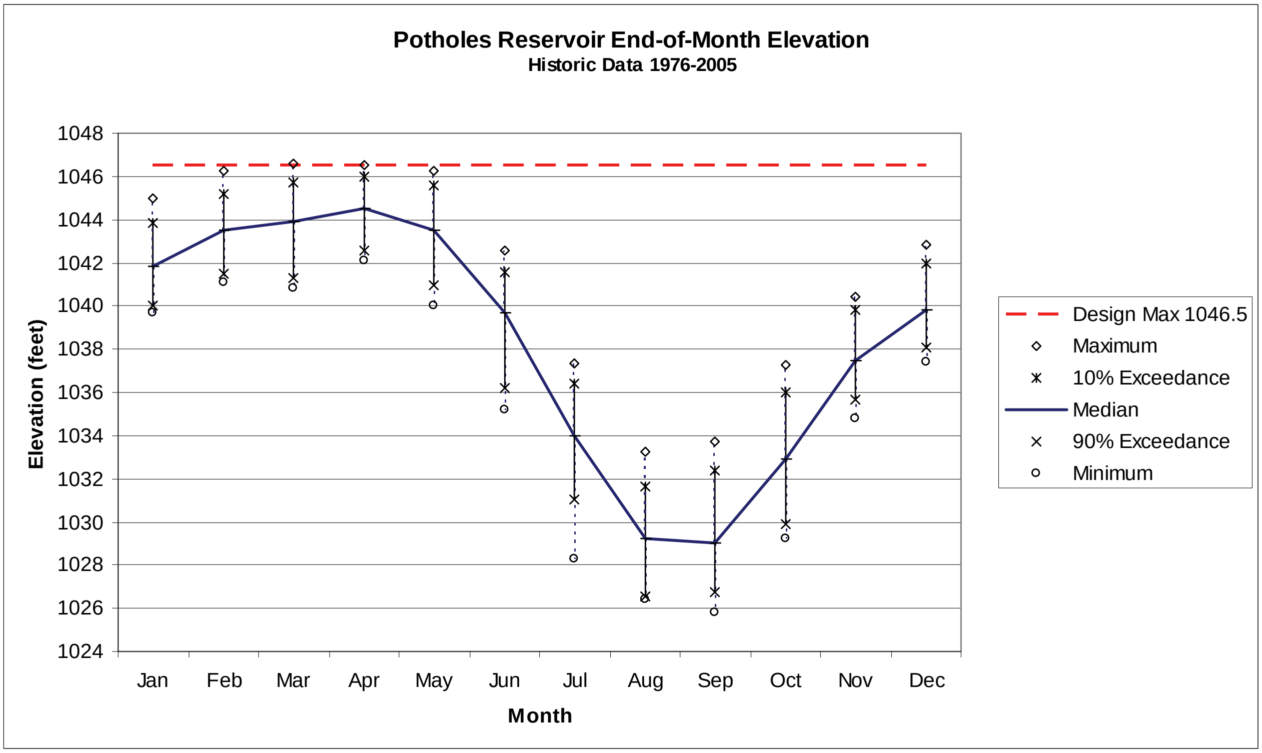

Figure 22. Potholes Reservoir historical end-of-month elevations for 1976-2005.

River flows exceed ESA flow objectives. This operational modification would raise the winter surface elevation of Potholes Reservoir about 3 feet and increase the probability of spring spill into Lower Crab Creek in greater volumes and more frequently than present operational constraints allow. This proposed operation would require acquisition of rights-of-way downstream to accommodate the possibility of these increased flood releases.

While the normal high pool elevation would not change, the pool would be at higher levels more frequently, thus increasing the annual average elevation. This higher annual average elevation may change dam safety risks to levels requiring structural modifications to keep this operation risk neutral.

Potential Structural Modifications

Reclamation conducted a preliminary risk analysis to determine potential risks from shifting delivery of feed water to Potholes Reservoir from the spring to the fall season, resulting in higher reservoir elevations in the winter. Based on this initial analysis, it may be necessary to make structural modifications to a portion of O'Sullivan Dam to ensure that dam safety criteria for Reclamation dams are met. The proposed modifications would generally be limited to the Lower Crab Creek area of the dam and would include a 5-foot crest raise, using conventional earthwork materials and procedures, and excavation of a crackstopper trench through the dam crest that would be backfilled with sand and gravel filter material. More detailed risk analyses, including risk reduction analyses, would be required in future design studies to verify the adequacy of these proposed modification measures.

4.4 Proposed Storage Facilities

Reclamation considered new off-stream storage reservoirs within the CBP at Dry Coulee, Rocky Coulee, and Lower Crab Creek to store a replacement water supply. Storage sites were proposed in the PASS based on location, size, and potential for gravity inflow and outflow. The appraisal-level investigation further developed these concepts and investigated these new reservoirs' operational capability with existing CBP operations.

4.4.1 Engineering Assumptions and Considerations

Embankment dam structures are proposed to provide new storage in the CBP. The design and construction considerations discussed below apply to all of the storage dams proposed in this Study. Safe embankments can be designed and constructed at each studied site without any particularly unusual measures or features beyond what are typically considered for a major embankment dam.

Reservoir Storage Volumes

Reclamation estimated reservoir storage volumes for the proposed storage sites based on water demands (which are based on crop distribution, annual on-farm allotments, and canal efficiencies), site capacity, canal availability and capacity, and the availability of Columbia River flows for diversion. Adjustments were made to account for reservoir seepage and evaporation losses. Preliminary assessments using limited data suggested that reservoir seepage might average about 30 cfs, or approximately 22,000 acre-feet per year. Reclamation also estimated the annual evaporation rate to be about 4.29 feet (applied to the average reservoir surface elevation). Using these loss values, Table 21 shows the estimated storage for each proposed reservoir.

Hydrologic Assumptions

Flood hydrographs were not available for the proposed water storage sites. Total runoff volumes for both the general and local Probable Maximum Flood (PMF) events were calculated as described in Reclamation 2006 (Drainage). The calculated flood volumes were conservative in

Table 21. Proposed reservoir storage (in acre feet)

Dam	Water Demand	Seepage Losses	Evaporation	Required Storage
Dry Coulee	448,000	22,000	11,000	481,000
Rocky Coulee	98,000*	22,000	6,000	126,000*
Lower Crab – large reservoir	448,000	NA**	24,000	472,000
Lower Crab – smaller reservoir	188,000	NA**	12,000	200,000

* Size of Rocky Coulee reservoir is limited by the invert of the feeder canal.
** Not applicable. No seepage losses assumed for Lower Crab Creek (offset by return flows).

assuming that all precipitation directly contributed to runoff, neglecting losses from basin infiltration and depression storage.

Reclamation generated simple, preliminary PMF volumes for each proposed site. Drainage areas were first estimated using digital, 7.5-minute quad sheets overlaid by hydrologic unit code drainages. The basin areas were highlighted manually, and the area was calculated. For Lower Crab Creek, this method was used only for the area below O'Sullivan Dam; the area upstream from O'Sullivan Dam was taken from published Reclamation data found on Reclamation's DataWeb <http://www.usbr.gov/dataweb>. Probable maximum precipitation (PMP) estimates followed the methods described in Hydrometeorological Report No. 57 (National Oceanic and Atmospheric Administration [NOAA] 1994). The results were compared to other nearby basins and to the 100-year events from the *Precipitation-Frequency Atlas of the Western United States*, Volume IX-Washington (NOAA 1973).

The PMF volumes were calculated first using the very simplified method of multiplying the drainage area times the PMP. Flood volumes for the Rocky Coulee storage site were adjusted based on a comparison of drainage basin areas and reported flood volumes for the hundred-million-year event at Pinto Dam. Table 22 shows the preliminary PMF flood volumes developed for the proposed reservoirs.

Table 22. Preliminary PMF flood volumes for proposed reservoir locations (in acre-feet)

Reservoir	General Storm Volume*	Thunderstorm Volume
Dry Coulee	13,900	8,800
Rocky Coulee	24,800*	15,700*
Lower Crab Creek	130,700	41,100

*Volumes adjusted/calibrated to Pinto Dam data

Without detailed flood studies, it is assumed that the dams would be sized to store the PMFs, with simple emergency spillways included in the design. Reclamation estimated the maximum water surface for each reservoir by adding the maximum flood volume to the required reservoir storage volume. The proposed Dry Coulee dam would be able to store the preliminary PMF volume with an estimated 3-foot increase in water levels. The proposed Rocky Coulee dam would be able to store the preliminary PMF volume with an estimated 9-foot increase in water levels. The proposed Lower Crab Creek dam (either dam option) would be able to store the preliminary PMF volume with an approximate 20-foot increase.

Seismic Loading Assumptions

A current site-specific seismotectonic evaluation has not been performed for any of the individual proposed dam sites in the Study area. Potential seismic hazard may exist due to the Yakima fold belt, a prominent group of mostly east-west striking folds, and the deep zone of the Cascadia Subduction Zone, which can produce very large magnitude earthquakes. Other local faults may be present in the vicinity, which could contribute to site seismicity. Reclamation assumed each dam site would have potentially high seismicity, with peak horizontal ground motions from design earthquakes (such as 10,000- or 50,000-year events) in the range of 0.5 to 1.0 g (gravity).

Potential Faulting

The possibility of fault displacements within the footprint of the embankments is a concern in areas subject to earthquake loading. Based on the preliminary geologic characterization of the site, there is no evidence to indicate that a potentially active fault exists within any of the dam or reservoir areas. Apparently inactive faults are present in the immediate vicinity of both Dry Coulee and Lower Crab Creek dam sites. However, relatively little exploration has been conducted in these areas to date. Further investigations could find evidence of foundation faulting that might be potentially active. An embankment dam structure may best accommodate potential fault displacements, as it is generally less stiff or rigid than a concrete dam.

Construction Material Availability

Forty-six developed borrow material sources were identified in the Columbia River basin. Two source types were identified: rock from basalt quarries or sand and gravel from alluvial deposits. Specific sites for mining impervious materials were not identified.

Embankment materials were based on materials used to construct Pinto Dam (Billy Clapp Reservoir) and O'Sullivan Dam (Potholes Reservoir). The embankment materials for these existing dams were mined locally from recent alluvium, glacial fluvial and glacial lacustrine deposits, and Palouse Formation (loess), as well as quarry rock from the numerous basaltic exposures. Commercial rock quarries, sand and gravel mines, and concrete batch plants also operate throughout the area. Sufficient embankment material sources were identified in the vicinity of the potential dam and reservoir sites to calculate rough estimates of haul distances for an appraisal-level cost estimate. Reclamation 2007 (Geology) mapped borrow areas for each potential dam site.

Dam Type Selection

Embankment dam types were selected for each proposed dam site based on the design considerations described above. Rockfill embankments were chosen for the Dry Coulee and Lower Crab Creek sites and appear to be better suited than zoned earthfill embankments for several reasons. First of all, the embankments at these sites would be large, with crest lengths of around 9,000 and 6,000 feet, respectively.

These structures would require large volumes of material. Thus, steep slopes (which are possible when rockfill shells are used) would result in significant embankment material savings. In addition, the overburden at both of these sites is quite deep and would have to be removed because of liquefaction concerns. Using steep slopes would result in saving a significant amount of embankment materials. Using rockfill will help minimize the amount of foundation excavation (and replacement with compacted embankment). Basalt is present throughout the dam and reservoir area at these two sites, with relatively little soil cover on the abutment and reservoir rims. The basalt, through quarrying, provides an unlimited source of rockfill.

At Rocky Coulee, the embankment would be relatively small, both in terms of length and height. In addition, the foundation overburden is not nearly as deep as at the other two sites. Therefore, a conventional earthfill embankment appears to be an economical option at Rocky Coulee. There appears to be sufficient borrow material in the vicinity to construct the embankment size anticipated at this site.

All three dam sites may be in an area of relatively high seismicity. In addition, there is some (perhaps small) potential that future site characterization could indicate the presence of foundation faults beneath the embankments, particularly at Dry Coulee and Lower Crab Creek, where faults are known to exist (although these faults are believed to be inactive). These potential seismic concerns dictate a dam type that is seismically stable even under very large loadings. Rockfill dams are recognized to be one of the best dams under these conditions, primarily because their design affords a large downstream portion that remains unsaturated and strong, and yet provides permeability to let seepage pass through if the impervious element of the dam is cracked or similarly damaged. This is further justification for selecting rockfill dams at Dry Coulee and Lower Crab Creek. To address any seismic concerns at the smaller Rocky Coulee dam, complete overburden removal and well designed filters would be included in the dam design.

Geological Conditions

An appraisal-level geologic investigation identified the depth to groundwater and of overburden (soil or other material layered over bedrock) in the vicinity of the proposed dam sites. This information is summarized in Table 23.

A key design consideration was to prevent the potential for foundation liquefaction. Complete excavation to bedrock beneath the majority of the footprint of each embankment was assumed. This will reduce all uncertainties of foundation liquefaction, and it may support the use of steeper slopes in later designs.

Water well drill logs, test pit logs, and any other available data from the vicinity of the dam sites were used to estimate the amount of overburden. However, without drilling holes along the dam axes, the depth to bedrock can not be known with any certainty. In general, these data indicated that the depth to rock at Dry Coulee and Lower Crab Creek could be significant, with a

Table 23. Depth to groundwater and of overburden in proposed dam sites vicinity

Dam Site	Depth to Groundwater (feet)	Depths of Overburden (feet)
Dry Coulee dam and dike	148	15 to 200
Rocky Coulee dam	65	25 to 75
Lower Crab Creek dam	82	5 to 150

maximum estimated overburden depth of around 200 feet and 150 feet, respectively. Consequently, considerable foundation excavation is expected at these two sites. Rocky Coulee is believed to have a shallower depth of overburden, with an estimated average depth of around 55 feet.

Water wells in the general vicinity of the dam sites indicate that groundwater depths are likely to be very deep in the alluvium at each site (Table 23). The majority of the foundation excavations are not likely to encounter groundwater, and dewatering is expected to be relatively straight-forward. Furthermore, at both Dry Coulee and Lower Crab Creek, the dams will be more than one mile long and contain large volumes of embankment materials. Thus, dewatering will comprise a very small cost component of the overall work. Conceptually, the dam foundation may be able to be dewatered by a relatively routine application of well points or deep wells and supplementary sumping. Due to the relatively small amount of dewatering work compared to the major earthwork activities associated with constructing the dam embankments, dewatering costs are expected to be minor. For the appraisal-level design, the dewatering scheme was not specified, and the costs are simply assumed to be a part of the unlisted items.

4.4.2 Dry Coulee Reservoir and Dams

This storage option would construct a new reservoir in Dry Coulee directly west of Billy Clapp Lake/Pinto Dam and about 10 miles south of Coulee City, in Grant County (Figure 19).

Design Concept

The design concept proposes to construct two central core rockfill embankment structures, consisting of a main dam at the southern end and a dike at a northern arm to prevent water from entering Soap Lake. An inlet canal would be constructed to fill the reservoir. Two outlets would be located at the main dam. The upper outlet would provide water for irrigation. A lower outlet would provide for reservoir evacuation, discharging into Crab Creek. Figure 23 shows this design concept and site plan.

The preliminary active storage would be 481,000 acre-feet. The preliminary total storage would be 571,500 acre-feet at normal water surface elevation 1485. The bottom of the active pool would be elevation 1329.5, which corresponds to a volume of 90,500 acre-feet. At full pool elevation, the estimated surface area would be about 5,100 acres in a reservoir about 7.5 miles long.

