DRAFT Technical Memorandum

Henrys Fork Basin Study
New Surface Storage Alternatives

Addendum to Technical Series No. PN-HFS-002

Prepared for

Bureau of Reclamation, Idaho Water Resource Board, and Henrys Fork Watershed Council

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Prepared by

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Contents

Exhibits **Page**

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Part I – Introduction and Methodology

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SECTION 1

Alternatives Introduction

1.1 Alternatives Overview

The Bureau of Reclamation and the State of Idaho, through the Idaho Water Resource Board, in collaboration with a stakeholder working group, is conducting a Basin Study on water resources in the Henrys Fork Basin to develop alternatives to improve water supply conditions in the basin, in the Eastern Snake Plain Aquifer (ESPA), and in the Upper Snake River basin in accordance with the ESPA Comprehensive Aquifer Management Plan. An interim report, dated July 2013, describes the Basin Study processes used to develop alternatives, summarizes the results of reconnaissance-level studies, and documents the selection of alternatives which will be carried forward for appraisal level analysis.

The interim report summarized results for several different types of water supply and conservation alternatives, including 8 surface water storage alternatives. A more detailed description of the analyses for the 5 new surface water storage alternatives (separate reports were developed for a rebuild of Teton Dam and for two dam raise alternatives) is presented in Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012. This addendum to PN-HFS-002 examines a larger configuration of Lane Lake and looks at Teton Dam in an approach similar to that used for the other alternatives assessed in the original PN-HFS-002 (dated November 2012). Additionally, since seepage of water through, under, or around the dam has been identified as a key issue at these sites, seepage received additional consideration and discussion.

A brief summary of each surface storage alternative is provided in the sections that follow, with reservoir locations depicted in Exhibit 1-1. In many cases the alternatives also have sub-alternatives, based primarily on various combinations of source water supplies and associated conveyance infrastructure. More detailed descriptions of each alternative and lists of their sub-alternatives are provided in the alternative-specific sections at the end of the report.

1.2 Lane Lake Dam - Enlarged

The enlarged Lane Lake alternative features a proposed new off-channel 160-foot-tall main dam, smaller saddle dam, and a 101,000 acre-feet (af) reservoir. The dam site is located in the Teton River watershed on a generally dry drainage that is situated about one mile north of the Teton River and five miles downstream of the Bitch Creek confluence. Water for the reservoir could be supplied from several sources, including the Teton River, Conant Creek, and Falls River. Optional supply from the Teton River would require pumping. When full, Lane Lake could provide a roughly 145-foot drop to a proposed new hydropower facility at the base of the dam.

1.3 Teton Dam

The Teton Dam alternative features a proposed new 300-foot-tall dam and a 265,000 af reservoir. The dam site is located on the Teton River approximately 16 miles upstream of the City of Rexburg (at the site of the old Teton Dam), and would require no secondary water sources. When full, Teton Reservoir could provide a roughly 285-foot drop to a proposed new hydropower facility at the base of the dam.

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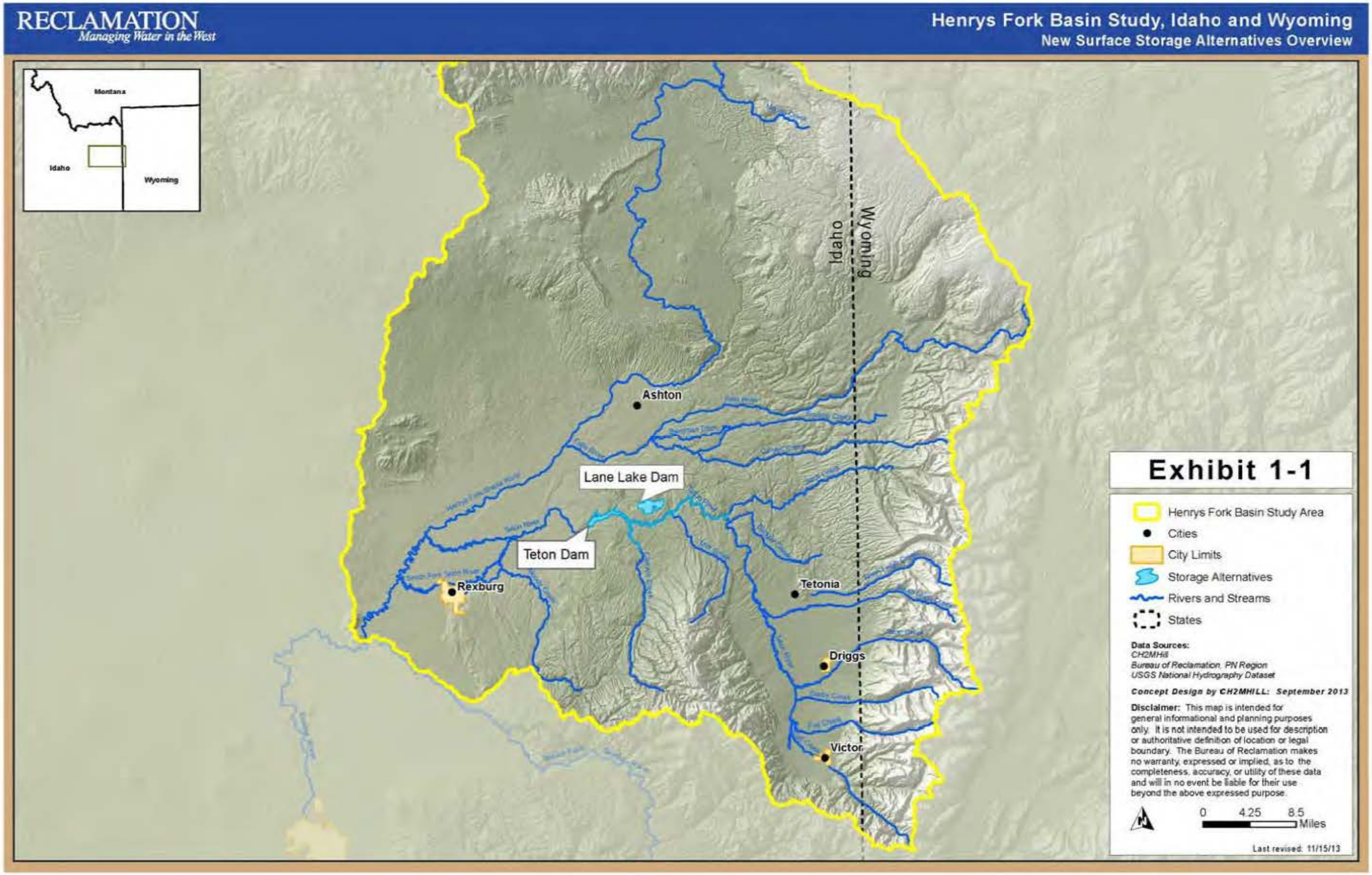

EXHIBIT 1-1
Overview of New Surface Storage Alternatives in Addendum

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SECTION 2

Evaluation Approaches, Assumptions, and Limitations

2.1 Overview

A description of the approaches, assumptions, limitations, and data used in the evaluations can be found in Section 2 of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012. The methodology described there is applicable to each alternative, except as noted in the alternative-specific sections in Part II of this report.

2.2 References

In addition to the data sources referenced in Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012, the following additional sources were referenced in this addendum.

- Chadwick, W.L. (Chairman), Casagrande, A., Coombs, H.A., Dowd, M.W., Fucik, E.M., Higginson, R.K., Leps, T.M., Peck, R.B., Seed, H.B., Jansen, R.B. (Executive Director). 1976. Failure of Teton Dam. Report to U.S. Department of the Interior and State of Idaho. Prepared by the Independent Panel to Review Cause of Teton Dam Failure. Idaho Falls, Idaho.
- Eikenberry, F.W. (Chairman), Arthur, H.G., Bogner, N.F., Lacy, F.P., Schuster, R.L., Willis, H.B. 1977. Failure of Teton Dam, A Report of Findings. Prepared by the U.S. Department of the Interior Teton Dam Failure Review Group.
- Eikenberry, F.W. (Chairman), Bogner, N.F., Lacy, F.P., Schuster, R.L., Willis, H.B. 1980. Failure of Teton Dam, Final Report. Prepared by the U.S. Department of the Interior Teton Dam Failure Review Group.
- Embree, G.F. and R.D. Hoggan. 1999. Secondary Deformation within the Huckleberry Ridge Tuff and Subadjacent Pliocene Units near the Teton Dam.
- Embree, G.F. and W.M. Phillips. 2011. Geologic Map of the Linderman Dam Quadrangle, Fremont, Madison, and Teton Counties, Idaho.
- Embree, G.F., Phillips, W.M., and J.A. Welhan. 2011. Geologic Map of the Newdale Quadrangle, Fremont and Madison Counties, Idaho.
- Prostka, H.J. 1977. Joints, Fissures, and Voids in Rhyolite Welded Ash-flow Tuff at Teton Dam Site, Idaho. U.S. Geological Survey, Open-File Report 77-211.

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Part II – Alternative Evaluation Results

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SECTION 3

Lane Lake Dam - Enlarged

3.1 Alternative Description

3.1.1 Overview

The enlarged Lane Lake alternative features a proposed new off-channel 160-foot-tall main dam, smaller saddle dam, and a 101,000 acre-feet (af) reservoir. The dam site is located in the Teton River watershed on a generally dry drainage that is situated about one mile north of the Teton River and five miles downstream of the Bitch Creek confluence. Water for the reservoir could be supplied from several sources, including the Teton River, Conant Creek, and Falls River. Optional supply from the Teton River would require pumping. When full, Lane Lake could provide a roughly 145-foot drop to a proposed new hydropower facility at the base of the dam.