The main dam would be about 6,400 feet long. The crest elevation would be at 1491 feet, which is 3 feet above the maximum water surface that results from storing the PMF flood volume. The

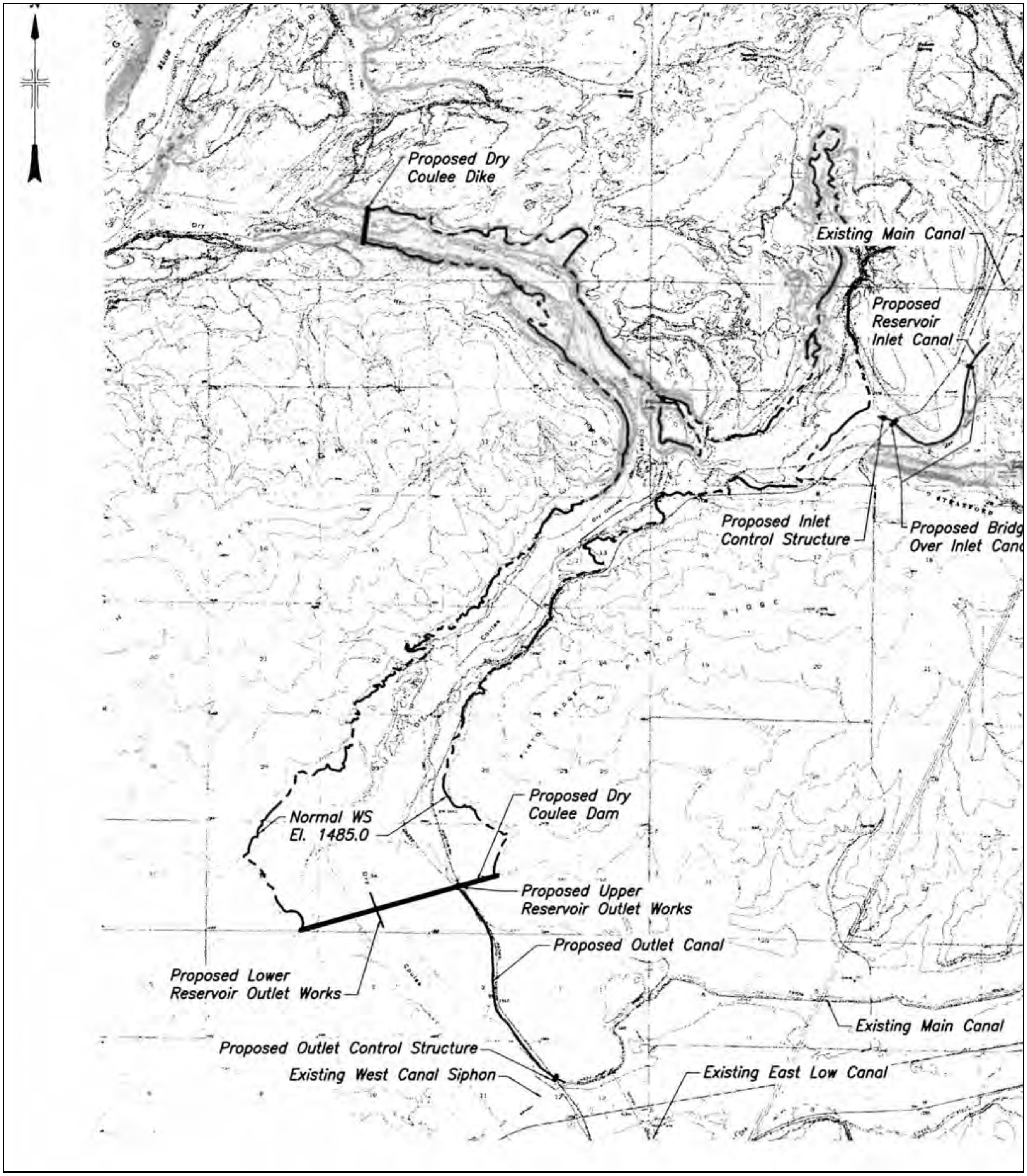

Figure 23. Dry Coulee reservoir design features

dam width at the crest would be 30 feet, a typical width for an embankment of this size. The downstream slope will be set at 1.5 (horizontal) to 1 (vertical), and the upstream slope at 2 to 1. The dam would consist of a central core rockfill embankment, with an upstream sloping impervious core. The primary reason an upstream sloping and relatively thin earth core was chosen is that inclining the core upstream ensures that a large portion of the dam (the large downstream zone) will consist of a strong, unsaturated rockfill, affording much static and dynamic stability. Secondly, the availability of impervious material in the immediate area is uncertain and could make the core relatively expensive. Keeping this zone relatively thin minimizes costs to some extent. The large zone of downstream rockfill needs far less foundation treatment (which would save more costs) than the treatment needed beneath an impervious zone. Finally, inclining the core should help reduce the potential for the core to crack due to differing settlement properties of the rockfill and impervious material.

The dike would be about 3,390 feet long and located just east of Blue Lake. Similar to the main dam, the crest elevation would be at 1491 feet. The embankment design would be essentially the same as for the main dam, consisting of a central core rockfill embankment with an upstream sloping impervious core.

A canal about 1½ miles long would be constructed from the existing Main Canal upstream of Summer Falls to the proposed northeast arm of the Dry Coulee reservoir to gravity feed the reservoir.

The proposed reservoir upper outlet works would have a design capacity for 2,290 cfs, which would meet the peak flow demand for alternative A. (Note: The proposed East High canal diversion from the Main Canal would be upstream of the proposed Dry Coulee reservoir return flow point.) The outlet works would feed a 2½-mile long outlet canal that would convey the water to the West Canal immediately upstream of the existing West Canal Siphon (at mile 0.2).

The lower outlet structure would be used to evacuate the reservoir, if needed, into Crab Creek. The lower outlet works would have a design capacity of 4,860 cfs.

Operational Description

Water would be diverted from the Columbia River at Grand Coulee Dam, pumped to Banks Lake, flow through the Main Canal, and be gravity fed into the proposed Dry Coulee reservoir. The reservoir would be fed via a new inlet canal from the existing Main Canal upstream of Summer Falls. The reservoir would be filled during September and October. Assuming 60 calendar days are available for inflow, the inflow rate to fill the active storage from empty would be about 4,000 cfs.

The upper outlet at the main dam would gravity feed via a new outlet canal to the existing West Canal, immediately upstream of the existing West Canal Siphon. This new outlet canal would be about 2½ miles long. The reservoir releases would be used to meet the demands for existing lands on the West Canal. Water currently diverted to the West Canal would be diverted to the East Low Canal instead. The projected demand for the East Low Canal groundwater-irrigated acres is less than the West Canal demand for existing irrigated lands, making this substitution viable. Irrigation water would be released on demand between March and August when water is not available for diversion from the Columbia River.

Geologic Conditions for Dry Coulee Site

Exposed bedrock at this site is composed of basalts of the Columbia River Basalt Group. About 25-218 feet of sedimentary overburden, composed of fine- to coarse-grained materials, overlies the valley floor. The overburden properties and depth to bedrock at the sites are based on limited data from water wells and surficial geologic maps.

Four deep wells are located in the vicinity of the Lower Dry Coulee dam site. The depth to bedrock in the bottom of the coulee ranged from 156 feet to 207 feet. The depth to bedrock in a well located in the valley upstream of the dam site exceeded 200 feet. The bedrock surface in the deepest section of the valley is likely at approximately elevation 1060 feet. This elevation was used for the bedrock profiles at both dam sites.

The overburden is about 200 feet thick and consists of fluvial gravel (Qg) deposits that range from boulders to fine sand. The upper surface is blanketed with a variable thickness (6 to 10 feet) of recent loess and alluvium consisting mostly of silt and fine sand. The side slopes are covered with talus and alluvial-fan deposits carried down from the upper slopes and cliffs in the coulee. The colluvium (Qc) is approximately 20 to 50 feet thick and consists of silt- to boulder-sized, mostly subangular, basaltic debris.

The bedrock at the Lower and Upper Dry Coulee sites consists of the Grande Ronde Basalt Formation (Tgr). The basalt is black or dark gray, fine-grained to aphanitic, with hackly jointing common. Columns are typically smaller than in the overlying Frenchman Springs, Roza, and Priest Rapids Basalt Members, and the unit includes thick zones of pillows and palagonite. The Grande Ronde consists of multiple flows with rare interbeds. Contacts between individual flows are sometimes rubbly and fractured, and these contact zones tend to be zones of higher permeability.

The bedrock foundation in the valley section and abutments at the Upper Dry Coulee site consist of Frenchman Springs Basalt (Tf). The basalt is dark gray and fine- to medium-grained. The bedrock forming the upper abutments is Roza Basalt (Trz), which is dark blue-gray and medium- to coarse-grained basalt that weathers to deep reddish-brown. The Roza Basalt has large columnar joints throughout that generally range from 5 to 10 feet across. The columns also have platy parting planes mostly normal to the axis of columns (Grolier and Bingham 1971 and 1978). The contact between the Frenchman Springs (Tf) and Roza (Trz) Basalt Members is marked by a thin, bed of clay or diatomaceous siltstone that is generally less than 1-foot thick.

Faults

Three faults have been delineated in the Dry Coulee area, one each at the Upper and Lower Dry Coulee dike and dam sites and the Pinto Fault that lies northeast of the Lower Dry Coulee dam site. All three are relatively short normal faults that are part of the same fault system. Analysis of aerial photographs shows that the faults have poor geomorphic expression, and interpretations also suggest that late Quaternary deposits associated with periodic floods from glacial Lake Missoula overlying the faults have not been displaced (Geomatrix 1990). Based on this information, the faults have been judged inactive (Geomatrix 1990).

Ground Water

Static water levels were estimated based on data from a well in Dry Coulee upstream from the dam site. The static water level was recorded in 2003 at about 148 feet below ground surface at approximately elevation 1122 feet.

4.4.3 Rocky Coulee Reservoir and Dam

This storage option involves constructing a new reservoir in Rocky Coulee upstream from where the East Low Canal siphon crosses the coulee, about 8 miles northeast of Moses Lake (Figure 24).

Design Concept

The design concept proposes a zoned earthfill embankment dam with a central impervious core. A canal would be constructed to fill and discharge water from the reservoir. A pumping plant would be needed to pump water from the reservoir when needed for irrigation. The design concept site plan is shown in Figure 24.

The proposed reservoir would have an active storage capacity of 126,000 acre-feet at a normal water surface elevation of 1290 feet. The bottom of the active storage would be elevation 1215 feet, which would not provide any water storage. At full pool, the estimated surface area would be about 3,000 acres in a reservoir about 8 miles long.

The dam would be about 3,850 feet long. The height at the crest would be at 1302 feet elevation, which is 3 feet above the maximum water surface resulting from storing the PMF flood volume. The embankment width would be 30 feet at the crest, a typical width for this type and size of embankment. The downstream slope would be set at 2:1 (horizontal to vertical ratio), while the upstream slope would be 2½:1.

A zoned earthfill dam was selected based on the relatively small size of the embankment, absence of very deep overburden, and apparent availability of various embankment materials in the immediate vicinity. This traditional design features a fairly wide central core consisting of impervious materials.

An inlet/outlet canal would be constructed from the East Low Canal immediately upstream of an existing siphon crossing Rocky Coulee to the reservoir just north of the right abutment of the proposed dam.

A lower outlet structure would be constructed at the dam to evacuate the reservoir, if needed. The outlet structure would have a design capacity of 1,460 cfs.

A large pumping plant immediately downstream of the proposed dam would pump water stored in the proposed reservoir into the inlet/outlet canal and into the existing East Low Canal. The pumping plant would be 70 feet wide by 310 feet long and would pump 714 cfs with a maximum head of 84 feet (total design head).

Operational Description

Water would be diverted from the Columbia River at Grand Coulee Dam, pumped to Banks Lake, flow through the Main Canal, and then flow into the East Low Canal. Water would be diverted into the reservoir via an inlet/outlet canal constructed upstream of the intake to the Rocky Coulee Siphon on the East Low Canal (Mile 23.0). The reservoir would be filled in the fall and water released back to the East Low Canal during the irrigation season. A proposed pumping plant would pump reservoir water back to the East Low Canal using the inlet/outlet canal to meet the irrigation demands of downstream farmlands to the south. Water would be pumped out March through August.

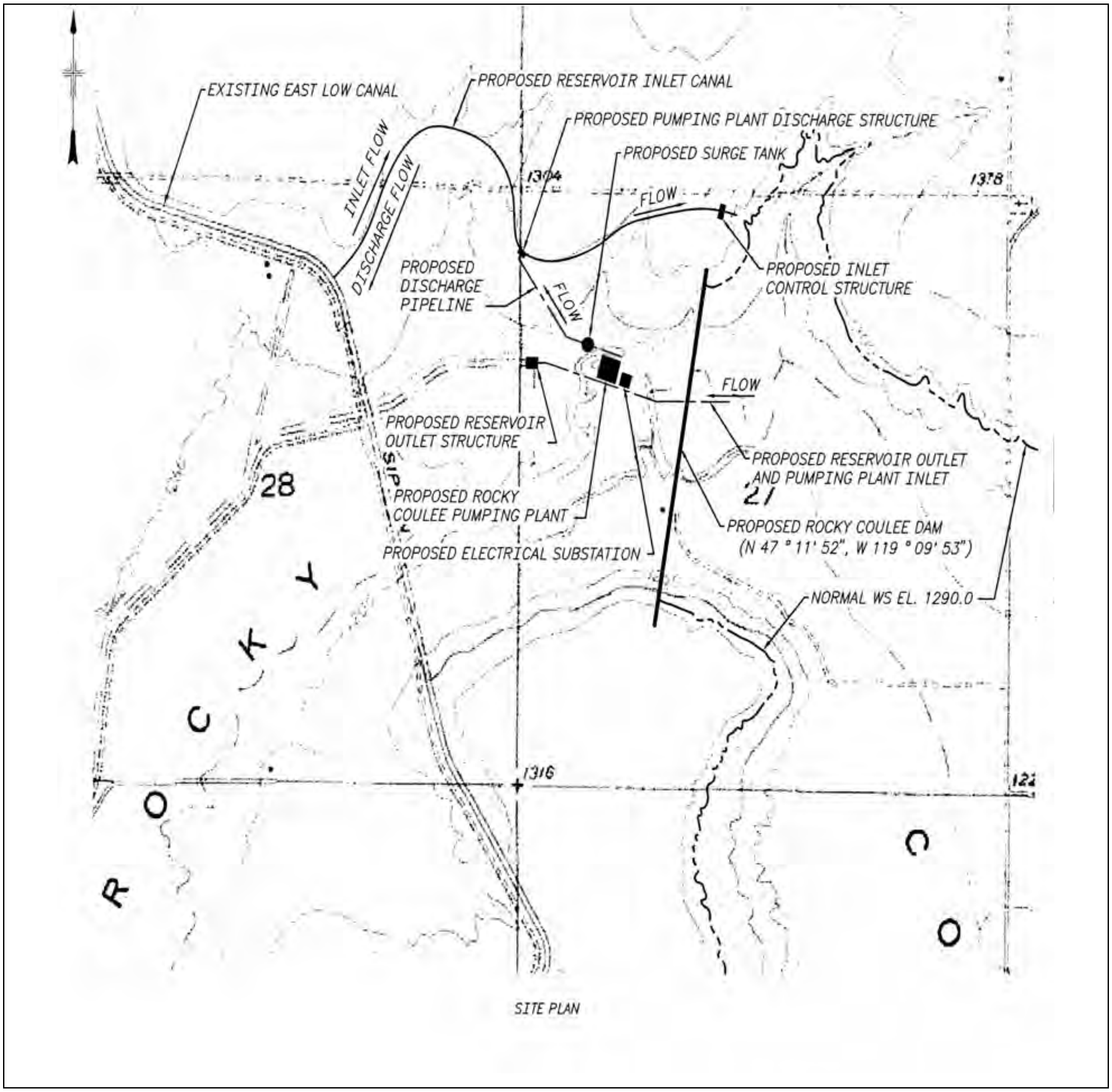

Figure 24. Rocky Coulee reservoir design concept.

The reservoir would be filled in September and October. Assuming 60 calendar days are available for inflow, the inflow rate needed to fill the reservoir would be about 1,060 cfs.

Geologic Conditions for the Rocky Coulee Site

Exposed bedrock at this site consists of basalts of the Columbia River Basalt Group. About 0 to 100 feet of sedimentary overburden, composed of fine- to coarse-grained materials, overlies the valley floor. The overburden properties and depth to bedrock are based on data from water wells, test pits along the nearby East Low Canal, and surficial geologic maps.

One deep well is located about 4,300 feet upstream of the dam site. The depth to bedrock in this well is 73 feet below the ground surface, which is postulated to be about the maximum depth to bedrock in the middle channel section of the coulee. Data from test pits excavated for the original design of the East Low Canal were used to estimate the depth to bedrock underlying the left and right sides of Rocky Coulee. The depth to bedrock is about 33 feet on the right side of the valley and about 26 feet on the le ft.

The overburden in the valley section is alluvium (Qa), overlying a combination of fluvial gravel (Qg) and fluvial and lacustrine sand (Qs). Based on test pits and well reports, these materials are composed primarily of fine sand and silt. The abutments are covered with lacustrine fine sand and silt (Qss).

The bedrock foundation in the valley section and lower abutments consists of Frenchman Springs Basalt (Tf). The basalt is dark gray and fine-to-medium grained. The bedrock forming the upper abutments is Roza Basalt (Trz), which is dark blue-gray and medium-to-coarse-grained basalt that weathers to deep reddish brown. The Roza Basalt has large columnar joints throughout that generally range from 5 to 10 feet across. The columns also have platy parting planes mostly normal to the axis of columns (Grolier and Bingham 1971 and 1978). The contact between the Frenchman Springs (Tf) and Roza (Trz) Basalt Members is marked by a thin, bed of clay or diatomaceous siltstone, generally less than 1-foot thick.

Ground Water

Static water level is estimated based on data from a well in Rocky Coulee upstream from the Rocky Coulee dam site. The static water level was measured at about 64.5 feet at approximately elevation 1156 feet. The water level was recorded in 1950 and may not reflect current conditions.

4.4.4 Lower Crab Creek Reservoir

This storage option involves constructing a new reservoir in Lower Crab Creek 2 miles upstream from the confluence with the Columbia River. The Lower Crab Creek site is east of the Columbia River, about 4 miles south of Wanapum Dam in southwest Grant County (Figure 25). Two sizes of reservoir were investigated: 472,000 acre-feet active storage and 200,000 acre-feet active storage, which would operate in the same way.

Design Concept

The design concept proposes to construct a central core rockfill embankment structure, with an upstream sloping impervious core. The dam location and alignment is the same for both reservoir sizes. The design concept site plan for the larger dam is shown in Figure 25, and the configuration for the smaller dam is similar.

472,000 Acre-foot Reservoir

The larger reservoir would have an active storage of 472,000 acre-feet at normal water surface elevation 585 feet. The bottom of active storage would be elevation 500 feet, which is zero

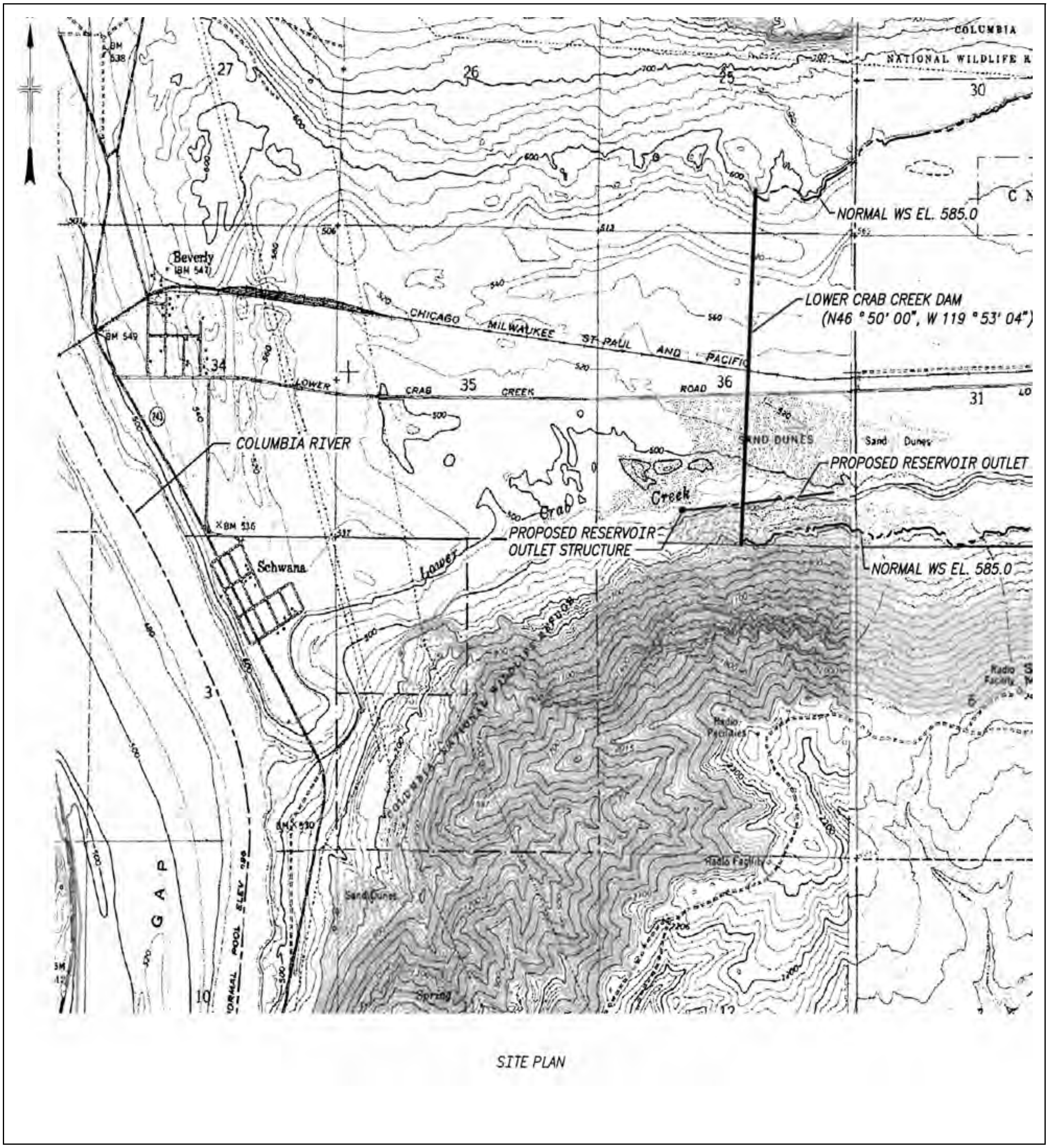

Figure 25. Lower Crab Creek (472 KAF) design concept.

capacity. Under full pool, the estimated reservoir surface area would be 12,682 acres in a narrow reservoir about 20.5 miles long.

The dam would be about 8,050 feet long and 99 feet high. The crest elevation would be 606 feet, which is 3 feet above the maximum water surface resulting from storing the PMF flood volume.

The dam would be a rockfilled embankment dam, consisting of a central core rockfill embankment with an upstream sloping impervious core. The embankment structure design, slopes, and material types are essentially the same as the proposed Dry Coulee main dam. However, source locations and haul distances would be different.

The reservoir outlet structure would have a design capacity of 4,420 cfs to meet irrigation demands and to evacuate the reservoir, if needed.

A new outlet structure would be constructed in the Potholes East Canal to allow releases into Lower Crab Creek to fill the proposed Lower Crab Creek reservoir.

200,000 Acre-foot Reservoir

The embankment structure design, slopes, and material types for the smaller reservoir would be essentially the same as the larger reservoir described above. The reservoir would have an active storage of 200,000 acre-feet at normal water surface elevation 557 feet. Under full pool, the estimated reservoir surface area would be 8,969 acres.

The dam would be about 8,050 feet long and 75 feet high. The crest height would be at 582 feet elevation, which is three feet above the maximum water surface resulting from storing the PMF flood volume.

The reservoir outlet structure would have a design capacity of 2,190 cfs to meet irrigation demands and to evacuate the reservoir, if needed.

A new outlet structure would be constructed in the Potholes East Canal to allow releases into Lower Crab Creek to fill the proposed Lower Crab Creek reservoir.

Operational Description

The proposed reservoir would be operated differently than the proposed Dry Coulee reservoir and Rocky Coulee reservoir. Water would be released from the proposed Lower Crab Creek reservoir to the Columbia River to offset upstream irrigation diversions at Grand Coulee Dam, as opposed to being released for delivery to the irrigated lands.

Lower Crab Creek reservoir would be filled by releases from the upstream Potholes Reservoir via Lower Crab Creek. Initial Columbia River diversions would occur at Grand Coulee Dam, and water to fill the proposed reservoir would be conveyed to Potholes Reservoir by pumping from Lake Roosevelt into Banks Lake, then released into the Main Canal to the East Low Canal, and then to Potholes Reservoir via Rocky Coulee and Lind Coulee Wasteways. Operations to fill the proposed reservoir would begin on September 1 and end when the reservoir is full or at the end of the irrigation season. The feed water needed to meet Potholes Reservoir target elevations to provide a water supply for existing irrigated lands located in the southern part of the CBP would take priority over providing water to fill the proposed Lower Crab Creek reservoir.

Releases for Potholes Reservoir into Lower Crab Creek to fill the proposed the Lower Crab Creek reservoir would be limited to 2,600 cfs for the larger reservoir and 1,600 cfs for the smaller reservoir. The peak Lower Crab Creek flow would be about 3,000 cfs during the filling period, which includes return flows. Acquisition of right-of-way downstream along Lower Crab Creek would be required to provide for the increased flows to fill the reservoir. Bridges, culverts, and other infrastructure located downstream would require improvement.

During irrigation season, water would be released into the Columbia River to offset new diversions at Grand Coulee Dam to provide the replacement water supply for the groundwater-irrigated lands. Water would be released from the Lower Crab Creek reservoir into the Columbia River based on the March through August irrigation demands. These releases would be in addition to any return flows.

Geologic Conditions for the Lower Crab Creek Site

The Lower Crab Creek site is in the western part of the Columbia River Plateau, a structural and topographic basin that encompasses most of the Columbia River drainage. Exposed bedrock at this site is composed of basalts of the Columbia River Basalt Group. About 50 to 100 feet of sedimentary overburden; mostly fine sand but also silt, coarse sand, and gravel; overlies the valley floor. The overburden properties and depth to bedrock at the site are based on data from a single well downstream of the dam site, Reclamation soil profiles (1939), and surficial geologic maps.

One deep well is about 2,500 feet downstream of the dam site. The depth to bedrock at the well is 108 feet below the ground surface, which is postulated to be about the depth to bedrock near the right-middle section of the coulee. The depth to bedrock underlying the left side of the valley and left abutment is probably deeper, as the basalt dips about 2 degrees from north to south toward the Saddle Mountains Fault. Based on this dip angle, the depth to bedrock is probably around 150 feet, or about elevation 330 feet, at the deepest section beneath Lower Crab Creek.

Soil profiles developed by Reclamation in 1939 yielded information regarding the depth to rock and overburden properties. The soil profiles range from 1.5 to 5.0 feet in depth and indicate that the overburden is primarily caliche, which is calcium-carbonate cemented silt, sand, and silty sand. The profiles do not indicate the degree of cementation. The depth to bedrock ranges from 1.5 to 3.0 feet near the right center of the valley and, based on rock outcrops, is presumed to be relatively shallow all the way to the upper right abutment.

Based on the well report data and surficial geologic maps, the valley fill materials range from alluvium (Qa) and dune sand (Qd) at the surface, to undifferentiated fluvial gravel (Qg) and fluvial and lacustrine sand (Qs) at depth. The left abutment is covered with talus and alluvial fan deposits, and these colluvial (Qc) materials are composed of silt- to boulder-sized, mostly subangular, basaltic debris and may be up to 80 feet thick near the base of the slope.

The majority of the bedrock underlying the Lower Crab Creek dam site consists of the Priest Rapids Basalt (Tpr). The basalt is dark gray and fine-to-medium grained, and weathers to reddish brown. The unit often has large columns with platy partings in basal flows, with pillow-palagonite containing petrified wood at the base (Grolier and Bingham 1971 and 1978).

The Saddle Mountains Basalt Formation (TSm) overlies the Priest Rapids Basalt (TP) and probably underlies much of the upper left abutment. The lower part of the Saddle Mountains Formation consists of the Mabton Sedimentary Interbed. The Mabton Interbed is a member of the Ellensburg Formation and includes the sedimentary deposits between the Saddle Mountains Formation and Priest Rapids Basalt Formation. The unit consists of tuffaceous siltstone, sandstone, and claystone. The Umatilla and Esquatzel Basalt Member overlie the Mabton Interbed. The flows consist of gray to dark gray, hard, dense to slightly vesicular, fine-grained basalt that is slightly weathered. Additional investigations are needed to characterize the Saddle Mountains Formation on the left abutment, as well as the geometry and seismic history of the Saddle Mountains Thrust Fault.

Ground Water

Static water level is estimated based on well data located along Lower Crab Creek about 2,750 feet upstream from the Lower Crab Creek dam site. The static water level was measured at about 82 feet, which is approximately elevation 428 feet.

5.0 Appraisal-Level Cost Estimates

These appraisal-level cost estimates can be used as preliminary ballpark figures to compare alternatives. The cost estimate data presented here are not suitable for determining actual construction costs or requesting construction fund appropriations from the Congress. Data are considered preliminary, and this information does not adequately cover all cost drivers that could increase costs. For example, the cost estimates do not include the cost of acquiring land, relocating utilities, or any mitigation that might be required. These costs will be calculated in the next Study phase.

5.1 Data Sources

Appraisal-level cost estimates are used to determine whether or not more detailed investigations are warranted. The appraisal-level cost estimates presented in this report are based on preliminary designs and analysis developed using limited available data and information. The estimates should only be used to assist in selecting the most viable water delivery alternative and water supply option to investigate in the next Study phase.

To expedite the appraisal designs and cost estimate analysis, Reclamation did not collect design data specific to the water delivery alternatives and water supply options. The costs are based on preliminary engineering designs and analyses using available design data and information and previous studies completed between the 1960s and 1980s (e.g., the 1972 initial plan formulation studies—see Section 3.1.1, "Previous Studies"). Reclamation collected some additional data, including limited field visits to collect geologic information, a review of drill holes, and other vicinity information to determine subsurface conditions and hydrologic modeling to help define required infrastructure capacities and verify proposed facilities operational capability with the current CBP infrastructure.

5.2 Construction Cost Calculation

The construction cost is made up of two components:

- **Field costs.** The direct costs of materials and services to construct facilities
- **Noncontract costs**. Includes facilitating services, investigations, developing designs and specifications, construction engineering and supervision, and environmental compliances. These were calculated as 20 to 40 percent of the field costs.

5.2.1 Field Costs

Reclamation developed a single field cost estimate for each water delivery alternative and water supply option. Field costs include the direct contract cost of materials and services for construction of facilities and include construction contract costs and contingencies.

Contract Costs

Contract costs represent the estimated cost of the contract at the time of bid or contract award and include additives for mobilization and unlisted items. At the appraisal-level investigation, it is not practical to identify all items associated with construction of a project. The cost estimates include an additive listed as a separate line item to account for the cost of minor undefined items of work. Unlisted items provide a contingency for minor design changes and for minor pay items that have not been itemized but that will have some influence on the total cost. A ± 10 to 15 percent allowance was included, using professional judgment, based on the confidence level in the available data and level of detail.

Mobilization involves costs associated with mobilizing contractor personnel and equipment to the project site during initial startup (calculated at ± 5 percent).

Escalation Costs

Reclamation allowed for escalation costs during construction. However, a preliminary construction schedule was not available. The allowance for escalation costs during construction would be revisited when a preliminary construction schedule for the selected water delivery alternative and water supply option is developed.

The field cost estimates have a price level of April 2007 and do not include escalation costs that may occur during the design and procurement. During the feasibility-level investigation, this issue would be revisited and field cost estimates adjusted accordingly. It is assumed that any alternative or option that is selected for feasibility-level authorization will include language in the legislation allowing for cost indexing.

Procurement Strategy

Reclamation assumed that a traditional Issue-for-Bid procurement strategy would be used for all contracts associated with this construction; therefore, the field cost estimates do not include a percentage allowance for a procurement strategy. This issue would be revisited in the next Study phase and, if needed, the field cost estimates would be adjusted accordingly.

5.2.2 Noncontract Costs

Noncontract costs are costs associated with work or services that support a project. Noncontract costs include sunk investigations costs, post-authorization investigations, project management costs, collection of design data, preparation of final designs and specifications (including Value Engineering studies), permits and environmental compliance costs, construction engineering, contract administration, and other related costs. Depending on the size, complexity, and environmental/ archeological considerations, noncontract costs were calculated at ± 20 to 40 percent of the total estimated field costs.

The noncontract percentages did not include considerations for land acquisition and utility relocation because these costs are specific to a particular feature's site. These costs would be developed in the next Study phase and added to the construction cost estimates developed then.

5.2.3 Most Probable Estimate

A recent trend in the preparation of cost estimates is to develop a range of estimates (most probable high, most probable, and most probable low) that reflect differing assumptions used in developing appraisal designs. This estimate range can be developed by preparing three separate designs and quantities estimates and then pricing them separately. For this Study, a single design and field cost estimate was developed for each water delivery alternative and water supply option. Reclamation then developed and calculated adjustment factors, based on the confidence in the available data for each alternative and option. These adjustment factors, which ranged from 20 to 40 percent, were then applied to the single cost estimate to arrive at a most probable low and most probable high cost estimate.

5.3 Water Delivery Alternatives

Construction cost estimates were developed for alternatives A through D using the methods and assumptions described below.

5.3.1 Cost Estimating Methods and Assumptions

Two methods for estimating the water delivery alternatives' field costs were used in this Study:

- **Indexed.** Reclamation cost estimators indexed feasibility-grade costs developed by Reclamation during the early 1970s up to current cost levels. The costs developed in the early 1970s were based on indexed costs from feasibility cost estimates prepared in 1963.
- **Unit Price.** Reclamation cost estimators developed unit prices and field cost estimates at current cost levels using appraisal-level quantity estimates specifically developed for this Study.

These two cost estimating methods are not equivalent but provide "ballpark" figures to determine the magnitude of costs associated with each alternative. Table 24 summarizes which method was used to develop the appraisal-level field cost estimates for each water delivery alternative. Appraisal-level field costs for all water supply options were developed using unit prices.

Table 24. Field cost estimate methods for the water delivery alternatives

Water Delivery Alternative (irrigated acreage)	Indexed Costs	Unit Price Costs
A (140,000)	X	----
B (128,000)	X (East High canal system)	X (East Low Canal system)
C (70,128)	----	X
D (40,670)	----	X

Estimated costs for alternatives involving components of the East High canal system relied on previous Reclamation investigations, including feasibility studies conducted from the 1960s to the 1980s. Estimated costs for alternatives involving components of the East Low Canal system used construction information from the existing East Low Canal. Reclamation used reports prepared during the feasibility studies for the East High canal system in the 1970s to index costs for the appropriate water delivery alternatives (alternatives A and B). Canals and pumping plants were prorated with respect to the relative flow rates. Data for the indexed costing were predominantly obtained from the *East High-East Low Extension - Supporting Data for Development of Costs for Initial Plan Formulation Studies* (Reclamation 1972).

5.3.2 Construction Costs

Table 25 provides a summary cost estimate breakdown for the four water delivery alternatives, reflecting field and noncontract costs. Total estimated costs are greatest for alternatives that involve construction of an East High canal system (alternatives A and B) because the East High canal system involves substantially more new infrastructure than the alternatives involving the East Low Canal. Table 26 compares the major infrastructure components that comprise the four water delivery alternatives.

The range between the most probable low and most probable high cost estimates for alternatives A and B is greater than for alternatives C and D, reflecting a lesser degree of confidence in the data and the greater number of assumptions used to calculate these costs. Since alternatives C and D rely on the existing East Low Canal, there are more reliable data gathered during original construction of the facilities; therefore, there is more confidence in the conditions that might be encountered during construction. Table 25 reflects estimated costs to construct the facilities only. It does not reflect operations, maintenance and replacement (OM&R) costs, which would vary for each alternative depending on the miles of canals, laterals, tunnels, and siphons; number of pumping plants; and power requirements. OM&R costs will be calculated in the next Study phase.

5.4 Water Supply Options

5.4.1 Cost Estimating Methods and Assumptions

Cost estimates for all water supply options were calculated by developing appraisal-level quantities specifically for this Study. Reclamation cost estimators developed unit prices and field cost estimates at current cost levels.

5.4.2 Construction Costs

Table 27 provides a summary cost estimate breakdowns for the water supply options using existing reservoirs and provides the same for water supply options proposing new reservoirs. Table 27 provides this information for options that rely on operational modifications at existing storage facilities. Table 28 provides similar information for options to construct new storage facilities. The least expensive water supply options use existing CBP storage reservoirs, including modifying operations at Banks Lake and Potholes Reservoir. The most expensive water supply option is construction of new storage facilities.