3.1.2 Alternative Variations

The following sub-alternatives were identified by varying potential water-supply sources. Conveyance routes for the sub-alternatives are collectively shown on Exhibits 3-2 and 3-4. Specific conveyance lengths and features are summarized below in Section 3.3.2 – *Conveyance.*

- LL-T-2: Enlarged Lane Lake supplied by the Teton River (pumped-storage with no canal)
- LL-CoF-2: Enlarged Lane Lake supplied by Conant Creek and Falls River (both gravity-flow canals)
- LL-F-2: Enlarged Lane Lake supplied by Falls River (gravity-flow canal)

3.1.3 Operational Assumptions

Detailed operations have not been evaluated or distinguished by alternative. Preliminary, generalized, non-binding operational assumptions were described in Sections 2.2 and 2.3 of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012, to evaluate potential water availability and design flow to identify sub-alternatives and develop relative costs.

3.2 Key Findings

Lane Lake would provide additional storage water for the Teton Basin, effectively enhancing water supply by capturing excess peak flows and redistributing that water during periods of higher demand. The available storage would enhance the in-basin water budget by diverting up to 101,000 af (if the reservoir was initially empty) during the annual high flow period and storing that water until more critical, higher demand periods. This storage water could help satisfy unmet irrigation demands in the Lower Watershed and Egin Bench irrigated regions. Reservoir releases during low flow periods would increase flow in downstream river segments, including the North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork of the Snake River (Lower Henrys Fork), which have all been identified as having additional ecological streamflow needs. Diversions would typically occur during periods when connectivity is not an issue, but nonetheless withdrawals may be expected to impact conservation populations of Yellowstone cutthroat trout in Conant Creek, Falls River, and the Teton River. The out-of-basin water budget would be temporarily reduced by up to 101,000 af during the annual high flow period when water is diverted to the reservoir, but some or all of that quantity may be available at a later time for numerous out-of-basin uses, including needs resulting from climate change; agricultural needs; domestic, municipal, and industrial needs; ecological needs; and for recharge of the Eastern Snake Plain Aquifer (ESPA). The site may be prone to high seepage rates, and measures intended to ensure stability and limit seepage led to increased estimated construction costs compared to the construction cost estimates for other alternatives described in Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012. Exhibit 3-1 provides a tabular summary of the key findings.

EXHIBIT 3-1
Key Findings from the Reconnaissance Evaluation

Estimated Cost per af	Impact on In-Basin Water Budget	Impact on Out-of-Basin Water Budget	Change in Connectivity of Impacted River Segment
$4,600 - $5,300	101,000 af, to be diverted during the annual high flow period and released during high demand periods.	101,000 af reduction during the annual high flow period, in accordance with priority rights. Part or all of this quantity would be available later for out-of-basin needs.	Improvement in connectivity of downstream river segments, including North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork. Potential impacts to supply sources, including Conant Creek, Falls River, and the Teton River, which contain conservation populations of Yellowstone cutthroat trout.

3.3 Engineering Results

3.3.1 Hydrology

Three potential water supply sources were identified: Teton River, Conant Creek, and Falls River (Exhibit 3-2). Exhibit 3-3 presents a summary of potentially available water from each source based on analyses using StreamStats (USGS, 2011; see Section 2.2.1 – *Hydrology*).

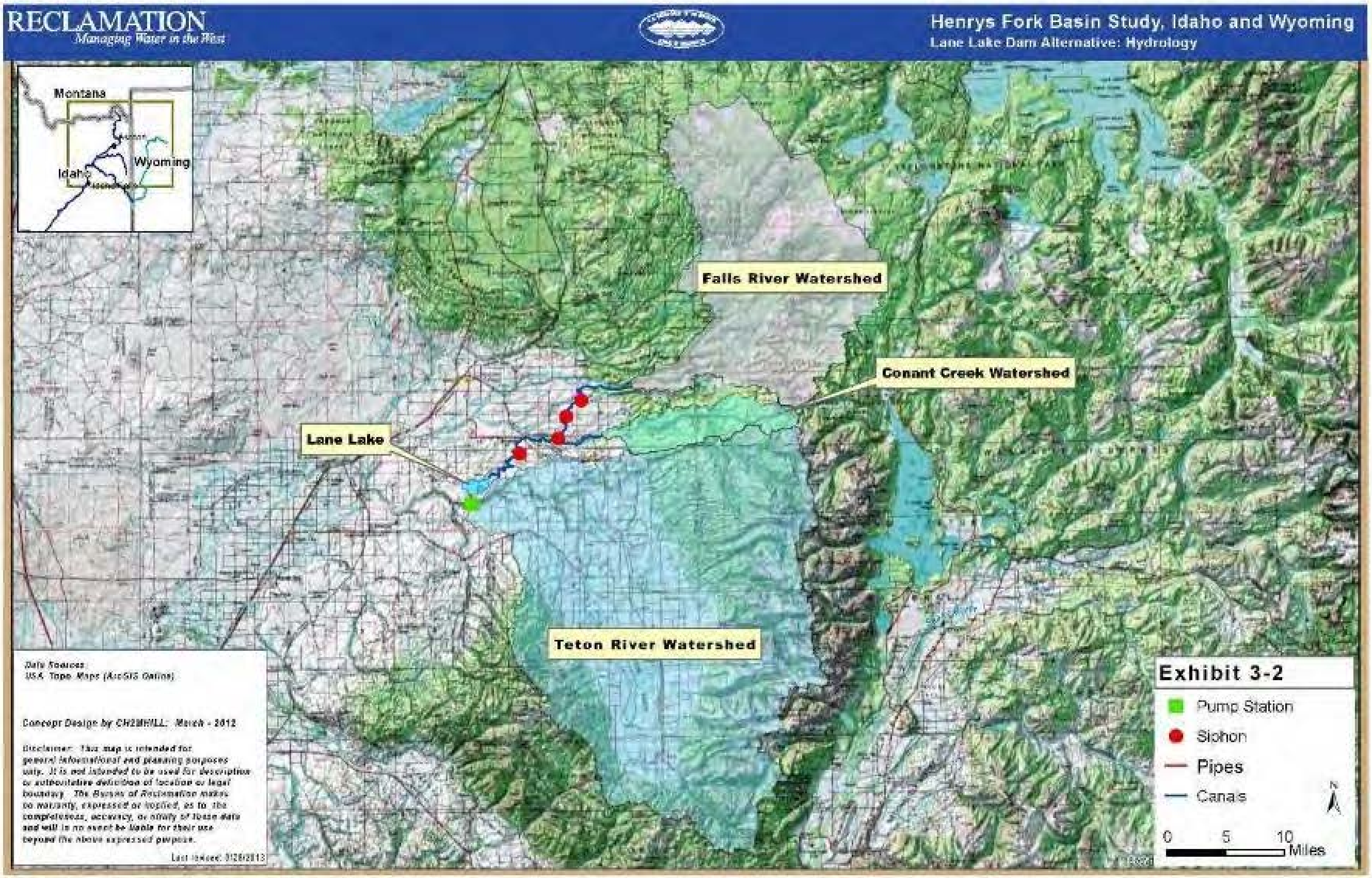

EXHIBIT 3-2

Lane Lake Dam Alternative: Hydrology

EXHIBIT 3-3
Water Potentially Available for Storage at Lane Lake

Source	Watershed Area (sq. mi)	Quantity (af/year)
Hog Hollow (impounded drainage)	Negligible	0
Teton River	720	328,840
Conant Creek	43.9	19,210
Falls River	323	146,920

3.3.2 Conveyance

Water supply routes were established from each source, using a combination of pressurized pipelines, canals, and siphons, as depicted in Exhibit 3-4. Conveyance routes are conceptual, and are intended only to provide a basis for relative cost comparison, rather than reflect actual alignments and features for design. Exhibit 3-5 summarizes the key physical characteristics of each sub-alternative.

EXHIBIT 3-5
Lane Lake Sub-Alternative Characteristics

Sub-Alternative	Source	Volume Diverted (af/year)	Maximum Diversion Flow Rate (cfs)	Conveyance Length (mi)	
				Canal	Pipe[1]
LL-T-2	Teton River	101,000	1,018	0.0	0.8
LL-CoF-2	Conant Creek	19,210	194	4.5	0.0
	Falls River	81,790	825	11.6	0.4
	Combined	0[2]	1,018	12.4	0.1
LL-F-2	Falls River	101,000	1,018	24.0	0.5

[1] – Pipe length includes siphons and pressurized pipe from pump stations, if applicable.
[2] – No additional diversion at the confluence of canals from Conant Creek and Falls River. Total conveyed quantity of canal segment is 101,000 af/yr.

Other conveyance features were also assessed during the evaluation including stream diversions, intake and fish screen structures, pump stations, and siphons. Those features are accounted for in the cost estimate, and the procedures used to identify and size those features are documented in Section 2.3.4 – *Cost Basis* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012.