Table 25. Summary of appraisal-level cost estimate breakdown

Cost Component	Alternative A* Construct East High Canal System	Alternative B * Northern Portion of East High Canal System/ Enlarge and Extend East Low Canal	Alternative C Enlarge East Low Canal	Alternative D Use Existing East Low Canal Configuration
Canals, laterals and pipe distribution	$1,226,454,000 - $2,452,908,000	$921,320,000 - $1,616,316,000	$351,401,000 - $516,642,000	$120,555,000 - $195,695,000
Siphons	$419,470,000 - $838,940,000	$300,460,000 - $600,920,000	$61,668,000 - $70,918,000	- - - -
Tunnels	$83,700,000 - $167,400,000	$43,600,000 - $87,200,000	- - - -	- - - -
Pumping plants	$46,140,000 - $92,280,000	$142,448,000 - $209,017,000	$152,319,000 - $203,472,000	$82,773,000 - $110,864,000
Transmission lines, substations, etc.	$24,236,000 - $48,472,000	$20,652,000 - $35,723,000	$13,421,000 - $19,385,000	$9,076,000 - $13,109,000
Mobilization @ ± 5%	*	*	$29,200,000 - $41,000,000	$10,500,000 - $16,000,000
Unlisted items @ ± 10-15%	*	*	$61,991,000 - $128,583,000	$27,096,000 - $54,332,000
Subtotal (contract costs)	- - - -	- - - -	$670,000,000 - $980,000,000	$250,000,000 - $390,000,000
Contingencies @ ± 20-30%	*	*	$130,000,000 - $290,000,000	$40,000,000 - $110,000,000
Field cost total	$1,800,000,000 - $3,600,000,000	$1,620,000,000 - $2,960,000,000	$800,000,000 - $1,270,000,000	$290,000,000 - $500,000,000
Noncontract costs	$360,000,000 - $1,080,000,000	$324,000,000 - $888,000,000	$200,000,000 - $444,500,000	$87,000,000 - $200,000,000
Total construction cost	$2,160,000,000 - $4,680,000,000	$1,944,000,000 - $3,848,000,000	$1,000,000,000 - $1,714,500,000	$377,000,000 - $700,000,000

*All or portions of cost estimate were indexed (40+ years) from feasibility cost estimates calculated in the 1970s. Indexed costs incorporated allowances for mobilization, unlisted items, and contingencies into each infrastructure cost component in the table.

Table 26. Summary of primary conveyance system features

Alternative Feature	Alternative A Construct East High Canal System	Alternative B Northern Portion of East High Canal System. Enlarge and Extend East Low Canal	Alternative C Enlarge East Low Canal	Alternative D Use Existing East Low Canal Configuration
Canals	190 miles	161 miles*	57 miles*	
Pressurized buried main distribution pipeline	250 miles	230 miles	123 miles	61 miles
Laterals and pipe distribution	Serves 140,000 acres	Serves 127,300 acres	Serves 70,100 acres	Serves 40,700 acres
Siphons	25/16.55 miles	17 siphons/11.20 miles**	7 siphons/3.09 miles**	0
Tunnels	5 tunnels/4.63 miles	3 tunnels/1.31 miles	0	0
Pumping plants	2 major/6 smaller	1 major/11 smaller	5 smaller	6 smaller
Other	1 re-regulating reservoir	1 re-regulating reservoir		

*57 miles are an expansion to the capacity of the existing East Low Canal.
**Enlargement of seven existing siphons.

Table 27. Summary of appraisal-level cost estimate breakdown for water supply options modifying operations

Cost Component	Banks Lake Drawdown*	Banks Lake Raise	Potholes Reservoir Reoperation
Canal/road modifications	$0	$6,152,000 - $8,323,000	- - - -
Dam modifications	$0	$4,147,000 - $55,298,000	$1,146,000 - $30,560,000
Canal radial gates modifications	$0	$885,000 - $1,071,000	- - - -

Table 27. Summary of appraisal-level cost estimate breakdown for water supply options modifying operations

Cost Component	Banks Lake Drawdown*	Banks Lake Raise	Potholes Reservoir Reoperation
Mobilization @ ± 10%	$0	$560,000 - $3,200,000	$57,000 - $1,550,000
Unlisted items @ ± 10-15%	$0	$1,256,000 - $10,108,000	$97,000 - $4,890,000
Subtotal (contract costs)	$0	$13,000,000 - $78,000,000	$1,300,000 - $37,000,000
Contingencies @ ± 20-30%	$0	$2,500,000 - $22,000,000	$300,000 - $11,000,000
Field cost total	$0	$15,500,000 - $100,000,000	$1,600,000 - $48,000,000
Noncontract costs	$0	$3,100,000 - $30,000,000	$320,000 - $14,400,000
Total construction cost	$0	$18,600,000 - $130,000,000	$1,920,000 - $62,400,000

*No structural modifications to dams required.

Table 28. Summary of appraisal-level cost estimate breakdown for water supply options constructing new storage facilities

Cost Component	Dry Coulee Reservoir	Rocky Coulee Reservoir	Lower Crab Creek Reservoir (472,000 Acre-Feet)	Lower Crab Creek Reservoir (200,000 Acre-Feet)
Canals, pumping plant structures, control structures, bridges, etc.	$28,402,000 - $32,887,000	$21,882,000 - $30,391,000	$458,000 - $531,000	$253,000 - $372,000
Outlet structures	$35,882,000 - $56,656,000	$6,102,000 - $8,992,000	$12,894,000 - $20,359,000	$6,225,000 -$9,174,000
Roads	$4,329,000 - $5,531,000	$3,669,000 - $4,689,000	$2,289,000 - $2,924,000	$2,289,000 - $2,924,000

Table 28. Summary of appraisal-level cost estimate breakdown for water supply options constructing new storage facilities

Cost Component	Dry Coulee Reservoir	Rocky Coulee Reservoir	Lower Crab Creek Reservoir (472,000 Acre-Feet)	Lower Crab Creek Reservoir (200,000 Acre-Feet)
Dam(s)	$516,804,000 - $820,806,000	$69,402,000 - $112,779,000	$184,582,000 - $299,946,000	$137,743,000 - $223,832,000
Mechanical	$1,283,000 - $1,426,000	$2,691,000 - $3,289,000	$475,000 - $528,000	$361,000 - $401,000
Gates	$11,388,000 - $12,654,000	$4,738,000 - $5,790,000	$4,761,000 - $5,290,000	$2,886,000 - $3,207,000
Radial gates	$1,191,000 - $1,323,000	$478,000 - $585,000	$218,000 - $242,000	$156,000 - $173,000
Pumping units	- - - -	$15,431,000 - $18,860,000	- - - -	- - - -
Outlet steel pipe/valves	$10,545,000 - $11,717,000	$7,975,000 - $9,747,000	$1,758,000 - $1,954,000	$1,148,000 - $1,276,000
Electrical plant	$199,000 - $221,000	$6,125,000 - $8,848,000	$50,000 - $73,000	$50,000 - $73,000
Transmission lines, substations, SCADA, etc.	$274,000 - $304,000	$1,247,000 - $1,802,000	$137,000 - $198,000	$137,000 - $198,000
Mobilization @ ± 5%	$31,000,000 - $47,000,000	$7,000,000 - $10,500,000	$10,500,000 - $16,500,000	$7,600,000 - $12,000,000
Unlisted items @ ± 10-15%	$68,703,000 - $159,475,000	$13,260,000 - $33,728,000	$21,878,000 - $51,455,000	$16,152,000 - $36,370,000
Subtotal (contract costs)	$710,000,000 - $1,150,000,000	$160,000,000 - $250,000,000	$240,000,000 - $400,000,000	$175,000,000 - $290,000,000
Contingencies @ ± 20-30%	$140,000,000 - $350,000,000	$35,000,000 - $70,000,000	$50,000,000 - $120,000,000	$35,000,000 - $90,000,000
Field cost total	$850,000,000 - $1,500,000,000	$195,000,000 - $320,000,000	$290,000,000 - $520,000,000	$210,000,000 - $380,000,000
Noncontract costs	$170,000,000 - $450,000,000	$39,000,000 - $96,000,000	$58,000,000 - $156,000,000	$42,000,000 - $114,000,000
Total construction cost	$1,020,000,000 - $1,950,000,000	$234,000,000 - $416,000,000	$348,000,000 - $676,000,000	$252,000,000 - $494,000,000

Construction costs were not estimated for the Banks Lake drawdown option at this time because no engineering modifications to the dams and associated facilities are anticipated. However, additional study may identify environmental and social effects that may require mitigation that would entail costs for this option.

5.5 Combining Water Delivery Alternatives and Water Supply Options

The total combined cost of providing a replacement water supply to groundwater-irrigated lands will depend on which water supply option or options are selected for a water delivery alternative. Several water supply options may be needed to provide sufficient water supply for an alternative. Banks Lake drawdown or construction of Dry Coulee or Lower Crab Creek reservoirs are the only options that could provide a replacement supply for 100 percent of the groundwater-irrigated acres in the Study area. The proposed Rocky Coulee reservoir, on the other hand, would only provide a replacement supply for about 34 percent of the acres. Any water delivery alternative will work with any of the water supply options studied, but combinations considered in this Study involved only those where the total water volume supplied did not exceed the volume of replacement water required. Table 29 shows possible combinations and a rough estimated cost range for these combinations.

Table 29. Water delivery alternative combined with appropriate water supply options

Banks Lake Draw-down	Banks Lake Raise (50 KAF)	Potholes Reopera-tion (50 KAF)	Dry Coulee (481 KAF)	Rocky Coulee (126 KAF)	Lower Crab (200 KAF)	Lower Crab (472 KAF)	Construction Cost Range (in $millions)	Cost Per Acre Foot ($)	Cost Per Acre of Land Served ($)
Alternative A (515 KAF storage required)									
X							2,160 – 4,680	4,192 - 9,082	15,429 - 33,429
X	X						2,179 – 4,810	4,228 – 9,334	15,561 – 34,357
X	X	X					2,181 – 4,872	4,232 – 9,455	15,575 – 34,803
X		X					2,162 – 4,742	4,195 – 9,203	15,442 – 33,874
			X				3,180 – 6,630	6,171 – 12,866	22,714 – 47,357
X				X			2,394 – 5,096	4,646 – 9,889	17,100 – 36,400
X	X			X			2,413 – 5,226	4,682 – 10,142	17,233 – 37,329
X	X	X		X			2,415 – 5,288	4,686 – 10,263	17,247 – 37,774
X		X		X			2,396 – 5,158	4,650 – 10,010	17,114 – 36,846
X					X		2,412 – 5,174	4,681 – 10,041	17,229 – 36,957
X	X				X		2,431 – 5,304	4,717 – 10,293	17,361 – 37,886
X	X	X			X		2,433 – 5,366	4,721 – 10,414	17,375 – 38,331
X		X			X		2,414 – 5,236	4,684 – 10,162	17,242 – 37,403
X						X	2,508 – 5,356	4,867 – 10,394	17,914 – 38,257
Alternative B (453 KAF storage required)									
X							1,944 – 3,848	4,289 – 8,491	15,271 – 30,228
X	X						1,963 – 3,978	4,331 – 8,778	15,417 – 31,249
X	X	X					1,965 – 4,040	4,335 – 8,915	15,432 – 31,739
X		X					1,946 – 3,910	4,294 – 8,628	15,286 – 30,718

Table 29. Water delivery alternative combined with appropriate water supply options

Banks Lake Draw-down	Banks Lake Raise (50 KAF)	Potholes Reopera-tion (50 KAF)	Dry Coulee (481 KAF)	Rocky Coulee (126 KAF)	Lower Crab (200 KAF)	Lower Crab (472 KAF)	Construction Cost Range (in $millions)	Cost Per Acre Foot ($)	Cost Per Acre of Land Served ($)
			X				2,964 – 5,798	6,540 – 12,793	23,284 – 45,546
X				X			2,178 – 4,261	4,806 – 9,402	17,109 – 33,472
X	X			X			2,197 – 4,391	4,847 – 9,689	17,255 – 34,493
X	X	X		X			2,199 – 4,453	4,851 – 9,827	17,270 – 34,984
X		X		X			2,180 – 4,323	4,810 – 9,581	17,124 – 33,962
X					X		2,196 – 4,342	4,846 – 9,540	17,251 - 34,108
X	X				X		2,215 – 4,472	4,887 - 9,868	17,397 – 35,130
X	X	X			X		2,217 – 4,534	4,891 -10,005	17,412 – 35,620
X		X			X		2,198 – 4,404	4,850 – 9,718	17,266 – 34,599
						X	2,292 – 4,524	5,057 – 9,982	18,005 – 35,538
Alternative C (217 KAF storage required)									
X							1,000 – 1,715	4,613 – 7,906	14,265 - 24,451
X	X						1,019 – 1,845	4,698 - 8,508	14,531 – 26,312
X	X	X					1,021 – 1,907	4,707 – 8,796	14,558 – 27,203
X		X					1,002 – 1,777	4,621 – 8,150	14,293 – 25,205
X				X			1,234 – 2,131	5,692 – 9,827	17,603 – 30,392
X	X			X			1,253 – 2,261	5,778 – 10,427	17,869 – 32,247
X		X		X			1,236 – 2,193	5,701 – 10,115	17,631 – 31,282
X					X		1,252 – 2,209	5,775 – 10,187	17,860 – 31,505

Table 29. Water delivery alternative combined with appropriate water supply options

Banks Lake Draw-down	Banks Lake Raise (50 KAF)	Potholes Reopera-tion (50 KAF)	Dry Coulee (481 KAF)	Rocky Coulee (126 KAF)	Lower Crab (200 KAF)	Lower Crab (472 KAF)	Construction Cost Range (in $millions)	Cost Per Acre Foot ($)	Cost Per Acre of Land Served ($)
Alternative D (125.9 KAF storage required)									
X							377 – 700	2,994 – 5,560	9,263 – 17,199
X	X						396 – 813	3,142 – 6,458	9,720 – 19,975
X	X	X					398 – 875	3,157 – 6,953	9,767 – 21,509
X		X					379 – 762	3,010 – 6,056	9,310 – 18,732
				X			611 – 1,116	4,853 – 8,864	15,012 – 27,420

6.0 Alternatives and Options Comparison

Reclamation will select one or more water delivery alternatives and water supply options evaluated during the appraisal-level investigation for more comprehensive feasibility-level investigation. The selection will consider engineering technical feasibility and costs; the alternatives' and options' performance in meeting Study objectives; and potential environmental and other resources issues associated with each. This chapter compares the alternatives and options performance in meeting Study objectives and identifies potential fish and wildlife, cultural, and land use issues. This comparison relied on existing available data and information and is considered only a preliminary assessment of possible issues.

6.1 Study Objective Measures

In the previous Study phase (Section 1.4, PASS), seven Study objectives, or guidance measures, were developed by stakeholders to evaluate and rank potential alternative concepts. The identification of these Study objectives is described in *Initial Alternatives Development and Evaluation* (Reclamation 2006). The following describes the information and measures used to compare the alternatives and options using these Study objectives:

- **Replace all or a portion of current groundwater withdrawals within the Study area with CBP water**. There are 140,000 eligible groundwater-irrigated acres within the Study area. Reclamation determined the number of current groundwater-irrigated acres that could receive CBP water as a replacement supply for each water delivery alternative and water supply option. Alternatives and options that would provide water to the greatest number of acres are preferred.
- **Maximize use of existing CBP infrastructure.** Alternatives and options that use existing CBP infrastructure by modifying operations or expanding existing facilities, as opposed to constructing new facilities, would be ranked higher. Relying on existing CBP facilities should result in smaller expenditures of funding and study time and expedite implementation of a preferred alternative.
- **Retain the possibility of full CBP development in the future.** Implementing an alternative or option should not prevent Reclamation from completing full development of the CBP in the future. (This Study is not investigating completion of the CBP.) Full development would entail eventual irrigation of 1,029,000 acres of lands.
- **Address ESA issues, including the NMFS's Columbia River seasonal flow objectives for salmon and steelhead, and potential impacts to shrub-steppe habitat.** Reclamation examined alternatives and options that would not affect Columbia River flow objectives identified by NMFS for ESA-listed salmon and steelhead. Reclamation also determined the acres of shrub-steppe habitat potentially affected by an alternative or option. Shrub-steppe habitat is important for a number of Federal and State Species of Concern. Alternatives and options that would affect the smallest shrub-steppe habitat acreage would be ranked higher.

- **Provide environmental and recreational enhancements.** Alternatives and options that could provide additional recreation opportunities or benefit wildlife and fish habitat would be ranked higher.
- **Minimize potential delay in the Study schedule.** Many consider the potential regional economic effects from continued aquifer decline to be at a critical point. Alternatives and options that can be studied and implemented as quickly as possible to minimize these effects are preferred.
- **Be developed in phases based on funding expectations, physical and operational constraints, and rate of groundwater decline.** Alternatives that could provide replacement water in a timely manner that would minimize disruption to existing CBP operations and work within budget constraints would be preferred. This is best achieved by selecting alternatives and options that can be studied and constructed in phases, to facilitate and expedite implementation.

Data collected or developed during the appraisal-level investigation were used to compare the ability of each alternative or option to accomplish each Study objective. Because the appraisal-level investigation relied on readily available information, quantitative data were not always available to compare performance of alternatives and options for all Study objectives. A combination of quantitative and qualitative information was compiled and is summarized in tables. These tables compare each water delivery alternative and water supply option, respectively, with respect to its ability to meet the Study objectives.

6.2 Environmental and Other Issues and Considerations

Potential environmental and cultural issues and concerns were identified for each alternative and option using readily available data. Much of the information described here was obtained from GIS databases developed by Federal and State agencies and communications with other agencies. The information is preliminary, as not all databases encompass the entire Study area. Extensive environmental surveys and analyses will be performed in the next Study phase to verify the presence of these resources and assess any potential effects. The information presented here is appropriate for appraisal-level investigation to identify major constraints to implementing an alternative or issues that make an alternative infeasible or potentially cost prohibitive. Issues may include:

- **Fish and Wildlife**. Reclamation, with the assistance of the FWS and WDFW, conducted an appraisal-level overview of potential fish and wildlife issues for each water delivery alternative and water supply option. The potential to affect wildlife-related recreation, such as hunting, fishing, and wildlife observation, was also considered. Much of this data were compiled from GIS datasets readily available to Reclamation such as the WDFW Heritage Dataset and Priority Habitats. However, not all datasets provide coverage for all of the Study area and may not adequately represent species occurrence. Additional surveys and studies will be required to verify presence.
- **Cultural Resources**. A high-level Class 1 inventory of cultural resources, summarized in Section 2.8. Historic and Prehistoric Resources, was conducted for most of the Study area. This survey reviewed information from previously recorded cultural resources. However, much of Study area has not been surveyed; more extensive surveys will be

conducted in areas that may be affected by proposed alternatives and options selected for study in the next Study phase.