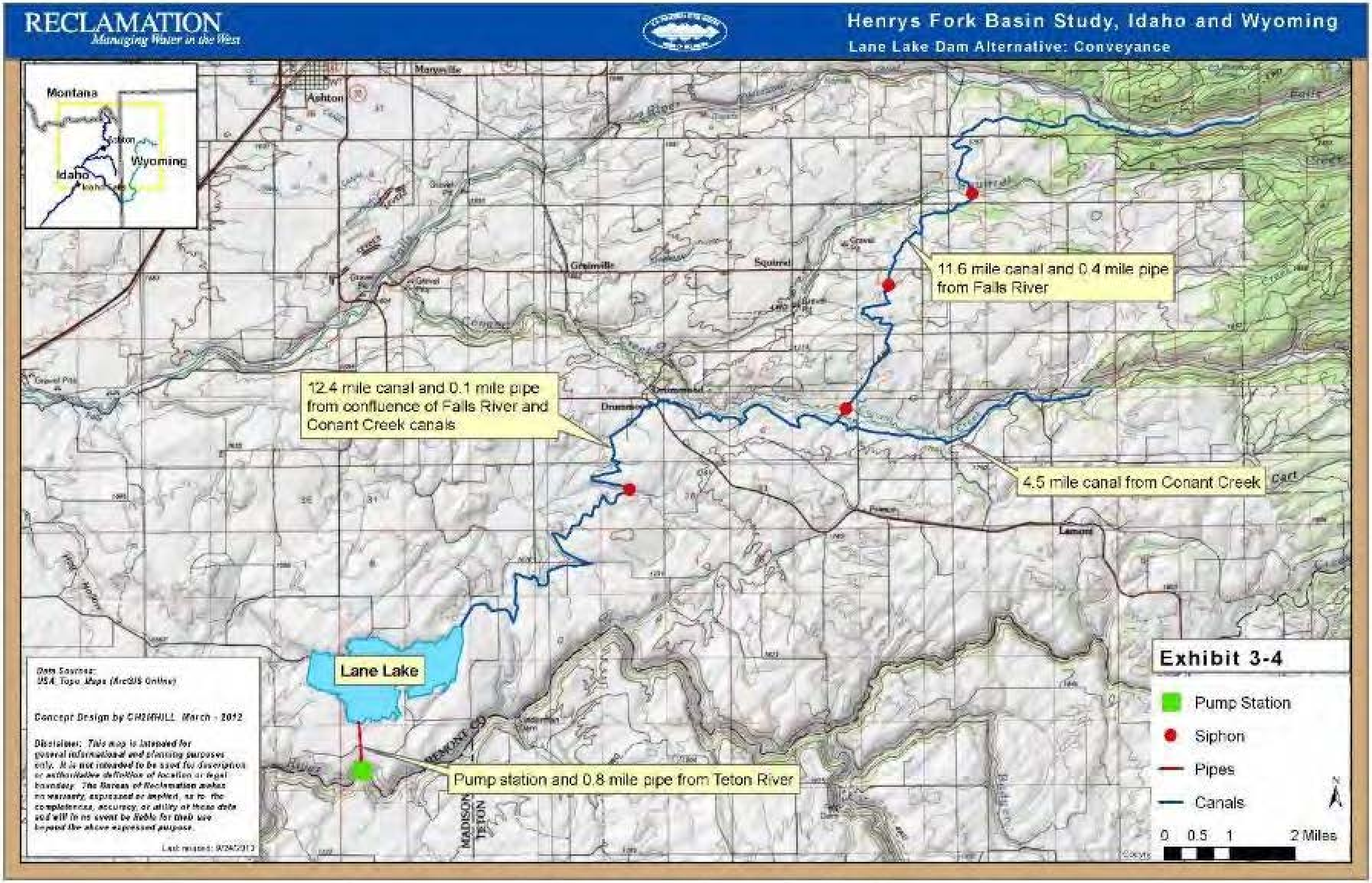

EXHIBIT 3-4
Lane Lake Dam Alternative: Conveyance

3.3.3 Dam Site Geology

3.3.3.1 Area Geology

The proposed Lane Lake reservoir site is on the Rexburg bench area north of the Teton River Canyon. The Teton River flows through a low basin between the Yellowstone Plateau volcanic field and the Big Hole Mountains. The Rexburg Bench was formed by the Huckleberry Ridge Tuff, which erupted from the Henrys Fork caldera and swept over previously-deposited Tertiary-age sediments, basalts, and rhyolitic rocks. Immediately following emplacement, a minimum of 0.6 mile of horizontal movement caused significant deformation in the partially-fluid tuff sheet. The tuff and underlying water-saturated deposits were deformed into large-scale antiform load structures, faults, and a tectonically-denuded valley known as Hog Hollow. Lateral faults produced by this deformation are interpreted to be relatively shallow structures confined to the tuff and upper portions of the sediments and are thus referred to as “rootless” faults because they only partially vertically extend into the underlying tertiary sediments. A thick mantle of loess (windblown silt) was deposited over the area after glaciation of the Yellowstone area, primarily derived from windblown sediments originating southwest of the area.

The proposed Lane Lake reservoir would be built within Hog Hollow. Exhibit 3-7 shows a geologic map of the reservoir area adapted from Embree and Phillips, 2011. The following is a description of the geologic units at the site based on published data (Embree and Hoggan, 1999), data from the nearby Teton Dam site, and site observations. The geologic unit abbreviations used below are consistent with those shown on Exhibit 3-7.

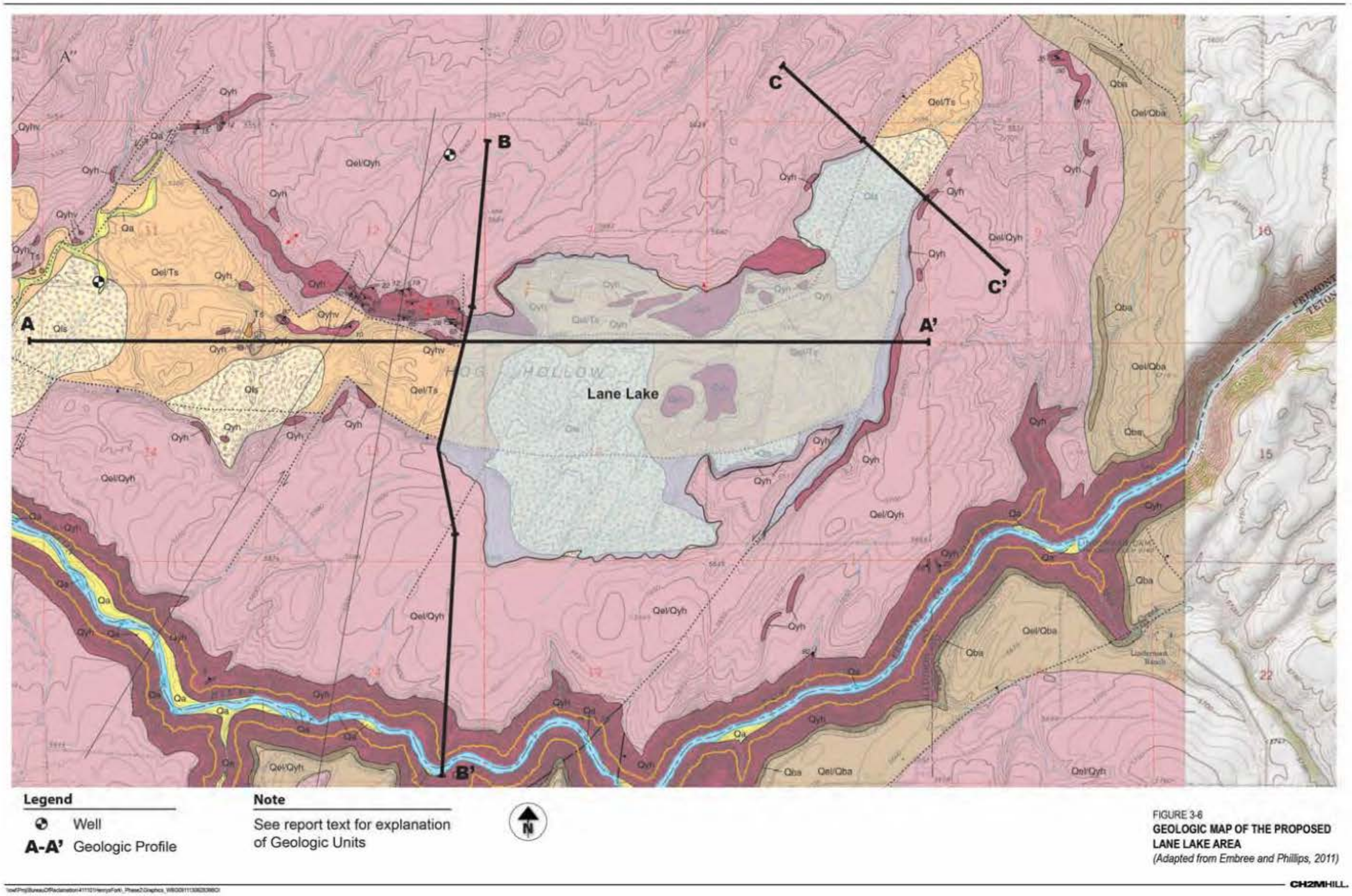

EXHIBIT 3-6
Geologic Map of the Lane Lake Area (adapted from Embree and Phillips, 2011)

3.3.3.2 Stratigraphy

Qyh –The Huckleberry RidgeTuff is the first rhyolitic welded ash-flow tuff of the Yellowstone volcanic group. This tuff unit was deposited over nearly 6,000 square miles and is approximately 1.9 to 2.0 million years old. This unit consists of crystal-rich, grayish-pink to light gray, rhyolitic welded ash-flow tuff and ash layers. The thickness of this unit ranges from 122 to 425 feet. This unit underlies the Rexburg Bench north and south of Hog Hollow and is exposed along the steep walls on the north and south sides of Hog Hollow. The proposed Lane Lake dam would be founded on rhyolite at both proposed abutments.

Qba – Basalt flows, described as dark gray, hard, fine-grained vesicular that include clay layers and contact breccias. This unit overlies the Huckleberry Ridge tuff east and south of the proposed reservoir site.

Ts – This unit consists of alluvial and lacustrine sediments that underlie the Huckleberry Ridge Tuff and are exposed in limited areas of the valley bottom of Hog Hollow but are generally covered by a thin mantle of loess at the present day ground surface. These consist of a thick sequence of light gray and yellow, weakly-cemented, strongly deformed tuffaceous and arkosic sandstone, siltstone, and conglomerate that is locally interbedded with tuff, diatomite, basalt, and rhyolite. Metamorphic and granitic clasts, arkosic sandstones, and diatomite beds suggest deposition in fluvial and lacustrine environments. According to drill holes conducted at the Teton Dam site that penetrated these sediments, the lithology of the sediments is very diverse and includes soft and friable tuff, hard and dense tuff, soft to hard siltstone, sand and gravel, boulders and cobbles, dense silt, tuffaceous sandstone and conglomerate, sandy clay, hard and brittle claystone, crumbly volcanic ash, and well-consolidated volcanic ash. This unit underlies the floor of Hog Hollow and would underlie the dam foundation and most of the reservoir.

Qel – This unit consists of thick loess on the upland areas that overlies the Huckleberry Ridge Tuff, and in Hog Hollow overlying the older sediments. Loess includes light gray to light brown to tan, wind-blown silt, clay, and very fine sand. The thickness of this material ranges from less than 5 to 44 feet thick. Where this unit overlies other geologic units, their unit names are preceded by “Qel/---“.

Talus/colluvium – This unit consists of locally-derived, unconsolidated angular gravel and soil deposits that mantle steep canyon walls along Hog Hollow and at the proposed dam site abutments (not shown on the geologic map in Exhibit 3-6).

Qls: Landslide deposits: Landslides are mapped within and around Hog Hollow. These consist of hummocky masses of disrupted blocks of Huckleberry Ridge Tuff and tuffaceous sediments that have mostly moved northward from head scarps on the south flank of the Hog Hollow Valley. These are inferred to have formed during or soon after emplacement of the Huckleberry Ridge Tuff and the formation of Hog Hollow. These are poorly exposed due to a thick loess cover. In addition, remnant blocks of tuffaceous rocks appear to have broken away and slid out into the valley, likely during formation of Hog Hollow.

Exhibits 3-7, 3-8, and 3-9 show geologic profiles, or cross-sections, of the interpreted subsurface conditions beneath the proposed dam, reservoir area, and saddle dam. The locations of the geologic profiles are shown on Exhibit 3-6. The geologic profiles were developed based on available geologic mapping (Embree and Phillips, 2011), geologic data from the nearby Teton Dam site, available water well logs in the area, and geologic site observations.