- **Land Use**. This assessment considered land uses that occurred within the footprint of proposed reservoirs. The inventory relied on GIS datasets that identified landownership and structures such as residences, roads, and railroads. This initial assessment was completed for the water supply options only.

6.3 Water Delivery Alternative Comparison

The four water delivery alternatives were compared for performance on Study objectives. Potential environmental and other issues were identified.

6.3.1 Study Objectives Comparison

Reclamation could fully develop the CBP in the future—regardless of the water delivery alternative selected. All alternatives are conducive to a phased study and construction approach.

Alternatives A and B would provide a replacement water supply to the greatest number of groundwater-irrigated acres, as they are configured to deliver a replacement water supply to all (alternative A – 140,000 acres) or most (alternative B – 127,3000 acres) of the eligible acres. Both of these alternatives entail construction of a new East High canal system and involve significant miles of new major canals, tunnels, and siphons, and a number of pumping plants as well as a re-regulating reservoir. The magnitude of new construction required would entail potentially greater study time, resources, and effort to complete the necessary level of engineering and environmental analyses. Despite this, these alternatives can be studied and implemented in increments, potentially expediting water delivery to some lands more quickly. Alternative B offers the greatest flexibility in terms of the number of infrastructure configurations possible. These alternatives may also have more significant environmental effects to address as they involve larger areas of disturbance.

Alternatives C and D best maximize the use of existing CBP infrastructure, both relying on the existing East Low Canal system. However, alternative C would still entail extensive construction to expand the capacity of the existing East Low Canal system. As currently configured, alternative C could cost as much or more to operate than the East High canal system (alternatives A and B) because of the maintenance and power associated with the numerous pumping plants required to pump replacement water to higher elevation lands. The East High canal system, as configured in alternatives A and B, would deliver water to some lands by gravity and some by pumping and would not need to pump water as high as the East Low Canal. Initial cost estimates in terms of groundwater acres served indicate that alternatives A and B may be comparable to alternative C.

Alternative D may result in the least amount of environmental impacts because it would rely on the existing conveyance system with less construction. It would also rank the highest of the four alternatives considered in terms of the amount of funding and time required to study the alternative. However, it would deliver a replacement water supply to the least amount of groundwater acreage–only 29 percent of the total.

Table 30 provides information to allow comparison of the water delivery alternatives' abilities to meet Study objectives. Table 30. Study objective performance comparison by water delivery alternative

Study Objective	Alternative A	Alternative B	Alternative C	Alternative D
Replace all or portion of current groundwater within the Study area with CBP water (groundwater-irrigated acres replaced).	140,000 acres 100%	127,300 acres 91%	70,100 acres 50%	40,700 acres 29%
Maximize use of existing infrastructure (no/minimal impact to existing users).	Significant new infrastructure construction, including East High canal system and Black Rock re-regulating reservoir. Requires new pipelines, laterals and pumping plants to convey water from main canals to irrigated lands. Construction of the inlet structure at the Main Canal will need to coordinate to not interfere with current irrigation delivery.	Significant new infrastructure construction, including East High canal system and Black Rock re-regulating reservoir. Expands capacity of southern portion of the existing East Low Canal; and extends it by 2.3 miles. Implementation of East Low Canal component will need to coordinate construction to not interfere with current irrigation delivery. Requires new pipelines, laterals and pumping plants to convey water from main canals to irrigated lands.	Expands capacity of southern portion of the existing East Low Canal. Implementing East Low Canal component will need to coordinate construction to not interfere with current irrigation delivery. Requires new pipelines, laterals, and pumping plants to convey water from main canals to irrigated lands.	Uses existing East Low Canal capacity and adjustments in operations. Requires new pipelines, laterals, and pumping plants to convey water from main canals to irrigated lands.
Retain the possibility of full CBP development in the future.	Yes	Yes	Yes	Yes

Address ESA issues (NMFS Columbia River flow objectives, shrub-steppe habitat impacts.)	No effects to Columbia River ESA flow objectives anticipated. New canal infrastructure construction would bisect large areas of shrub-steppe habitat.	No effects to Columbia River ESA flow objectives anticipated. New canal infrastructure construction would bisect large areas of shrub-steppe habitat.	No effects to Columbia River ESA flow objectives anticipated. Laterals may cross some areas of shrub-steppe habitat.	No effects to Columbia River ESA flow objectives anticipated. Minimal effects to shrub-steppe habitat anticipated.

Table 31. Study objective performance comparison by water delivery alternative

Study Objective	Alternative A	Alternative B	Alternative C	Alternative D
Provide environmental and recreational enhancements.	Possible secondary benefits from conveyance facilities seepage that may result in wetlands and wildlife habitat.	Possible secondary benefits from conveyance facilities' seepage that may result in wetlands and wildlife habitat, although not as great as alternative A.	Possible secondary benefits from conveyance facilities' seepage that may result in wetlands and wildlife habitat, although not as great as alternatives A or B.	Possible secondary benefits from conveyance facilities' seepage that may result in wetlands and wildlife habitat, although not as great as alternatives A, B, or C.
Minimize Study schedule delays (NEPA/Feasibility completed in 2011).	Significant new infrastructure entails greater engineering design effort to complete.	New infrastructure entails greater engineering design effort and time.	Will require more time to study than alternative D, but not as much as alternatives A and B.	Least amount of study time required.
Developed in phases.	Conducive to an incremental phased implementation approach; desirable and necessary given the implementation costs and anticipated construction schedule.	Conducive to an incremental phased implementation approach; desirable and necessary given the implementation costs and anticipated construction schedule.	Conducive to an incremental phased implementation approach.	Conducive to an incremental phased implementation approach.

6.3.2 Environmental and Other Resources Issues

In general, the more construction required, the more acreage may be disturbed and the greater the potential for effects to environmental and other resources.

Fish and Wildlife Issues

Potential fish and wildlife issues associated with the water delivery alternatives include loss of terrestrial habitat due to destruction, fragmentation, or inundation. Habitats of particular concern in the Study area include shrub-steppe, cliffs, rock outcrops, and talus slopes. Many Federal and State Species of Concern depend on or use these habitat types. As described in Section 2.7, Fish and Wildlife, WDFW believes that over half of the shrub-steppe habitat in the State has already been lost to development. Alternatives that affect large acreages would cause concern. New canals and laterals bisecting through currently intact habitat areas could fragment remaining habitat and interfere with species dispersal.

All alternatives have the potential to affect wildlife-related recreation activities either negatively or positively. Constructing new canals and laterals, and the resulting seepage, could create new habitat that may benefit some species.

Water delivery alternatives A and B have the greatest potential to impact fish and wildlife because larger land areas would be disturbed to construct new infrastructure, thus bisecting shrub-steppe habitat. These alternatives also require larger volumes of a replacement water supply. See Section 6.4 “Water Supply Option Comparison” for a discussion of potential issues associated with a water supply. Table 32 summarizes the potential occurrence of Federal and State species of concern in areas where alternatives are proposed. Table 33 summarizes potential fish and wildlife issues and concerns for each water delivery alternative.

Cultural Resource Issues

Information on potential cultural resources within the Study area is limited. Previous surveys have occurred in response to development activities (e.g., roads). Reclamation will conduct additional surveys in future Study phases to determine the presence and significance of any cultural resources. Water delivery alternatives A and B, which involve more miles of new construction and disturbance, have a greater probability of encountering cultural resources along their alignment compared to alternatives C and D, which involve construction largely in previously disturbed areas. The East Low Canal is eligible for listing on the NHRP.

6.4 Water Supply Option Comparison

Water supply options considered during the appraisal-level investigation included modifying operations at existing storage facilities, including Banks Lake and Potholes Reservoir, or constructing new storage facilities at three possible locations: Dry Coulee, Rocky Coulee or Lower Crab Creek. In general, modifying operations at existing storage facilities best meets the identified Study objectives and introduces fewer environmental issues and concerns compared to construction of new storage facilities.

Table 32. Potential occurrence of Federal and State species of concern

Species	Alternative A	Alternative B	Alternative C	Alternative D
Federal Endangered				
Columbia River basin pygmy rabbit	P*	P	P	
Federal Candidate				
Washington ground squirrel	L	L	P	P
Greater sage grouse	L	L		
State Endangered				
Northern leopard frog	P	P		
American white pelican	P	P		
Sandhill crane	P	P		
State Threatened				
Bald eagle	P	P		
Ferruginous hawk	L	L	P	P
State Sensitive				
Common loon	P	P		
Peregrine falcon	P	P		
State Candidate				
Burrowing owl	P	K	K	P
Golden eagle	P	P	P	P
Loggerhead shrike	K	K	P	P
Merlin	P	P	P	P
Merriam’s shrew	P	P	P	P
Washington ground squirrel	L	L	P	P
Sagebrush lizard	L	L	P	P
Sage thrasher	L	L		
Sage sparrow	L	L		
Western grebe	P	P		

Table 32. Potential occurrence of Federal and State species of concern

Species	Alternative A	Alternative B	Alternative C	Alternative D
Black-tailed jackrabbit	P	P		
Townsend's big-eared bat	P	P		
Pallid Townsend's big-eared bat	P	P		

*K= Known occurrence; L = Likely occurrence; P = Possible occurrence.

6.4.1 Study Objectives Comparison

Water supply options that use existing storage facilities best meet the Study objectives. These options are the most cost effective in terms of volume of water supplied per dollar spent and would likely require fewer resources and effort to complete the necessary level of engineering and environmental analyses.

Drawing Banks Lake down or constructing large new storage facilities, such as proposed at Dry Coulee or Lower Crab Creek are the only options that could provide sufficient water to replace all eligible groundwater acreage. Constructing new storage is costly and may result in greater environmental issues compared to drawing down Banks Lake. However, significant draw down of Banks Lake would be required to provide a full replacement water supply. A combination of several water supply options will likely be needed to minimize potential effects and provide sufficient water in a cost-effective manner. Modifying operations at Banks Lake, combined with modifications at Potholes Reservoir, could provide sufficient water for all groundwater-irrigated acres in the Study area and had the best performance for the majority of Study objectives.

Of the proposed storage reservoirs, Rocky Coulee is the most economical to construct and has fewer complex environmental issues compared to the Dry Coulee and Lower Crab Creek sites. However, Rocky Coulee can only provide a replacement water supply for up to 34 percent of the groundwater-irrigated acres and would need to be used in conjunction with other measures. Dry Coulee is in a central location and is ideally located for effective CBP operations. Lower Crab Creek is the least effective operationally as it would require pumping water from Grand Coulee Dam twice (once to fill the proposed Lower Crab Creek reservoir and a second time to supply groundwater-irrigated land) and would result in reduced flows in the Columbia River from Grand Coulee Dam to the mouth of Lower Crab Creek.

Reclamation could fully develop the CBP in the future regardless of the water supply options selected. All options are conducive to a phased study and construction approach. Table 35 provides information to allow comparisons of each water supply option's ability to meet Study objectives.

Table 33. Comparison of potential fish and wildlife issues by water delivery alternative

Alternative A	Alternative B	Alternative C	Alternative D
Upper end of East High canal system crosses significant areas of shrub-steppe habitat. The new East High canal system might result in barriers to wildlife (e.g., mule deer), fragmented habitat (e.g., Washington ground squirrel), or may be constructed near areas where sensitive species nest (e.g., ferruginous hawks or loggerhead shrikes). Potential for effects to wildlife-related recreation. Potentially supports 3 Federal and 17 State Species of Concern. Black Rock Coulee re-regulating reservoir site potentially supports 20 State Species of Concern. It would inundate habitat for State Threatened and candidate species (e.g., loggerhead ferruginous hawk, loggerhead shrike and Washington ground squirrel).	Upper end of East High canal system crosses significant areas of shrub-steppe habitat. The new East High canal system might result in barriers to wildlife (e.g., mule deer), fragmented habitat (e.g., Washington ground squirrel), or may be constructed near areas where sensitive species nest (e.g., ferruginous hawks or loggerhead shrikes). Black Rock re-regulating reservoir—Same as alternative A. The East Low Canal enlargement might further limit dispersal potential of mammals and reptiles if enlargement makes crossing the canal more difficult and may occur in areas supporting a high density of burrowing owl nesting sites. Potential for effects to wildlife related recreation. Potentially supports 3 Federal and 17 State Species of Concern.	The East Low Canal enlargement might further limit dispersal potential of mammals and reptiles if enlargement makes crossing the canal more difficult and may occur in areas supporting a high density of burrowing owl nesting sites. Laterals may affect some shrub-steppe habitat. Potential for effects to wildlife-related recreation. Potentially supports 2 Federal and 8 State Species of Concern.	Predominantly cropland. Laterals may affect some shrub-steppe habitat. Potential for effects to wildlife related recreation. Potentially supports 1 Federal and 8 State Species of Concern.

Table 34. Study objectives performance comparison for water supply options

Study Objective	Banks Lake Drawdown	Banks Lake Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek (472 KAF)	Lower Crab Creek (200 KAF)
Replace all or portion of current groundwater within the Study area with CBP water (groundwater-irrigated acres replaced).	Up to 140,000 acres 100%	Up to 16,700 acres 12% (50 KAF)	Up to 16,700 acres 12% (50 KAF)	Up to 140,000 acres 100% (481 KAF)	Up to 46,900 acres 34% (126 KAF)	Up to 140,000 acres 100% (472 KAF)	Up to 60,000 acres 43% (200 KAF)
Maximize use of existing infrastructure (no/minimal impact to existing users).	Yes; new impacts to users of recreation and other resources from draw down lower than current operations.	Yes; requires modifications to both dams and to Grand Coulee Feeder Canal.	Yes; requires modification at dam; flood evacuation route downstream.	New construction.	New construction.	New construction.	New construction.
Retain possibility of future full CBP development.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Address ESA issues (NMFS Columbia River flow objectives, shrub-steppe habitat impacts).	Operational modification designed to avoid effects to Columbia River ESA flow objectives. No significant ESA issues anticipated.	Operational modification designed to avoid effects to Columbia River ESA flow objectives. No significant ESA issues anticipated.	Operational modification designed to avoid effects to Columbia River ESA flow objectives. Potential downstream issues to Lower Crab Creek; ESA listed steelhead.	Designed to avoid effects to Columbia River ESA flow objectives. 4,442 acres shrub-steppe inundated.	Designed to avoid effects to Columbia River ESA flow objectives. 392 acres shrub-steppe inundated. Site predominantly under agricultural production.	Columbia River flows from Grand Coulee Dam to Crab Creek confluence reduced in irrigation season. 6,476 acres shrub-steppe and 1,868 acres wetlands inundated. ESA-listed Upper Columbia River steelhead critical habitat.	Columbia River flows from Grand Coulee Dam to Crab Creek confluence reduced in irrigation season. 3,874 acres shrub-steppe and 1,603 acres wetlands inundated. ESA-listed Upper Columbia River steelhead critical habitat.

Table 34. Study objectives performance comparison for water supply options

Study Objective	Banks Lake Drawdown	Banks Lake Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek (472 KAF)	Lower Crab Creek (200 KAF)
Provide environmental and recreational enhancements.	Draw downs below current baseline of 1565 feet will likely affect recreation access and experience; fisheries effects anticipated.	Possible impacts to recreational facilities in short term and may extend seasonal access in long-term.	Higher winter elevation may impact recreation facilities in short term and enhance in long term.	New reservoirs may provide additional opportunities, but timing of refill (Sept. - Oct.) and draw down (April-August) may preclude quality experience.	New reservoirs may provide additional opportunities, but timing of refill (Sept. - Oct.) and draw down (April-August) may preclude quality experience.	New reservoirs may provide additional opportunities, but timing of refill (Sept. - Oct.) and draw down (April-August) may preclude quality experience. Existing recreation opportunities would be impacted.	New reservoirs may provide additional opportunities, but timing of refill (Sept. - Oct.) and draw down (April-August) may preclude quality experience. Existing recreation opportunities would be impacted.
Minimize Study schedule delays (NEPA/Feasibility completed in 2011).	Least amount of study time required.	Requires study of possible modifications to dams.	Requires study of possible modifications to dam.	New infrastructure entails greater engineering design effort and time.	New infrastructure entails greater engineering design effort and time.	New infrastructure entails greater engineering design effort and time.	New infrastructure entails greater engineering design effort and time.
Developed in phases	All water supply options are conducive to sequencing with any water delivery alternative selected.						

Table 35. Comparison of fish and wildlife issues for water supply options

Banks Lake Drawdown	Banks Lake Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek (472 KAF)	Lower Crab Creek (200 KAF)
Potential for increased bank erosion. Aquatic, emergent, and shoreline vegetation may	Nesting bird habitat may be inundated. Potential short-term impacts to fish	Increased possibility of downstream releases in winter could impact ESA-listed steelhead and other aquatic and	Inundation of 4,442 acres of fair to good quality shrub-steppe habitat and talus	Inundation of 392 acres of shrub-steppe habitat; fair shrub-steppe corridor through extensive	Inundation of 6,476 acres shrub-steppe,1,868 acres wetlands.	Inundation of 3874 acres shrub-steppe, 1,603 acres wetland.