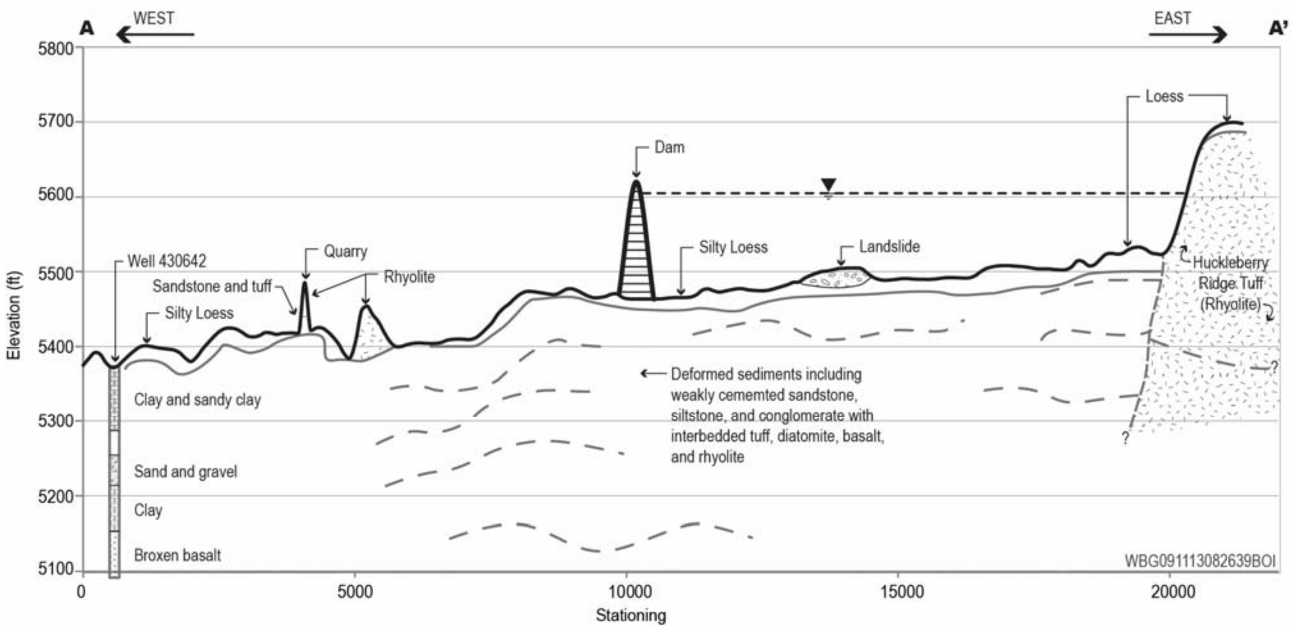

EXHIBIT 3-7
Geologic Profile A-A' (Longitudinal) from West to East

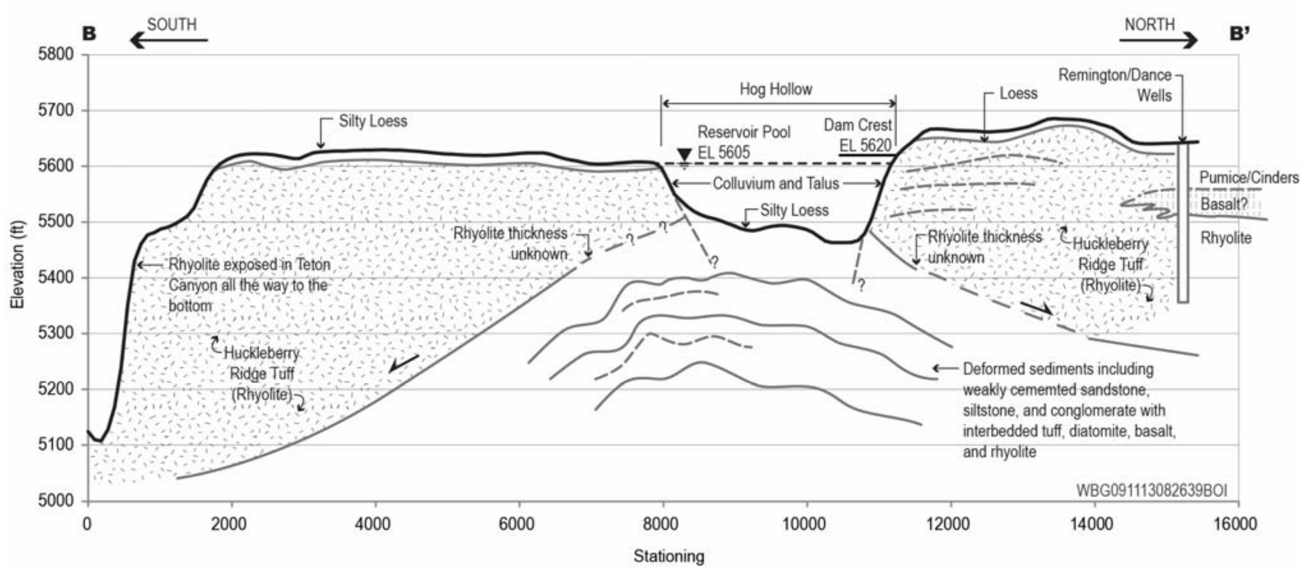

EXHIBIT 3-8
Geologic Profile B-B' (Main Dam) from South to North

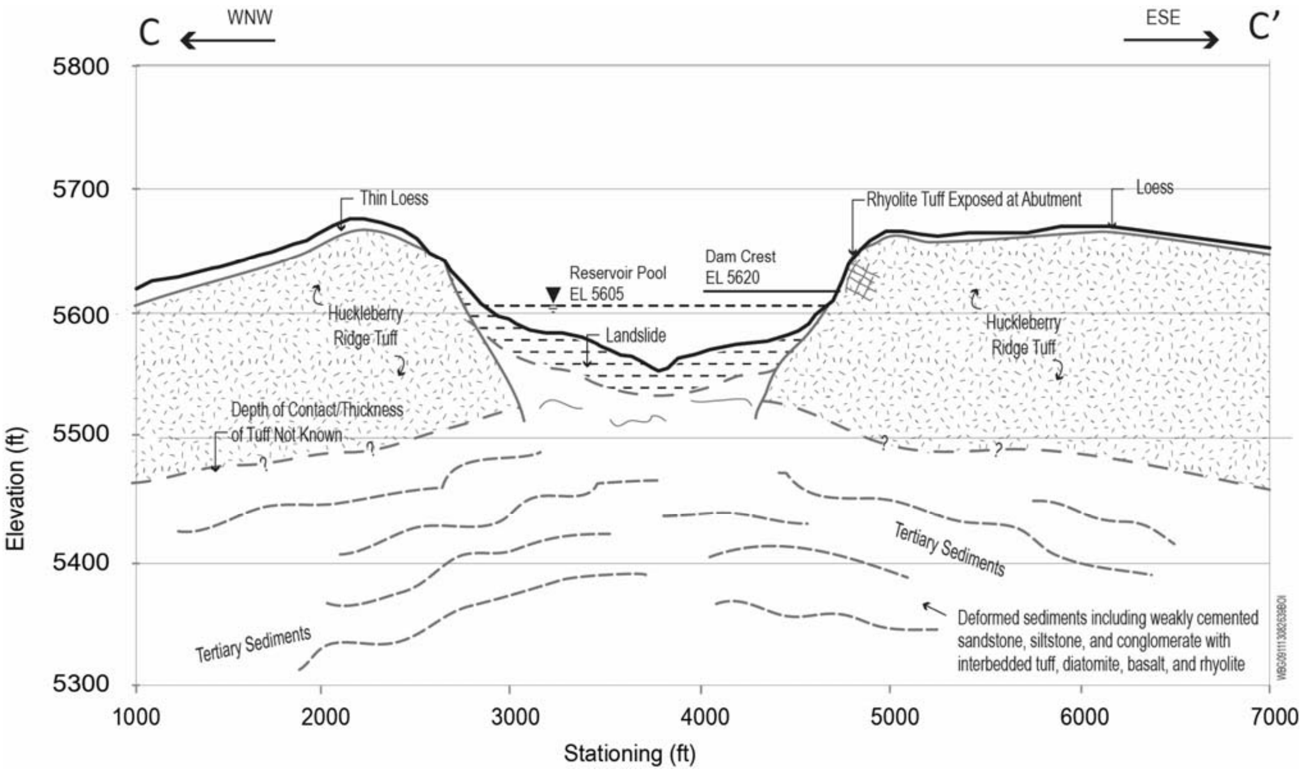

EXHIBIT 3-9
Geologic Profile C-C' (Saddle Dam) from Northwest to Southeast

3.3.3.3 Area Structural Geology

An extensive network of joints has rendered the volcanic rock of the Rexburg Bench into a highly permeable aquifer. Very long, through-going extensional fractures and strike-slip faults have been mapped in the area (Embree and Phillips, 2011; Prostka, 1977). The Snake River Plain has been undergoing regional tectonic stress from late Miocene time (approximately 5 million years ago) to present. However, tectonic extension in the Rexburg-Teton bench has been most active since the deposition of the Huckleberry Ridge Tuff. The northwest trend of extensional fissures at the Teton Dam site is consistent with the predominant northwest trend of Quaternary fissure zones in the Snake River Plain, such as the Great Rift, and active normal faults in the area.

3.3.4 Dam Configuration and Design Considerations

An earth core rock fill dam would be constructed to impound Lane Lake. The bottom of the valley at the proposed dam location is at an approximate elevation of 5,460 feet and the top of the dam would be at an approximate elevation of 5,620 feet for a maximum height of about 160 feet. The length of the dam at this elevation would be about 6,040 feet, which includes a low dike extending for 1,500 feet at the left abutment. A saddle dam would also be constructed at the east end of the valley to maximize reservoir capacity. The resulting reservoir would have about 101,000 acre-feet of storage with a maximum surface area of 1,380 acres. Exhibit 3-10 shows the general locations for the dam, appurtenant structures, and emergency spillway. The dam features a wide central core with filter blanket drains and rock fill shells, and a continuous concrete cutoff wall in the foundation would also be incorporated to limit seepage through the dam foundation.

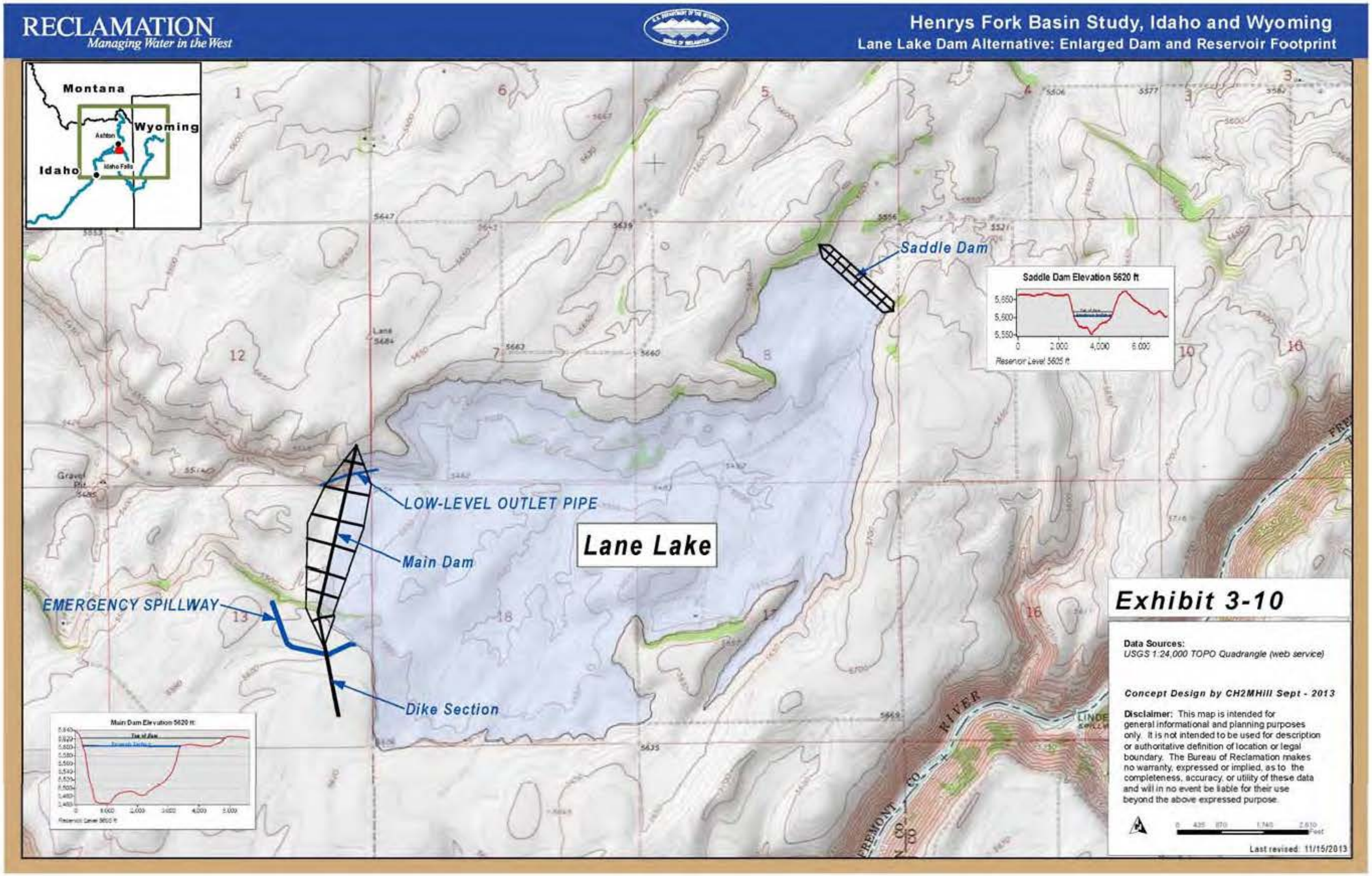

EXHIBIT 3-10
Lane Lake Dam and Reservoir Layout

At this preliminary stage of evaluation, dams with earth fill and dams with zoned rock fill with a low permeability core (i.e., earth core rock fill dam [ECRD]) were considered. An ECRD was selected for advancement because of the geologic and geotechnical challenges at the site. There appears to be adequate quantity of available materials to construct this type of dam. However, foundation conditions at the Lane Reservoir site can be expected to vary greatly between the deeper valley segment and the abutment areas and careful evaluation is necessary to assure that proper zoning, filters, cutoffs, and drainage relief can be achieved. Additionally, particular attention needs to be paid to controlling settlement and stress within the foundation and embankment to prevent transverse cracking in the embankments because of differential movement. At this stage of the evaluation process it is our judgment that an ECRD can be safely constructed at this site; however, further geotechnical evaluations are needed for confirmation.

Exhibit 3-11 shows a longitudinal section along the main dam axis and illustrates the changes in geologic conditions. Due to the variability in foundation conditions, the geometry and cross-section of the proposed dam is expected to vary. Exhibits 3-12 through 3-14 illustrate potential dam configurations at several locations along its axis and correspond with dam sections A through C called out in Exhibit 3-11. In the deeper valley segment, the dam is expected to be underlain by very thick deposits of Tertiary-age sediments consisting of unconsolidated tuffaceous gravel, sand, silt, and lacustrine clay, with possible local interbedded basalt flows. Based on a preliminary understanding of the regional geology of the site, it is postulated that these underlying sediments historically experienced widespread movement, detachment, and uplift as a result of overloading by rapid deposition of the Huckleberry Ridge Tuff. This movement may have resulted in cracking, faulting, folding, and other disturbances to these sediments. As observed in exposures near the proposed dam site, it is likely that sediment cracks that may have existed have since filled in or partially filled in from subsequent (secondary) erosion and effects of gravitational forces. Field observations indicate that several similar near-surface cracks have subsequently filled in with finer-grained sediments. It has been estimated that disturbance to these sediments may have typically extended to a depth of 100 feet or more below the base of the rhyolite tuff (Embree and Hoggan, 1999).

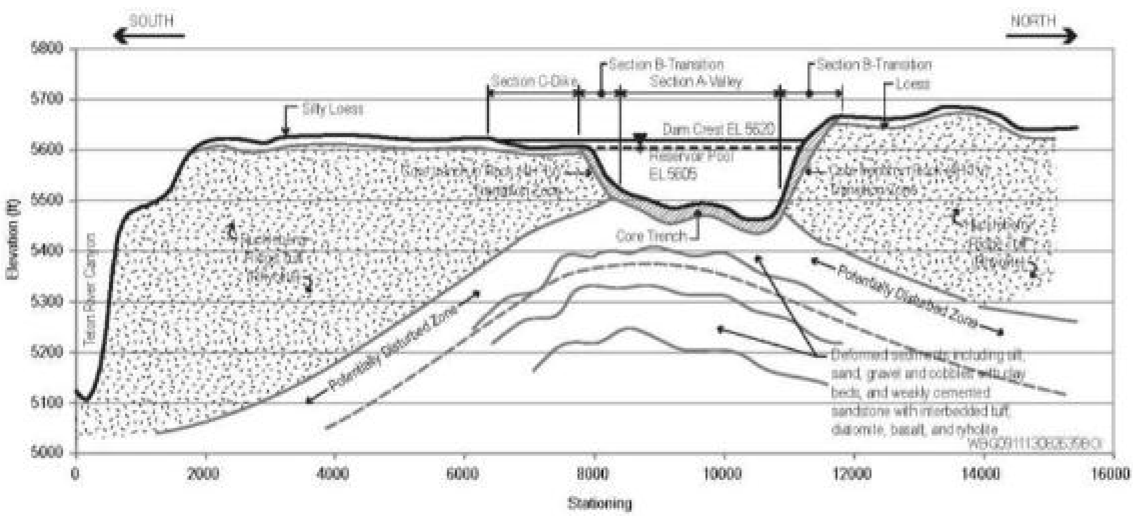

EXHIBIT 3-11
Longitudinal Section along Main Dam Axis

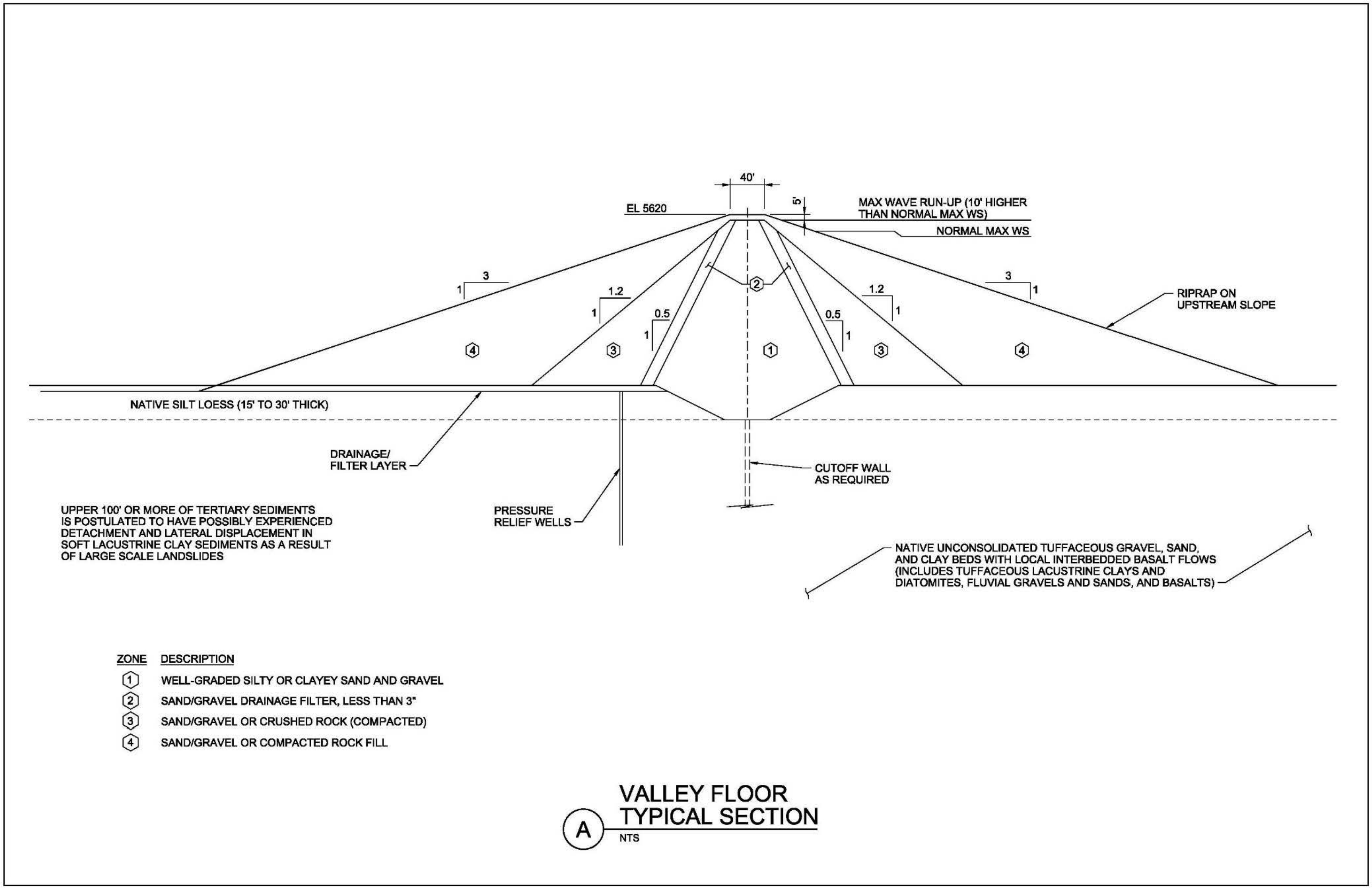

EXHIBIT 3-12

Typical Dam Configuration in the Valley Floor (Section A)

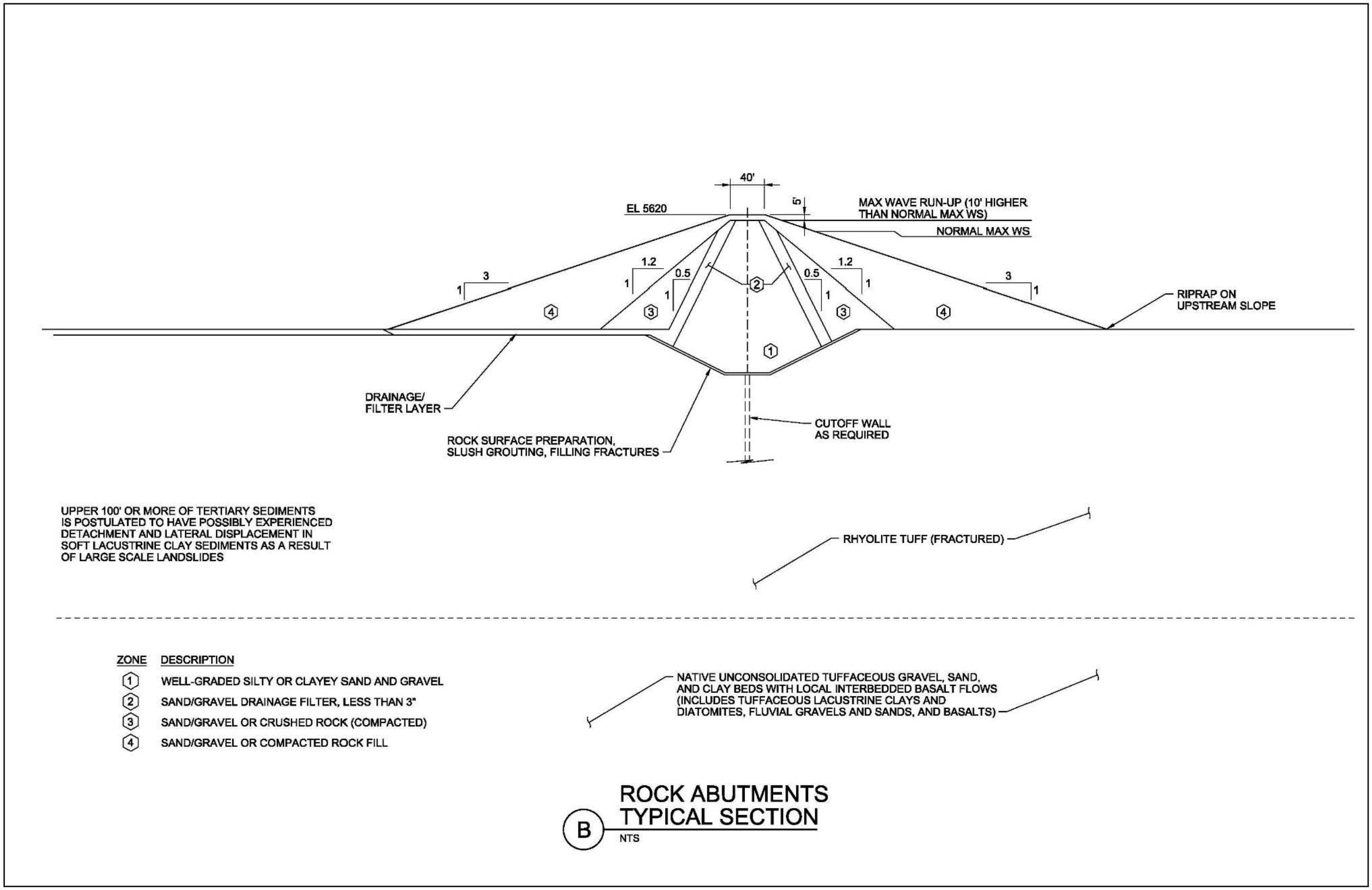

EXHIBIT 3-13

Typical Dam Configuration in the Rock Abutments/Transition (Section B)