Table 35. Comparison of fish and wildlife issues for water supply options

Banks Lake Drawdown	Banks Lake Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek (472 KAF)	Lower Crab Creek (200 KAF)
be impacted. Potential impacts to goose nesting by creating land bridges to nesting islands, allowing access for predators. Reservoir fisheries and other aquatic species impacted through entrainment, increased predation, decreased productivity, and loss of spawning and rearing habitat. Quality of angling experience could be affected (estimated value of $6 million in 2003).	species and habitats. Inundation of existing shoreline vegetation. Riparian habitat, nesting habitat, and vegetation may be impacted. Potentially supports 7 species of concern.	wildlife resources associated with Lower Crab Creek and Columbia National Wildlife Refuge (CNWR). Undesirable fish species may become entrained and introduced into downstream lakes in the CNWR, impacting current trout fisheries. Northern leopard frog (State endangered, Federal Candidate) may be affected−last remaining State population occurs in North Potholes. Colonial nesting birds could be impacted by water-level changes. Potentially supports 10 species of concern.	and cliffs (both priority habitats). Potentially supports 19 species of concern. Breeding area for State Candidate species (loggerhead shrikes, sage thrasher). Rare plants in area (sagebrush stickweed *Hackelia hispida var. disjuncta*; State Sensitive). Mule deer wintering area. Nonconsumptive wildlife recreation could be impacted.	dryland and irrigated farmland. Important habitat downslope includes mixed grass and seasonal emergent wetland as a result of irrigation seepage. Potentially supports 15 wildlife species of concern. Important for nesting and wintering birds, including nesting burrowing owls (State Candidate).	Diversity of habitat types, including large block of contiguous shrub-steppe habitat, wetland, forest, cliffs and talus slopes, sand dune habitat, marsh areas, greasewood, saltgrass, and extensive riparian zone. Potentially supports 23 wildlife species of concern. Potential occurrence of State endangered or threatened plant species. Known populations of 5 rare plants. Travel corridors for land dwelling mammals and reptiles. Primary staging site for spring and fall migrating sandhill cranes (State Endangered) Potential ESA issues (ESA-listed Upper Columbia River steelhead critical habitat). Breeding habitat for loggerhead shrikes. Waterfowl and game species concentration area. Extensive public hunting opportunities for upland birds, waterfowl, deer, and/ small game, supporting up to 10,000 ducks and geese during the hunting season and early spring.	

6.4.2 Environmental and Other Resource Issues

Environmental issues identified for the water supply options were based on a review of previous investigations involving similar issues and overlaying various GIS datasets over the proposed reservoir footprints. These methods are useful to initially identify potential issues or constraints associated with an option. However, further study and analysis will be required to verify the presence of these resources.

Fish and Wildlife Issues

Potential fish and wildlife issues associated with proposed water supply options include loss of terrestrial habitat due to inundation by proposed reservoirs. Habitats of particular concern in the Study area include shrub-steppe because many Federal and State Species of Concern depend on or use these habitat types

Operational changes at existing reservoirs, such as draw downs below current elevations or increased Columbia River diversions and the resulting increased flow through the CBP, have the potential to degrade fisheries habitat. Increased flows through existing reservoirs may increase fish entrainment and increase the probability of dispersing exotic species (that may degrade habitat or compete or prey on native fish) throughout the CBP and, possibly, to the Columbia River. Dispersion of species known to degrade habitat (e.g., carp), highly fecund species that compete with native species (carp, lake whitefish), and predators (walleye and smallmouth and largemouth bass) are of particular concern. Other potential issues include loss of fish-rearing habitat, predation, and loss of primary productivity.

Draw downs to elevations lower than current operations decrease reservoir volume and may increase the density of all species relative to the amount of habitat remaining, potentially changing predator-prey dynamics. As overall habitat volume decreases, encounters between predator and prey species may increase. Draw downs may also reduce productivity and the amount of suitable spawning grounds. The nests of spawning fish may become dewatered and rearing habitat may be lost. Over time, continuous draw down may diminish both littoral and riparian vegetation, and bank erosion may increase.

Table 36 lists potential occurrence of Federal and State species of concern by water supply option. Existing species-specific data for the proposed water storage sites consist primarily of casual observations, rather than standardized surveys. Further studies will be needed to assess habitat and wildlife resources as well as human use of these resources at the proposed storage sites.

Cultural Resource Issues

Changes in reservoir operations could potentially affect cultural resources located along the reservoir perimeter. Drawing down Banks Lake may expose additional cultural resource sites or add to the cumulative amount of time that resources are exposed, making them susceptible to damage from recreational activities and looting. Modified operations could also increase bank erosion and slumping, which could bury some sites.

Table 36. Potential occurrence of Federal and State species of concern for water supply options

Species of Concern	Banks Lake Drawdown or Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek
Federal Endangered					
Columbia River basin pygmy rabbit			P	P	P
Upper Columbia River steelhead					K
Federal Candidate					
Washington ground squirrel		P	P	P	K
Greater sage grouse			P	P	
State Endangered					
Northern leopard frog		K	P		P
American white pelican	K	K			P
Sandhill crane			P		K
State Threatened					
Bald eagle	K	K			L
Ferruginous hawk			P	P	K
State Sensitive					
Common loon	K	K			P
Peregrine falcon	K	K	K		K
State Candidate					
Burrowing owl			P	L	L
Golden eagle	K	P	L	P	K
Loggerhead shrike			L	L	K
Merlin			P	P	P
Merriam's shrew	P	P	P	P	P
Washington ground squirrel		P	P	P	K
Sagebrush lizard		P	L	L	K
Sage thrasher			L	L	L
Sage sparrow			L	L	L
Western grebe	K	K			L
Black-tailed jackrabbit			P	P	K
White-tailed jackrabbit			K		
Townsend's big-eared bat			P	P	P
Pallid Townsend's big-eared bat			P	P	P
Striped whipsnake					K

*K= Known occurrence; L = Likely occurrence; P = Possible occurrence.

Constructing new reservoirs may inundate significant resources with later exposure as reservoir elevations fluctuate to meet irrigation demands. The proposed reservoirs are located in coulees, which have a higher probability for prehistoric sites than the surrounding uplands.

Land Use Issues

Modifying operations at existing reservoir facilities may affect current recreation access and quality, as well as other infrastructure and uses surrounding the reservoir shorelines. Construction of new reservoirs will inundate existing uses and structures. Table 37 identifies potential land use issues associated with each water supply option. This is not meant to be a comprehensive list of issues as comprehensive land use surveys have not yet been made.

Table 37. Land use issues associated with water supply options.

Banks Lake Drawdown[1]	Banks Lake 2' Raise	Potholes Reoperation	Dry Coulee	Rocky Coulee	Lower Crab Creek (472 KAF)	Lower Crab Creek (200 KAF)
May affect recreation access and quality. No pump storage generating capacity when reservoir is below elevation 1560 feet. May affect State Highway 155 road stability next to reservoir.	May affect recreation access and land use surrounding reservoir. Possible impacts to nearby communities, canal operations, intake/outlet structures, and other CBP infrastructure.	Increased possibility of downstream releases in winter into Lower Crab Creek may affect roads, bridges, utilities, recreation facilities, other structures, and cropland associated with the CNWR and private entities.	1,342 acres public 3,766 acres private Inundation of at least: 6 residences 10 miles road 258 acres cropland	79 acres public 2,941acres private Inundation of at least: 6 residences 5 miles road 1,925 acres cropland	7,876 acres public 4,806 acres private Inundation of at least: 20 residences 27 miles road 1.3 miles railroad 2,933 acres cropland	5,411 acres public 3,558 acres private Inundation of at least: 20 residences 21 miles road 0.8 miles railroad 2,291 acres cropland
					Infrastructure in the CNWR would be inundated affecting refuge facilities throughout creek bottom, including: ponded areas, dikes, roads, creek crossings, and recreation facilities	

7.0 Findings and Recommendations

Reclamation conducted an appraisal-level investigation of the water delivery alternatives and water supply options that were recommended for further analysis by the PASS. This report documents these analyses. The following summarizes the investigation findings and Reclamation's recommendations.

7.1 Findings

Reclamation determined that all water delivery alternatives and water supply options examined are technically feasible. Preliminary cost estimates indicate that alternatives that require constructing major infrastructure are more expensive, but when compared per acre served, all alternatives are within a comparable range of costs. Because these costs estimates are preliminary and entail different costing methods, additional design data and analysis are required to refine the construction costs. Costs associated with OM&R, land acquisition, mitigation, and relocating utilities will also need to be calculated to fully understand the costs associated with implementation of any alternative or option selected for construction. These data will be compiled in the next Study phase. However, the information developed for this investigation does allow general comparisons between alternatives and options.

All alternatives and water supply options examined will have some magnitude of environmental impact. Reclamation will need to collect data and analyses in coordination with State and Federal agencies to identify specific effects and measures to mitigate effects where possible and appropriate.

Reclamation held public information meetings in October 2007, and distributed mailings in October and November 2007, to individuals on its mailing list to present information about the appraisal-level investigation and request comment. Reclamation received 84 written comments from State agencies; environmental, conservation, and non-governmental organizations; State residents; and representatives for agriculture and recreation interests (Table 38).

Those expressing support for the Study predominantly advocated alternatives A and B, with some support for alternative C. Many noted that alternative D, which would rely on the existing CBP canal system, could not deliver a replacement water supply to sufficient acres to address the issues associated with the declining aquifer and would not be able to deliver water to lands south of I-90, an area where significant aquifer decline is occurring. Many suggested that Reclamation examine less expensive alternatives such as water conservation, water measurement, water markets, conversion to dryland farming, and reconstruction of wells, given the significant economic costs associated with constructing the water delivery alternatives. Others noted that construction costs were not significant when considering the current economic benefits of sustaining current agricultural production in the Odessa Subarea.

Most of the comments that were received opposed construction of a Lower Crab Creek reservoir because of concerns about possible impacts to fish, wildlife, recreation, infrastructure, and private property. Many advocated modifying operations at existing CBP reservoirs as the best options to provide a replacement water supply because it would be more cost effective and would result in fewer environmental issues than constructing new dams and reservoirs.

Table 38. Stakeholders providing written comments

Stakeholder Category	Description	Stakeholders (percent)
State government	Washington State agency.	2
Agriculture	Individual farmers or organizations representing agricultural interests.	14
Environmental group	Groups advocating on behalf of natural resources.	7
Non-governmental organization	Groups advocating for a variety of interests.	1
Recreation	Individual or groups advocating for recreation opportunities such as angling, boating, etc.	10
Resident	Residents living in the State of Washington and not indicating affiliation with any of the above categories.	43
Other	Groups or individuals that do not fall within above categories, reside outside the State, or did not provide information to determine appropriate category.	23

However, there are concerns about impacts to recreation and the surrounding local communities from additional draw down of Banks Lake. Appendix D summarizes public feedback.

7.2 Recommendations

Reclamation reviewed the information developed during the appraisal-level investigation and considered public feedback to compare and evaluate the water delivery alternatives and water supply options. Engineering technical feasibility and estimated costs, performance in meeting Study objectives, public comment, and potential environmental and other issues informed the selection of alternatives and options for future investigation. Reclamation has selected water delivery alternative B and water supply options that include modifying operations at Banks Lake and Potholes Reservoir and constructing a Rocky Coulee reservoir for further investigation.

7.2.1 Water Delivery Alternative Selected for Further Study

Reclamation has decided to initiate additional study of water delivery alternative B, which would construct a new East High canal system north of I-90 and expand the capacity of the existing East Low Canal south of I-90 and extend it for 2.3 miles. Alternative B was one of only two alternatives that could deliver a replacement water supply to all or a majority of the groundwater-irrigated acres in the Study area; public feedback cited this as a Study priority. While alternative B involves constructing major new infrastructure (East High canal system), it also relies on existing project infrastructure (an expanded East Low Canal system) to deliver water to about half of the acres. The alternative accommodates study and implementation in a phased manner, with several infrastructure configurations possible. This flexibility could expedite delivery of water to some Study area lands. Public comment advocated alternatives that could be phased and implemented quickly. Initial cost estimates indicate the cost per acre served is within a comparable range to alternative C, but alternative B would deliver water to 40 percent more acres.

7.2.2 Water Supply Options Selected for Further Study

A combination of water supply options will be required to provide sufficient water to replace groundwater irrigation in the Study area. Reclamation has determined that operational modifications at existing facilities (i.e., Banks Lake and Potholes Reservoir) and construction of a Rocky Coulee dam and reservoir best meet the Study objectives. The majority of public comment supported operational modifications as preferred water supply options because they are less costly and are anticipated to result in fewer environmental impacts compared to construction of new storage facilities.

Reclamation will also continue investigation of a proposed Rocky Coulee dam and reservoir because additional storage may be required to minimize the effects associated with some of the operational modifications proposed (e.g., additional draw down at Banks Lake). Of the three potential storage sites examined, the Rocky Coulee location could improve operational flexibility and reliability within the CBP and is estimated to have lower construction costs than other proposed reservoir sites. The Lower Crab Creek site, while having comparable estimated construction costs per acre-foot provided, does not offer the operational flexibility and efficiency of the proposed Rocky Coulee site. Initial identification of potential environmental issues indicates that the Rocky Coulee site would have less complex issues to address compared to the Dry Coulee and Lower Crab Creek sites.

7.3 Future Actions

Reclamation will initiate additional investigation of water delivery alternative B and water supply options involving Banks Lake drawdown, Banks Lake operational raise, Potholes Reservoir reoperation, and a proposed Rocky Coulee dam and reservoir. Additional data collection and analyses will occur to further develop engineering designs and improve the accuracy of cost estimates. Economic analyses will occur to determine if the alternative and options are economically justified and financially feasible. Reclamation will begin data collection and surveys to determine the presence of fish, wildlife, plants, and cultural resources in areas potentially affected by the selected alternative and options. Additional geologic and hydrologic investigations will occur. Reclamation will continue aquifer monitoring activities that began in 2006.

Reclamation will conduct scoping meetings to initiate compliance with NEPA. These meetings will identify environmental issues and concerns and assist in defining the scope of analyses that Reclamation will conduct to determine environmental effects and possible mitigation. Reclamation will also initiate consultation with Tribal governments, as well as ESA consultation with the FWS and NMFS, as appropriate.

The Odessa Subarea Special Study is scheduled for completion in 2011. A planning report and appropriate NEPA report will be prepared to document the investigation and recommendations. This document will provide supporting information for any requests to Congress for construction funding for any selected alternative or options.

8.0 Literature Cited

Text Citation	Reference
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Appendix A: Geologic Units

The surface units include alluvium (Qa), colluvium (Qc), dune sand (Qd), Missoula Flood deposits (which include fluvial gravel [Qg], fluvial and lacustrine sand [Qs], and lacustrine fine sand and silt [Qss]), loess deposits of the Palouse Formation (Ql), and the Tertiary Ringold Formation (Tr), consisting of fluvial and lacustrine sediments. The surface of the Study area reflects the scouring and erosional remnants from the large glacial catastrophic floods. The area is characterized by undisturbed uplands mantled with loess that are dissected by eroded channels, or coulees, where the underlying bedrock is exposed and where fluvial and lacustrine flood materials were deposited during the large flood events (Grolier and Bingham 1971 and 1978). The surface units are described from recent to oldest in the list below.

Quaternary Alluvium (Qa) Quaternary alluvium (Qa) consists of sand and silt, including fossiliferous lacustrine silt and silty peat deposited by existing streams in channels and along the bottoms of the larger coulees. The alluvium is reworked outburst flood deposits or loess and is sometimes difficult to distinguish from the older material.

Quaternary Colluvium (Qc) The Quaternary colluvium (Qc) is generally silt- to boulder-sized, mostly subangular basaltic debris, and includes talus and alluvial fan deposits carried down from the steeper slopes and cliffs in the coulees and valleys.

Quaternary Dune Sand (Qd) The Quaternary dune sand (Qd) is generally fine to medium sand, mostly quartz, feldspar, and basalt, and includes active barchan (crescent-shaped) dunes in the Lower Crab Creek valley that consist of sand derived from floodplain deposits of the Columbia River.

Quaternary Fluvial Gravel (Qg) The Quaternary fluvial gravel (Qg) is Missoula flood gravel deposits ranging from boulders to sand, with laminated silts derived from the numerous outburst floods from the glacial Lake Missoula. The material was deposited at points where scabland channels emptied into basins or large river valleys and diminished water velocity resulted in deposition of the floodwater sediment load.

Quaternary Fluvial-Lacustrine Sand and Silt (Qs) The Quaternary fluvial-lacustrine sand and silt (Qs) are generally a finer-grained facies of the Missoula flood deposits, consisting of fine to coarse, horizontally bedded basaltic sand and silt. As with the fluvial gravel, the material was deposited at points where scabland channels emptied into basins or large river valleys and diminished water velocity resulted in deposition of the floodwater sediment load.

Quaternary Lacustrine Fine Sand and Silt (Qss) The Quaternary glacial-lacustrine (Missoula flood) fine sand and silt (Qss) were deposited in temporary lakes formed as ice and debris dammed the Columbia River. Two principal periods of deposition of lacustrine silt are recognized, based on two faintly defined shorelines, at elevations of 1, 200 and 1,350 feet in the Quincy basin (Grolier and Bingham 1971 and 1978). The deposits are calcareous throughout, loosely compacted, slightly cohesive, and temporarily stand in steep walls in ravines and cuts. Another characteristic of the lacustrine fine sand and silt is the presence of numerous clastic dikes. The upper limit of the glacial-lacustrine deposits is marked by the presence of erratic pebbles and boulders interpreted as ice-rafted debris that was stranded along the shoreline of the lakes in which deposition of the silt occurred.

Quaternary Palouse Formation (Ql) The Quaternary Palouse Formation (Ql) consists of eolian loess (windblown silt) that covers the majority of the surface area of the Study area. Deposits consist primarily of silt, but include some fine sand, clay, and volcanic ash. Wind action and loess deposition occurred during the Pleistocene, with glacial drift providing a source of silt. The loess occurs throughout much of the Columbia River Plateau and reaches its greatest thickness and continuity in the southeastern part of the Palouse Subprovince, where locally it is as much as 250 feet thick (Hansen et al. 1994). Within the Study area, the loess ranges in thickness from 10 to 50 feet in the upland,s where it was not removed by the scouring effects of outburst floods. The loess can be very stable when dry, but it is susceptible to piping, as well as subsidence and settlement when saturated.

Tertiary Ringold Formation (Tr) The Tertiary Ringold Formation (Tr) consists of three facies divided into lower, middle, and upper. The lower is largely clayey silt with sand and gravel, the middle is composed of gravel and cobbles with a silt matrix, and the upper sediments are composed of sand and silt with some minor fine gravel (Lillie et al. 1978). The unit is exposed along the west shore of Potholes Reservoir, Frenchman Hills, and Saddle Mountains, and along the Columbia River south and west of the Study area. The Ringold is up to 600 feet thick in exposures in the Pasco Basin.

Bedrock Units

Bedrock underlying the Study area is composed of volcanic rocks of the Columbia River Basalt Group. Within the Study area, the Columbia River Basalt Group is composed of, from youngest to oldest, the Saddle Mountains, Wanapum, and Grande Ronde Formations. The long periods between eruptions allowed for the deposition of sediments between flows. These sediments, known as the Ellensburg Formation, include sand-and-gravel-bar deposits from the Columbia River and finer-grained silt and clay layers deposited in shallow lakes formed by temporary damming of the Columbia River.

Saddle Mountains Formation - Undifferentiated (Tsm)

The formation consists of four basaltic members and three sedimentary interbed units that are part of the Ellensburg Formation. The basaltic units are the Elephant Mountain, Pomona, Esquatzel, and Umatilla Basalt Members consisting generally of fine- to medium-grained, slightly weathered, hard, intensely to moderately fractured basalt. The sedimentary units are the Rattlesnake Ridge, Selah, and Mabton, and they are composed of weathered basaltic fragments and tuffaceous silt and clay. The Saddle Mountains Formation is exposed at the surface along the ridge north of the Lower Crab Creek dam site and is presumed to underlie the Saddle Mountains Thrust Fault on the left abutment of the proposed Lower Crab Creek dam site.

Wanapum Basalt Formation

The Wanapum Basalt Formation is divided into the Priest Rapids (Tp), Roza (Trz), and Frenchman Springs (Tf) Members. Locally, the Ellensburg Formation is represented by the Quincy Interbed within the Wanapum Formation and the Vantage Member that overlies the Grand Ronde Basalt Formations. The Wanapum Basalt is exposed in the folded belt west of the Study area and in scoured coulees and river channels.

Priest Rapids Basalt (Tp) The Priest Rapids Basalt Member (Tp) is the uppermost basaltic flow in the Wanapum Basalt Formation. The Priest Rapids Member consists of grayish black, medium to coarse-grained, dense to vesicular basalt. The rock weathers to reddish-brown, and often has large columns and platy partings in basal flows, with pillow-palagonite containing petrified wood at the base (Grolier and Bingham 1971 and 1978). The unit consists of four flows and is about 200 feet thick in the northwest part of the Study area. The Priest Rapids Basalt forms the bedrock on the right abutment and channel section for the proposed Lower Crab Creek dam site.

Quincy Diatomite (Tq) The Quincy Member (Tq) is a sedimentary unit between the Priest Rapids and Roza Basalt Members. The unit consists of diatomite and is about 30 feet thick based on well logs. Diatomite is a friable, earthy deposit composed of silica consisting of frustules (siliceous shell) of microscopic plants called diatoms. Diatoms secrete silica frustules that may accumulate in enormous numbers in fresh water, likely in lakes ponded behind lava flow dammed streams. The Quincy Diatomite is not present in the near surface foundation at any of the potential dam sites.

Roza Basalt (Trz) The Roza Member (Trz) is near the middle of the Wanapum Basalt Formation. The Roza Basalt is dark blue-gray and medium- to coarse-grained, porphyritic (1 centimeter plagioclase phenocrysts), and weathers to deep reddish-brown. The Roza Basalt has large columnar joints throughout that generally range from 5 to 10 feet across. The columns also have platy parting planes mostly normal to the axis of columns (Grolier and Bingham 1971 and 1978). The unit consists of one or two flows and is about 100 feet thick in the northwest part of the Study area. The Roza Basalt forms the upper abutments at the proposed Upper Dry Coulee, Black Rock Coulee, and Rocky Coulee dam sites.

Frenchman Springs Basalt (Tf) The Frenchman Springs Member (Tf) is the lowest flow in the Wanapum Basalt Formation. The Frenchman Springs Basalt is dark gray, fine to medium-grained, and porphyritic (10 to 25 millimeter plagioclase phenogrysts). The upper contact is marked by cherty concretions and sandy clay, and the basal part of the flows have thin (less than 1-foot thick) pillow-palagonite zones containing petrified logs (Reidel and Campbell 1989). The unit consists of four flows and is about 200 feet thick in the northwest part of the Study area. The Frenchman Springs Basalt forms the foundation for the abutments and channel sections at the proposed Upper Dry Coulee, Black Rock Coulee, and Rocky Coulee dam sites.

Vantage Sandstone (Tv) The Vantage Member (Tv) is a sedimentary unit between the Wanapum and Grande Ronde Formations. The unit consists of light colored, weakly cemented tuffaceous sandstone and siltstone, and ranges from 1 to about 35 feet thick based on well logs. The Vantage Sandstone is generally concealed by talus that has fallen from overlying flows onto lower basaltic benches. The sedimentary unit may be present in the deeper foundation under the upper abutments at the proposed Lower Dry Coulee dam site, and the channel section at the proposed Upper Dry Coulee dam site at the contact between the Grande Ronde (Tgr) and Frenchman Springs (Tf) Basalt units.

Grande Ronde Basalt Formation - Undifferentiated (Tgr)

The Grande Ronde Formation is the most aerially extensive unit of the Columbia River Basalt Group and it underlies the entire Study area to depths of several hundred feet. The basalt is black or dark gray, fine-grained to aphanitic, and often with hackly jointing. Columns are commonly smaller than in the Frenchman Springs, Roza, and Priest Rapids Members, and the unit includes thick zones of pillows and palagonite (Grolier and Bingham 1971 and 1978). The Grande Ronde consists of multiple flows with rare interbeds, and contacts between individual flows are sometimes rubbly and fractured. These contact zones tend to be zones of higher permeability (Hansen et al. 1994). The Grande Ronde forms the foundation for a portion of the channel section at the proposed Upper Dry Coulee dam site and the entire foundation at the proposed Lower Dry Coulee dam site.

Appendix B: Birds, Mammals, and Reptiles that May Be in the Study Area

Birds

Common Name	Scientific Name
Turkey vulture	*Cathartes aura*
Osprey	*Pandion haliaetus*
Bald eagle	*Haliaeetus leucocephalus*
Sharp-shinned hawk	*Accipiter stratus*
Cooper's hawk	*A. cooperii*
Northern harrier	*Circus cyaneus*
Swainson's hawk	*Buteo swainsoni*
Red-tailed hawk	*B. jamaicensis*
Ferruginous hawk	*B. regalis*
Golden eagle	*Aquila chrysaetos*
American kestrel	*Falco sparverius*
Prairie falcon	*F. mexicanus*
Peregrine falcon	*F. perigrinus*
Barn owl	*Tyta alba*
Western screech owl	*Otis kennicotti*
Great-horned owl	*Bubo virginianus*
Northern pygmy owl	*Glaucinium gnoma*
Northern saw-whet owl	*Aegolius arcadicus*
Burrowing owl	*Athene cunicularia*
Long-eared owl	*Asio otis*
Short-eared owl	*A. flammeus*
Great-blue heron	*Ardea herodias*
Ruffed grouse	*Bonasa umbellus*
Sage grouse	*Centrocercus urophasianus*
Sharp-tailed grouse	*Tympanuchus phasianellus*
Mountain quail	*Oreotyx pictus*
California quail	*Callipepla californica*
Sandhill crane	*Grus canadensis*
Upland sandpiper	*Bartramia longicauda*
Killdeer	*Charadrius vociferus*
Long-billed curlew	*Numenius americanus*
Rock dove	*Columba livia*
Mourning dove	*Zenaida macroura*
Yellow-billed cuckoo	*Coccyzus americanus*
Common poorwill	*Phalaenoptilus nuttalli*
Common nighthawk	*Chordelles minor*
Black swift	*Cypseloides niger*
White-throated swift	*Aeronautes saxatalis*
Black-chinned hummingbird	*Archilochus alexanri*
Calliope hummingbird	*Stellula calliope*
Broad-tailed hummingbird	*Selasphorus platycercus*
Rufous hummingbird	*S. rufus*
Belted kingfisher	*Ceryle alcyon*
Lewis' woodpecker	*Melanerpes lewisi*
Red-naped sapsucker	*Sphyrapicus nuchalis*

Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*P. villosus*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Western wood-pewee	*Contupus sordidulus*
Willow flycatcher	*Epidonax traillii*
Least flycatcher	*E. minimus*
Dusky flycatcher	*E. oberholseri*
Cordilleran flycatcher	*E. occidentalis*
Gray flycatcher	*E. wrightii*
Ash-throated flycatcher	*Myiarchius cinerascens*
Say's phoebe	*Sayornis saya*
Western kingbird	*Tyrannus verticallis*
Eastern kingbird	*T. tyrannus*
Horned lark	*Eremophila alpestris*
Tree swallow	*Tachycineta bicolor*
Violet-green swallow	*T. thalassina*
Northern rough-winged swallow	*Stelgidopterix serripennis*
Bank swallow	*Ripariariparia*
American robin	*Turdus migratorius*
Cliff swallow	*Petrochilodon pyrrhonota*
Loggerhead shrike	*Lanius ludovicianus*
Cedar waxwing	*Bombycilla cedrorum*
American dipper	*Cinclus mexicanus*
Rock wren	*Salpinctus obsoletus*
Canyon wren	*Catherpes mexicanus*
House wren	*Troglodytes aedon*
Sage thrasher	*Oreoscoptes montanus*
Gray catbird	*Dumetella carolinensis*
Western bluebird	*Sialia mexicana*
Veery	*Catharus fuscescens*
Blue-gray gnatcatcher	*Polioptila caerulea*
Bushtit	*Psaltriparus minimus*
Black-capped chickadee	*Poecile atricapilla*
White-breasted nuthatch	*Sitta carolinensis*
Brown creeper	*Certhia americana*
Juniper titmouse	*Baeolophus ridgwayi*
Song sparrow	*Melospizo melodia*
White-crowned sparrow	*Zonotrichia leucophrys*
Savannah sparrow	*Passerculus sandwichensis*
Grasshopper sparrow	*Ammodramus savannarum*
Brewers sparrow	*Spizella breweri*
Vesper sparrow	*Pooecetes gramineus*
Lark sparrow	*Chondestes grammacus*
Black-throated sparrow	*Amphispiza bileata*
Sage sparrow	*A. belli*
Chipping sparrow	*Spizelia passerina*
Dark-eyed junco	*Junco hyemalis*
Spotted towhee	*Pipilo maculatus*
Green-tailed towhee	*P. chlorurus*
Black-headed grosbeak	*Pheucticus melanocephalus*
Lazuli bunting	*Passerina amoena*
Western tanager	*Piranga ludoviciana*
Orange-crowned warbler	*Vermivora celata*
Nashville warbler	*V. ruficapilla*
Yellow warbler	*Dendroica petechia*
Black-throated gray warbler	*D. nigrescens*
Virginia's warbler	*V. virginae*

American redstart	*Setophaga ruticilla*
Northern waterthrush	*Seiurius noveboracensis*
Common yellowthroat	*Geothlypis trichas*
MacGillivary's warbler	*Oporornis tolmieri*
Wilson's warbler	*Wilsonia pusilla*
Yellow-breasted chat	*Icteria virens*
Cassin's vireo	*Vireo cassenni*
Red-eyed vireo	*V. olivaceous*
Warbling vireo	*V. gilvus*
Bullock's oriole	*Icterus bullocki*
Western meadowlark	*Sturnella neglecta*
Red-winged blackbird	*Aeelaius phoeniceus*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown-headed cowbird	*Molothrus ater*
Bobolink	*Dolichonyx oryzivorous*
American goldfinch	*Carduelis tristis*
Cassin's finch	*Carpodacus cassinni*
House finch	*C. mexicanus*
Pinyon jay	*Gymnorhinus cyanocephalus*
Black-billed magpie	*Pica hudsonia*
American crow	*Corvus brachyrhynchos*
Common raven	*Corvus corax*

Mammals

Common Name	Scientific Name
Merriam's shrew	*Sorex trowbridgii*
Water shrew	*Sorex palustris*
Wandering shrew	*S. vagrans*
Northern grasshopper mouse	*Onychomys leucogaster*
Sagebrush vole	*Lagurus curtatus*
Montane vole	*Microtus montanus*
Columbian ground squirrel	*Citellus columbianus*
Deer mouse	*Peromyscus maniculatus*
Forest deer mouse	*P. keenii*
Western jumping mouse	*Zapus princesp*
Porcupine	*Erethizon dorsatum*
Western harvest mouse	*Reithrodontomys megalotis*
Least chipmunk	*Eutamias minimus*
Yellow-bellied marmot	*Marmota flaviventris*
Yellow-pine chipmunk	*Tamias amoenus*
Ord's kangaroo rat	*Dipodomys ordii*
Northern pocket gopher	*Thomomys talpoides*
Beaver	*Castor canadensis*
Muskrat	*Onadontra zibethica*
Washington ground squirrel	*Spermophilus washingtoni*
Townsend's ground squirrel	*S. townsendii*
California ground squirrel	*S. beecheyii*
Columbia Basin pygmy rabbit	*Brachylagus idahoensis*
White-tailed jackrabbit	*Lepus townsendii*
Black tailed jackrabbit	*L. californicus*
Nuttall's cottontail	*Sylvilagus nuttalli*
Bushy-tail woodrat	*Neotomys cinerea*

Common Name	Scientific Name
Badger	*Taxidea taxus*
Mink	*Mustela vison*
River otter	*Lutra canadensis*
Long-tailed weasel	*Mustela frenata*
Short-tailed weasel	*M. erminea*
Bobcat	*Lyns rufus*
Cougar	*Felis concolor*
Raccoon	*Procyon lotor*
Black bear	*Ursus americanus*
Gray wolf	
Coyote	*Canis latrans*
Muledeer	*Odocoileus hemionus*
Whitetail deer	*O. virginianus*
Elk	*Cervus elaphe*
Yuma myotis	*Myotis yumanensis*
Small-footed myotis	*M. ciliolabrum*
Long-eared myotis	*M. evotis*
Fringed myotis	*M. thysanodes*
Pale Townsend's big-eared bat	*Plecotus townsendii pallescens*
Little brown bat	*M. lucifigis*
Keen's myotis	*M. keenii*
Long-legged myotis	*M. volans*
California myotis	*M. californicus*
Silver-haired bat	*Lasionycterus noctivagans*
Western pipistrelle	*Pipistrellus hesperus*
Big brown bat	*Eptesicus fuscus*
Pallid bat	*Antrozous pallidus*
Hoary bat	*Lasiurus cineurus*
Townsend's big-eared bat	*Corynorhinus townsendii*
Spotted bat	*Euderma maculata*
Western small-footed myotis	*Myotis coopabari*

Reptiles and Amphibians

Common Name	Scientific Name
Garter snake	*Thamnophis sirtalis*
Short-horned lizard	*Phrynosoma douglassi*
Sagebrush lizard	*Sceloporus graciosus*
Side-blotched lizard	*Uta stansburiana*
Western skink	*Eumeces skiltonianus*
Racer	*Coluber constrictor*
Rubber boa	*Charina bottae*
Striped whipsnake	*Masticophis taeniatus*
Ringneck snake	*Diadophus punctatus*
Sharptail snake	*Contia tenius*
Gopher snake	*Pituophis catenifer*
Western rattlesnake	*Crotalus viridis*
Night snake	*Hypsiglena torquata*
Long-toed salamander	*Ambystoma macrodactylum*
Tiger salamander	*A. tiginum*
Pacific treefrog	*Pseudacris regilla*
Bullfrog	*Rana catesbiana*
Columbia spotted frog	*R. luteiventris*
Northern leopard frog	*R. pipiens*
Western toad	*Bufo boreas*

Common Name	Scientific Name
Woodhouse’s toad	*B. woodhousei*

Appendix C: Description of Federally Protected Species

The following information is based on communications with the Fish and Wildlife Service (2007 [First PAM]).

Federal Endangered Species

Four species are listed under the ESA and administered by the FWS in the general Study area. These are described here.

Pygmy Rabbit

The pygmy rabbit (*Brachylagus idahoensis*) is a federally endangered mammal. The pygmy rabbit depends largely upon sagebrush, primarily big sagebrush, *artemisia tridentata*, and is usually found in very dense big sagebrush. It selects sites with the greatest sagebrush cover and feeds primarily on big sagebrush, sometimes even climbing into the tops of the larger plants. In winter, big sagebrush may comprise up to 99 percent of their diet; grasses may comprise 30-40 percent of their diet in the summer (Bailey 1936, Green 1978, and Wilde 1978).

The pygmy rabbit is found throughout much of the sagebrush area of the Great Basin, as well as some of the adjacent intermountain areas (Green and Flinders 1980). In Washington, the pygmy rabbit was historically found in several areas in the Columbia River basin (Couch 1923). The rabbit has more recently been found in two separate locations within Douglas County and at Sagebrush Flat. However, no pygmy rabbits are thought to exist in the wild within Washington. About 100 pygmy rabbits are kept in captivity. Reintroduction of pygmy rabbits within recovery emphasis areas in the Study area is planned for the future.