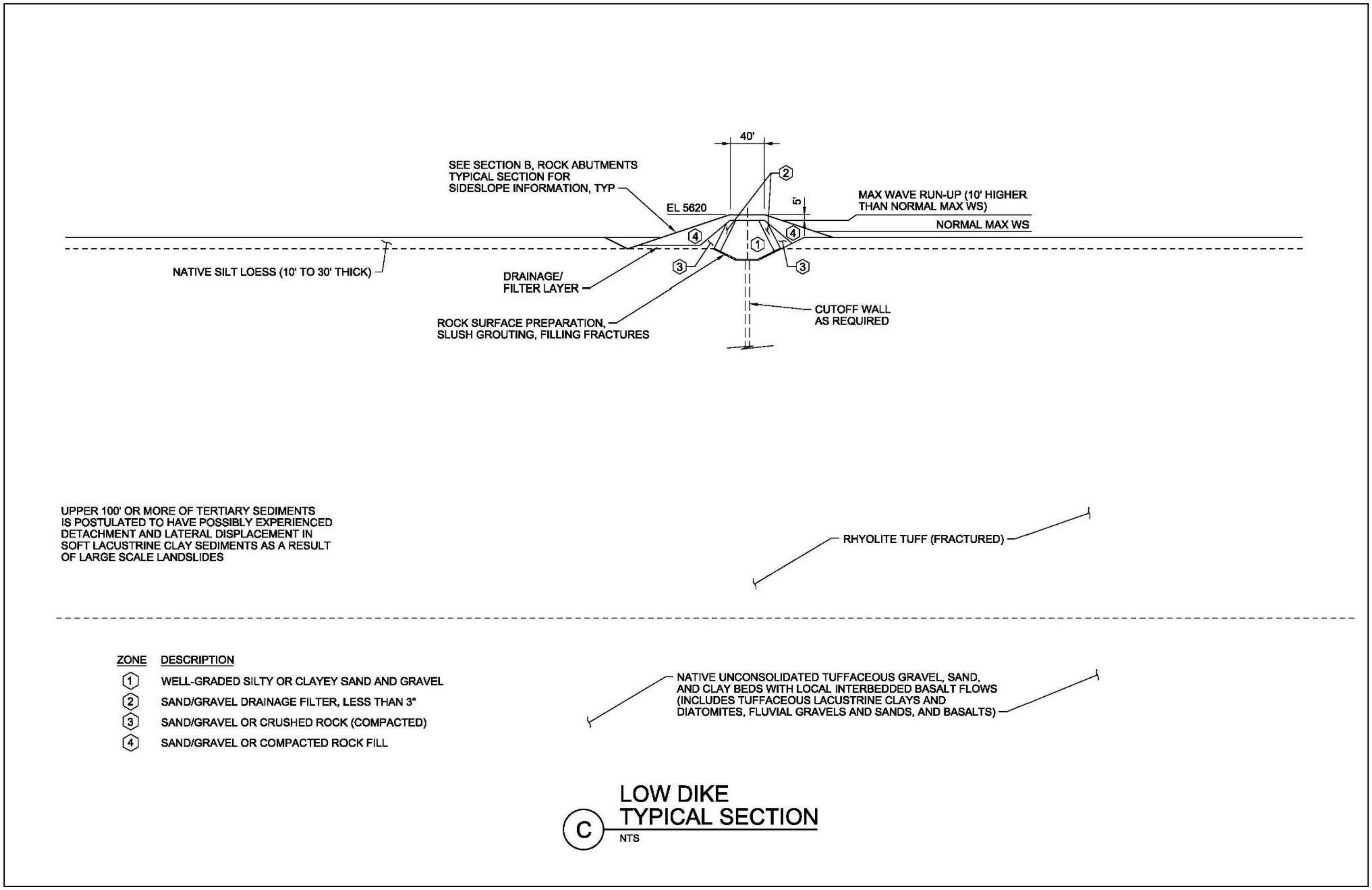

EXHIBIT 3-14

Typical Dam Configuration in the Low Dike (Section C)

Landsliding is also noted to have occurred along both sides of the Hog Hollow depression. Evaluation of the Hog Hollow depression by others has suggested that this landsliding has been due to the incompetence of underlying soft sediments and could be evidence of underlying clay seams that possess low strength. These conditions will require further investigation in the field to address these questions and to better define the characteristics of the underlying sediments and the possible risks associated with global instability of the dam or reservoir sideslopes. Field investigations in the area have identified slikensides in the ryholite tuff. Similar slikensides likely exist in the underlying clay deposits that form the base of the "rootless" faults in the rhyolite tuff, caused by historic landslides and tectonic extension. Movement along some of these faults has resulted in landslide blocks that are known to have moved a 0.6 mile or more in total distance.

Pervious zones may also exist within the sediments in the broad valley bottom that would form the foundation of the dam. These zones may consist of layers of sand and gravel deposited by ancient streams. Foundation conditions that include deep sediments and pervious zones can sometimes be suitable for an ECRD, but construction of a deep cutoff wall may be necessary to control seepage.

At the dam abutments a transition zone is required to help control stress within the foundation and embankments. The existing topography along the proposed dam axis changes abruptly as the foundation transitions from the deep valley sediments to hard, devitrified (non-glassy) and vitrophyric (glassy) rhyolite tuff bedrock. The rock abutments are close to vertical in some areas and exhibit near-vertical columnar jointing. Other areas are steep and are highly folded and cracked as a result of viscous to brittle secondary movement that occurred within the bedrock shortly after its deposition over the underlying Tertiary-age sediments. These bedrock characteristics present several difficult issues for the construction of a dam:

- Joints and open vertical, horizontal, and en-echelon cracks may be prevalent in the rock formation (Huckleberry Ridge Tuff) at the abutments based on published literature, field observations, and similar characteristics that were encountered with the same rock type in the foundation of Teton Dam. These facture systems may require a foundation cutoff wall, extensive pressure grouting, cleaning and filling, placement of slurry grout and concrete, placement of filters and other means to control seepage and piping.
- The steep abutments that transition from potentially compressive foundation conditions in the valley to hard non-compressible conditions in the abutments are likely to result in transverse cracking in the embankments due to differential settlement. To control these conditions, staged construction may be required to allow most of the settlement of valley sediments to occur prior to construction of embankments in the abutment transition areas. It may also be necessary to cut deep, wide core trenches sloped at 4H:1V or flatter to create a gradual transition into the areas underlain by bedrock. The core trench should be sufficiently wide and sloped at sufficiently flat slopes to prevent arching of the core embankment soils into the rock sides which could result in loss of confinement and reduction in overburden pressure on the deepest zones of the low permeability core. Because of these issues, the dam may need to be built in two phases to allow settlement in the valley sediments prior to building on the rock abutments to reduce potential for differential settlement and transverse cracking. A transition zone consisting of a wide core, wide filters and drains, and a wide upstream filter of cohesionless material to form a crack stopper may also be required in addition to these measures.

A long, low, embankment or dike is needed to achieve the full dam height (elevation 5,620) at the south (left) abutment. Verification of actual contour elevations is necessary before finalizing the dam height. The area where the dike would be located likely consists of rhyolite tuff bedrock overlain by silty loess. Although the head would be low, the silty soils overlying the fractured bedrock would be unlikely to meet filtering criteria with the cracks the may exist in the underlying bedrock. This may necessitate the removal of all overlying silt to expose the bedrock foundation, and then require the use of filters to provide stable conditions that would avoid piping of the silt loess soil into underlying bedrock cracks. If the proposed top of dam elevation results in a very long dike or an inordinate expense for foundation preparation in this segment, consideration should be given to reducing the top elevation of the dam as necessary, which would slightly reduce the available reservoir storage volume but could substantially reduce the construction cost.

Section C, as shown in Exhibit 3-14, represents the anticipated foundation conditions in the vicinity of dike extending from the south abutment. In these areas, the bedrock is overlain by mantling of loess of unknown and likely variable thickness. The loess consists primarily of non-plastic silt or low plasticity silt and silt-sand mixtures. The underlying bedrock is believed to be fractured and is likely not compatible with the overlying loess from a filtering standpoint. Seepage from the reservoir could result in sinkholes, seepage, and piping into cracks in the underlying bedrock unless the rock is exposed, grouted as required, and foundation and embankment filters are constructed to control piping and enhance drainage that may occur within the dam and its foundation.

A potential spillway alignment has been identified on the left abutment (refer to Exhibit 3-10), and the dam would require a low-level outlet that provides a safe way to drain the reservoir and integrate with ultimate water distribution and hydropower schemes. The lowest part of the existing valley is located near the right abutment. Since the entire valley appears to be underlain by deep sediments, an outlet alignment that places the outlet within the rock abutment at the right side of the valley would serve as a likely location for the outlet. The outlet may be excavated into bedrock or could be developed as a tunnel that is bored within the right abutment depending upon the nature and configuration of the bedrock foundation.