The burrowing habit of the pygmy rabbit is unique among the western North American rabbits. Burrows are usually under big sagebrush and are only rarely located in an opening of vegetation, reinforcing the dependence of this rabbit on dense sagebrush clumps (Green 1978, Green and Flinders 1980, and Wilde 1978). Proper soil structure is thought to be a key feature because the rabbit makes its own burrows. Generally soft, deep soils are required for burrowing. Pygmy rabbits will only live where the soil is deep enough and of a certain quality (Wilde 1978). Pygmy rabbits also use holes in volcanic rock, rock piles, and around abandoned buildings. These cares (burrows) are associated with pygmy rabbits using typically deep soil and sagebrush burrow sites and may only be an energy efficient alternative to digging a burrow or may give added protection against predators that excavate burrows (Green and Flinders 1980).

Because of low numbers and limited distribution, pygmy rabbit populations in Washington are vulnerable to fire, disease, intense predation, and genetic and demographic parameters that sometimes cause the collapse of small populations. Habitat degradation and loss are likely to continue without active prevention efforts. The primary threats to pygmy rabbit habitat include the fragmentation or removal of sagebrush rangeland for development and agriculture or through wildfire, which isolate populations. As the "islands" of habitat are smaller, local extinctions may occur. The probability of extinction increases when habitat modification and removal or genetically related stochastic events occur. These local extinctions contribute to a reduction of the species distribution (Dobler and Dixon 1996).

Figure C-1 shows the pygmy rabbit historic range (magenta polygon), location of two past wild populations that are recovery emphasis areas where future reintroduction may occur (solid cream polygons), and areas of possible remnant habitat or populations (light green areas). The areas shown as potentially occupied are areas where suitable soil types and sagesteppe occur; although pygmy rabbits are thought to no longer exist there.

Ute Ladies'-tresses

Ute ladies'-tresses (*Spiranthes diluvialis*), federally listed as threatened, is a wetland-dependant member of the orchid family, found in areas of Washington.

Ute ladies'-tresses are typically found in wet meadows, riparian areas, abandoned riparian zones, or in damp areas near natural water sources or water bodies (NatureServe 2006).

No Ute ladies'-tresses are known to occur in the Study area. However suitable habitat has not yet been surveyed.

Spalding's Catchfly

Spalding's catchfly (*Silene spaldingii*) is an herbaceous perennial plant, federally listed as threatened. A total of 66 populations (12 in Idaho; 8 in Montana/British Columbia, Canada; 8 in Oregon; and 38 in Washington) have been documented. Most of the Spalding's catchfly populations are small in size and located on privately-owned parcels. Fifty-two percent of its populations have less than 100 plants each. Five extirpations have been recorded to date rangewide. Potential unsurveyed habitat exists in all physiographic regions in which Spalding's catchfly occurs.

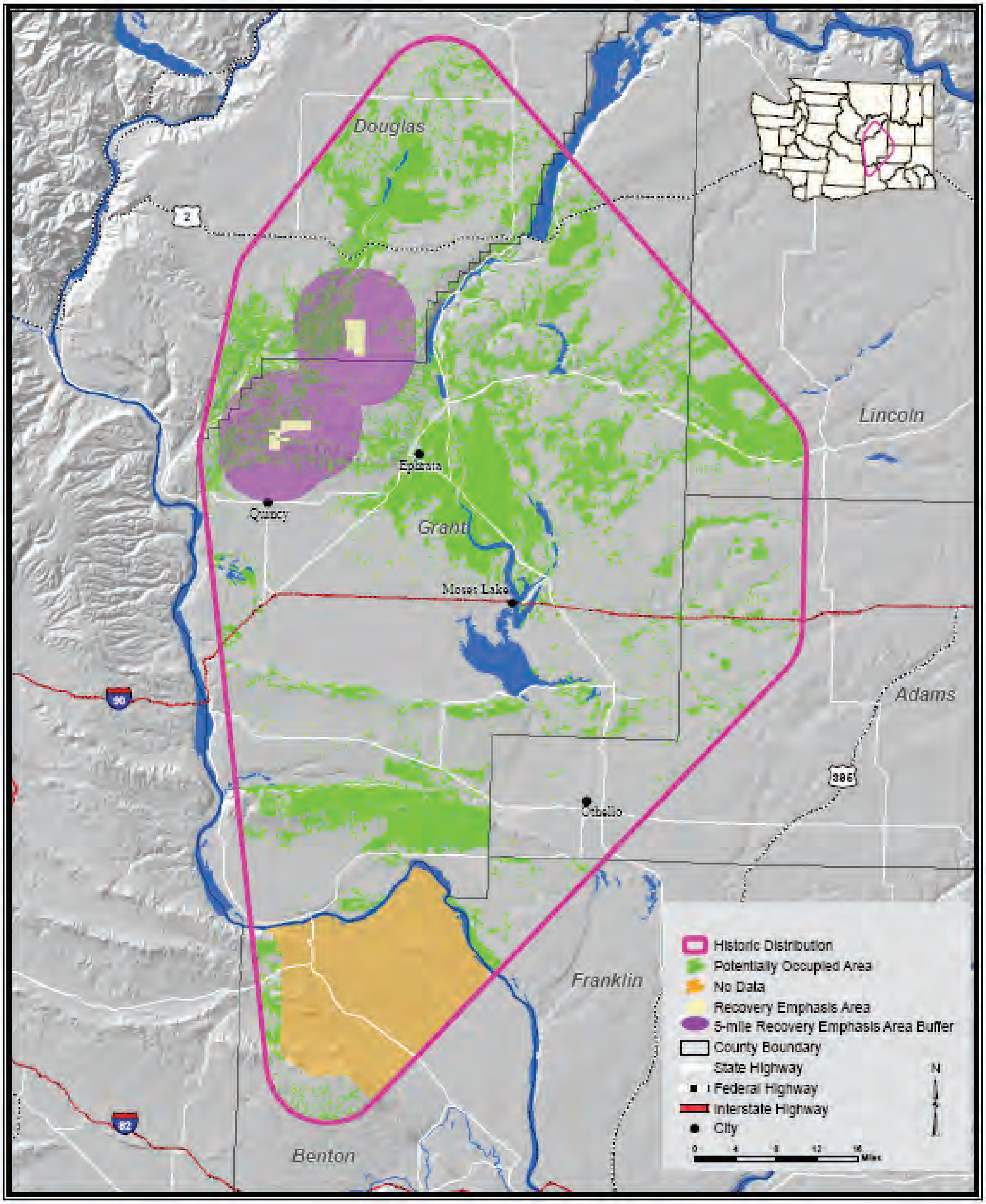

Figure C-1. Range of the Columbia Basin pygmy rabbit within the Study area.

Roughly 18 percent of the plants in Washington are found on U.S. Forest Service lands (997 out of 5,264 plants). In Washington, two populations are located entirely on the Umatilla National Forest in the Blue Mountains.

Spalding's catchfly is a regional endemic, restricted to remnant grasslands in the channeled scablands. It is generally found in open mesic grassland communities of the Pacific Northwest Bunchgrass Grasslands type, with deep productive loess soils (Tisdale 1983). Plants are generally found in swales or on north or east facing slopes where soil moisture is relatively higher (FWS 2005). This habitat is often characterized by high cover of perennial bunchgrasses, a relatively abundant and diverse perennial forb component, often a minor shrub component, and a well-developed cryptogamic crust layer. Spalding's catchfly is occasionally found in shrub and forest habitat types, including sagebrush-fescue and open canopy pine-fescue types. The fescue associations in these shrub- and tree-dominated communities are very similar to the mesic fescue grassland habitat types (Daubenmire 1968). Within Washington, Oregon, and Idaho, spalding's catchfly is associated with Idaho fescue (*Fescue idahoensis*).

Spalding's catchfly's current threats are habitat loss due to human development, habitat degradation associated with domestic livestock and wildlife grazing, and invasions of aggressive nonnative plants (FWS 2005). Drought conditions have also had a negative effect on Spalding's catchfly populations by limiting growth and reproduction (Lesica 1988).

Bull Trout

Bull trout *(Salvelinus confluentus)* is a federally threatened char found throughout the coastal and inland streams and lakes in Washington. Bull trout are not known to spawn in any of the streams or inhabit any aquatic habitat, other than the mainstem Columbia River, within the Study area. Although some individuals may spend their entire life in a small segment of a stream, most are highly migratory, traveling to headwater streams to spawn and later migrate back to larger stream segments or lakes to rear (McPhail and Murray 1979). Bull trout exhibit three life-history forms: a resident, fluvial, and anadromous. The multiple life-history strategies found in bull trout populations provide important spatial and genetic diversity that helps protect these populations from environmental stochasticity.

Bull trout spawn in cold, high elevation streams located in the upper reaches of clear streams, where areas of flat gradient, uniform flow, and uniform gravel or small cobble are found. Strict habitat requirements make spawning and incubation habitat for bull trout limited and valuable (Fraley et al. 1989). Bull trout require hiding cover, such as logs and undercut banks, when spawning and relatively little streambed sediment. Fry are found in shallow, slow backwater side channels and eddies (Shepard et al. 1984 and Elliott 1986). Adults are often found in pools sheltered by large, organic debris or "clean" coble substrate (McPhail and Murray 1979). Juveniles are primarily bottom dwellers, occupying positions above, on, or below the bottom.

Bull trout feed on a variety of water column organisms and bottom dwellers (Thompson and Tufts 1967; Shepard et al. 1984, and Pratt 1984).

The maintenance of riparian vegetation for controlling stream temperature, providing cover, and protecting against lateral erosion (WDW 1991) is important for bull trout. Removing streamside vegetation lowers canopy density (shading) and increases sedimentation. Increases in solar radiation raise stream temperatures, thereby negatively impacting spawning, hatching, and rearing survival. Increased sedimentation contributes to the loss of spawning habitat and decreases the diversity of aquatic invertebrates and other food items (Newbold et al. 1977).

Federal Candidate Species

Candidate species are those petitioned species that are actively being considered for listing as endangered or threatened under the ESA, as well as those species for which NMFS or FWS has initiated an ESA status review announced in the *Federal Register*. Candidate species receive no statutory protection under the ESA. However, the FWS and NMFS encourage forming partnerships to conserve these species, since they are, by definition, species that may warrant future protection under the ESA.

Washington Ground Squirrel

The Washington ground squirrel (*Spermophilus Washingtoni)* is a Federal candidate species that depends highly on sage-steppe habitat. It prefers sandy soils in dry, open sagebrush and grassland habitats. Land development and conversion to agricultural use are threats to its habitat.

Washington ground squirrels are not known to exist in the Study area. However, all existing habitat has not been surveyed.

White Bluffs Bladderpod

The White Bluffs bladderpod (*Lesquerella tuplashensis*) is a Federal candidate plant species that is limited to the White Bluffs area of Hanford National Monument, particularly a 1.5-to 12-meter strip along the top of the White Bluffs, in Franklin County, Washington.

Northern Wormwood

Northern wormwood (*Artemisia campestris* ssp. *borealis* var) is a Federal candidate plant species that is restricted to exposed basalt, cobbly-sandy terraces, and sand habitat along the shore and on islands in the Columbia River. It is currently only known in two sites in Klickitat and Grant counties. No additional plants have been detected in recent surveys of apparently suitable habitat along the Hanford Reach of the Columbia River (FWS 2006).

Threats to northern wormwood include direct loss of suitable habitat through changing water levels in the Columbia River, placement of riprap along the river bank, trampling of plants as a result of recreational use, competition with nonnative invasive species, a small population size that makes both sites susceptible to genetic drift and inbreeding, and the potential for hybridization with two other species of *Artemisia*.

Federal Species of Concern

Species of concern are those species about which FWS or NMFS have some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA. "Species of concern" do not carry any procedural or substantive protections under the ESA. Animals identified by FWS as Federal Species of Concern (FWS 2007 [First Letter]) include:

Common Name	Scientific Name
Animals	
Burrowing owl	*Athene cunicular*i
Northern goshawk	*Accipiter gentilis*
Kincaid meadow vole	*Microtus pennsylvanicus kincaidi*
Wolverine	*Gulo gulo*
Greater sage grouse Columbia Basin distinct population segment	*Centrocercus urophasianus*
Olive-sided flycatcher	*Contopus cooperi*
Columbian sharp-tailed grouse	*Tympanuchus phasianellus columbianus*
Western brook lamprey	*Lampetra richardsoni*
River lamprey	*Lampetra ayresi*
Redband trout	*Oncorhynchus mykiss*
Pacific lamprey	*Lampetra tridentata*
Giant Columbia spire snail	*Fluminicola columbiana*
Ferruginous hawk	*Buteo regalis*
Loggerhead shrike	*Lanius ludovicianus*
Long-eared myotis	*Myotis evotis*
Northern leopard frog	*Rana pipiens*
Pallid Townsend's big-eared bat	*Corynorhinus townsendii pallenscens*
Dragonfly	
Columbia clubtail	*Gomphus lynnae*
Mussel	
California floater	*Anodonta californiensis*
Sagebrush lizard	*Sceloporus graciosus*

Common Name	Scientific Name
Vascular Plants	
Washington polemonium	*Polemonium pectinatum*
Gray cryptantha	*Cryptantha leucophaea*
Hoover’s desert-parsley	*Lomatium tuberosum*
Wanapum	*Oxytropis campestris* var. *wanapum*
Crazyweed	*Oxytropis lambertii*
Prairie lupin	*Lupinus cusickii*

Appendix D: Summary of Public Feedback

Reclamation solicited feedback about the appraisal-level investigation. Eighty-four written comments were received from a variety of stakeholders. Reclamation conducted a content analysis and categorized the comments according to stakeholder category. This analysis and copies of all written comments are available in Reclamation 2008, located in Reclamation files. The following summarizes the comments received, grouped by those specific to water delivery alternatives and water supply options.

Water Delivery Alternatives

- Address the restricted capacity of the East Low Canal south of I-90; make it a Study priority.
- The selected alternative needs to deliver water south of I-90 as there are significant aquifer declines there.
- Building major infrastructure to meet needs of Odessa Subarea irrigators on a scale that would facilitate expanding the CBP in the future is unnecessary and not justified.
- Invest in the East High canal system infrastructure now to more cost effectively facilitate future CBP development.
- Alternative must supply water to every acre currently irrigated.
- Alternative A offers the best opportunity for potentially reducing aquifer depletion. However, alternative A may be the most difficult to implement, involve more environmental issues, and take longer to study and construct.
- Alternative B can be phased to deliver water to Odessa Subarea lands expeditiously by implementing the East Low Canal component first; full implementation will deliver water to sufficient acreage to help declining aquifer.
- Combine elements of alternatives B and C in a phased manner; will address the current East Low Canal capacity restrictions south of I-90 and has the most operational and implementation flexibility.

- Alternatives C and D may have less potential fish and wildlife impacts than alternatives A and B.

- Combine elements of alternatives C and D, looking at a phased implementation approach.

- Alternative C would not provide a replacement water supply to sufficient acreage but would have a slight advantage over alternative D because it would provide water to lands south of I-90.

- Alternative D would not provide a replacement water supply to sufficient acreage to address the declining aquifer problem; it does not deliver water to lands located south of I-90.

- Sustain agriculture in the Odessa Subarea in a cost effective, environmentally sensitive manner by examining alternatives that rely on the East Low Canal and reoperations at existing water storage facilities in combination with water conservation and efficiency, water markets, conservation reserves, well reconstruction, and conversion to dryland farming, as opposed to building significant new infrastructure.

- Do not support providing surface water to groundwater farmers.

Water Supply Options

- Examine options that use existing storage facilities in combination with water conservation, efficiency, and water markets as opposed to building new dams.

- Water supply options involving minor operational modifications to Banks Lake and Potholes Reservoir in combination with a smaller sized storage reservoir may result in less impact to wildlife.

- Using existing CBP storage facilities (e.g. Banks Lake drawdown or operational raise); it would cost less and have less environmental effects compared to building new storage facilities.

- Banks Lake drawdown would have recreation-related impacts to Coulee City and the surrounding area.

- Dry Creek Coulee is an ideal location from an operational standpoint; it could potentially provide a water supply for future full CBP development if used in combination with Banks Lake and Potholes Reservoir reoperation.

- Reconsider Lind Coulee and Black Rock Coulee as potential new water storage sites; sites have lower potential wildlife impacts than other proposed storage facilities.

- Proposed Rocky Coulee reservoir provides increased operational flexibility and reliability, costs less to construct, and has less potential impact to wildlife than other new storage facilities examined.

- Opposition to a proposed Lower Crab Creek Reservoir:
    - Because of impacts to fish, wildlife, recreation, CNWR, and private property

    - Releases from the proposed reservoir would impact the Columbia River fishery as opposed to benefiting it because of anticipated high water temperatures

    - Not ideally located from a CBP operational standpoint. Energy requirements to operate would be high as water would be pumped twice - first in the fall season to fill the proposed reservoir and a second time during irrigation season to deliver water to Study area lands.

    - Operating the reservoir would result in Columbia River flow reductions from Grand Coulee Dam to Lower Crab Creek confluence during the summer and may affect ESA species.

    - Significant economic and environmental costs compared to other water supply options.

Other

- Ability to implement quickly should be a factor in selecting alternatives and options.

- Support alternatives that sustain existing agricultural acreage in the Odessa Subarea.

- Partner to implement immediate actions consistent with Study objectives to expedite and facilitate Study solutions.

- Seek least cost approaches and innovative financing such as local improvement districts.

- Convene stakeholders group to review future information to facilitate public confidence and support of Study results.

- Avoid water delivery and storage alternatives that eliminate large acreages of shrub-steppe habitat.

- Cost estimates may be deficient because they do not include operating costs or environmental costs.

- Two recent economic studies identified significant regional economic impacts associated with continued decline of the aquifer. Others have questioned the studies' validity and the economic impacts identified.

- Insufficient opportunities provided for public comment.

- Recreation benefits associated with the CBP have often come at the loss of river recreation opportunities. The Study should quantify and consider impacts to river-based recreation.

- Design the selected alternative in sequential, incremental steps to facilitate understanding of implementation actions required.