3.3.5 Seepage Potential

Since seepage of water through, under, or around the dam has been identified as a key issue at this site (both from a water supply and dam risk standpoint), seepage received substantial additional consideration and discussion, as presented below.

3.3.5.1 Seepage Considerations for Main Dam Abutments in Huckleberry Ridge Tuff

Lane Lake would be built in Hog Hollow, which is described as a “large, arcuate depression with vitrophyric walls, monoclinal flexure, and gravel floor” with an absence of natural inlet or outlet (Embree and Hoggan, 1999). Hog Hollow is interpreted to have been formed by a load structure, secondary flow, and extension in the area accompanied by upwelling diapirism of the underlying water-saturated sediments. The tuff and rhyolite exposed in the walls of Hog Hollow lost heat more quickly than the tuff away from the edges and would not have been devitrified. In addition, as extension occurred, the tuff was pinched off which resulted in thinning the unit and producing dips toward the center of the basin. This is apparent on the northern rim in particular, where the tuff forms a monoclinal fold with dips that range from 20 to 80 degrees from horizontal (Exhibit 3-15). In addition, due to the extension and gravity sliding, large semi-intact blocks of tuff and rhyolite form irregular topography across the valley floor.

EXHIBIT 3-15
Photo of Fold and Dipping Bedding in Rhyolite Tuff

The Huckleberry Ridge Tuff has been deformed for a variety of reasons. These include: 1) fissures and voids formed in the ash-flow sheet during secondary flowage likely caused by differential compaction or settling over irregular topography, 2) steep cooling joints possibly subject to enlargement and widening farther by horizontal tectonic extension and gravitational creep. Platy joints appear to have resulted from depositional layering and flattening and collapse of the ash-flow sheet. During secondary flowage, they formed horizontal zones a few inches to about 1 foot thick of closely-spaced imbricate joints.

Long, northeast-trending strike-slip faults accommodate regional stress and the lateral extension and opening of the Hog Hollow structure (see Exhibit 3-6). Of important note is that these faults extend from the Teton River Canyon all the way to Hog Hollow, which indicates the potential for several-mile long, through-going geologic structures that could result in seepage paths. These joints provide multiple and multi-directional groundwater flow paths. The faults are strike-slip offset and are not active but could have contributed to shearing and fracturing of bedrock.

During the geologic exploration of the Teton Dam site, water pressure testing was conducted in diamond drill holes in and near the dam abutments; in particular the right (northern) abutment. Some of these tests indicated very high water losses and very high fracture permeability in the rhyolite. Also, in some tests the water was pumped into drill holes in the right abutment. The injections were metered and the effects of groundwater levels in nearby wells were monitored. In one test, after a 15-day period of injecting 440 gpm (24 acre-feet total), the borehole did not fill with water. Neighboring drill holes showed water level increases of 6 to 10 feet, and water levels in these neighboring boreholes dropped immediately after termination of the pumping. These test results indicate very high permeability and a network of interconnected, transmissive fractures throughout the rhyolite.

Exhibit 3-16 provides a summary of the seepage estimates from the drill holes in the rhyolite tuff in the Teton Dam right abutment. The information presented in this table, plus regional geologic conditions and structure of the Huckleberry Ridge Tuff could potentially be used to estimate potential seepage issues in the proposed Lane Lake dam abutments, which would be constructed in rhyolitic bedrock with potentially similar fracturing.

EXHIBIT 3-16
Seepage Estimates from Teton Dam Drill Holes in Rhyolite

					Estimated K Range (ft/day)	
Teton Dam Drill Hole #	**Depth Interval**		**Water Pressure (psi)**	**Water Loss (gpm)**	**Low Value**	**High Value**
5	160.2	220.2	50	52	8.5	
	222.6	232.6	25	62.1		56.7
6	254.6	304.6	100	51.6	5.7	
	71.9	100.4	25	59.8		22.7
102	15.5	306.1	6	112	ND[1]	ND[1]
301	134.5	144.5	25	162	8.5	
	235.5	255.5	100	32		141.7
302	49.4	59.4	90	62.1	255.1	
	211.1	221.2	0	180		226.8
303	90	100	80	100	56.7	
	98.8	109.8	0	179		226.8
504	597		0	823	ND[2]	ND[2]
505	160	199.8	0	57.5	ND[3]	ND[3]

ND – Not determined
[1] – No specific depth intervals tested.
[2] – Pumped 6,589 gallons in 8 hours into open hole.
[3] – Pumped 2,300 gallons in 40 minutes with no water level rise.

Using the water pressure testing data and correlative hydraulic conductivities of the fractured rhyolite, potential leakage through the steep reservoir walls where rhyolite is exposed, primarily upstream from the abutments, was estimated. Exhibit 3-17 provides a summary of potential minimum and maximum leakage based on various hydraulic conductivity values, reservoir depths, and surface area of exposed rhyolite for a given depth. The potential losses were calculated as acre-feet per day, because the depth of the reservoir is likely to vary significantly and daily leakage can change as a result. However, the degree of fracturing in the rhyolite at the Hog Hollow area is not known, and may or may not be as severe as the fracturing at Teton Dam. Site-specific investigations must be conducted to confirm the rock properties.

EXHIBIT 3-17
Summary of Seepage Estimates through Fractured Rhyolite Upstream from Abutments of Proposed Lane Lake Dam

Location	Water Surface Elevation (ft)	Depth (ft)	Seepage Range, Q (cfs)		Seepage Range, Q (acre-ft/day)	
			High	Low	High	Low
Right Abutment	5605	105	26	10	52	21
L = 3,000 Bottom Elevation = 5500	5600	100	24	9	47	19
	5590	90	19	8	38	15
	5580	80	15	6	30	12
	5570	70	12	5	23	9
	5560	60	9	3	17	7
	5550	50	6	2	12	5
	5540	40	4	2	7	3
	5530	30	2	1	4	2
	5520	20	1	0	2	1
	5510	10	0	0	0	0
Left Abutment	5605	55	3	1	6	2
L = 1,300 Bottom Elevation = 5550	5600	50	3	1	5	2
	5590	40	2	1	3	1
	5580	30	1	0	2	1
	5570	20	0	0	1	0
	5560	10	0	0	0	0

Assumptions:
- Head is the depth of water in the reservoir, and in contact with exposed rhyolite.
- Length is the reservoir walls upstream from dam where rhyolite is exposed.
- Gradient (i) is the hydraulic gradient (head/length).
- Q is flow rate from the Darcy Equation where Q = k*i*A
- A = area (depth x length)
- k = horizontal hydraulic conductivity, range determined from Teton Dam pressure testing data in rhyolite.
- Worst case: rhyolite is exposed and not covered by low-permeability soil/colluvium/loess or piping develops by forming sinkholes exposing the water in the reservoir to cracks in the foundation.
- Once water surface is below a given elevation, not in contact with rhyolite exposures.
- High seepage rate is based on a hydraulic conductivity of 0.02 cm/sec; low seepage rate is based on a hydraulic conductivity of 0.008 cm/sec.

3.3.5.2 Seepage Considerations for the Reservoir Bottom in Tertiary Sediments

The Tertiary sediments are not well exposed in the vicinity because they are typically covered with loess. The best exposure is in a road cut/quarry in the far northeastern corner of Section 14 (Exhibit 3-18). At this location, which is approximately one mile west of the proposed dam alignment, the sediments consist of tuff, clays, gravel, weakly-cemented sandstone, gravel, silt, rhyolite glass shards, pumice, and scoria. In addition to being highly variable in lithology, the sediments are highly folded, fractured, and faulted, which likely occurred during extension and upwelling while Hog Hollow was being formed and while the sediments were water-saturated (Exhibit 3-19). Extensional tectonics are demonstrated by the presence of clastic dikes, where extensional cracks formed in the sediments and were infilled by material either flowing upwards from below or falling in from above. Randomly-oriented and vertical gravel clasts provide additional evidence for the motion of these clastic dikes (Exhibit 3-20).

EXHIBIT 3-18
Photo of Road Cut Showing Exposed Sediments

EXHIBIT 3-19
Photo of Folded, Fractured, and Faulted Sediments

EXHIBIT 3-20
Photo of Vertical Gravel Clast

Groundwater occurs in these sediments at depth; however, these sediments are considered poor aquifers in comparison to the densely jointed volcanic rocks. Well drillers are known to terminate drilling when these sediments are encountered because of the lower probability of developing a satisfactory well in them. Only one well log for a well completed in the sediments was located in the area. This well is located approximately 2 miles west of the proposed dam site and is located in the bottom of Hog Hollow. The lithology of the sediments in this well (according to the driller's interpretation) includes clay, sandy clay, sand and gravel, broken basalt with black sand, and black basalt. The well log notes water in the sandy clay and sand/gravel layer. However, the well was ultimately completed at depth in the black basalt and not the sediments.

Exhibit 3-21 provides a summary of water pressure testing conducted within the older sediments in drill holes at the Teton Dam site. The results of the water pressure testing indicate that some relatively permeable zones within these sediments. These sediments were originally horizontally bedded, but it has not been possible to correlate these permeable zones from one drill hole to another due to pinch-outs, possible faulting, and their lenticular structure.

EXHIBIT 3-21
Summary of Water Pressure Testing from Drill Holes at the Teton Dam Site

Drill Hole	Sediment Lithology	Test Zone Length (feet)	Elevation Interval (ft)		Water Loss (gpm)	Water Pressure (psi)	Hydraulic Conductivity (ft/day)
			Bottom	Top			
DH-1	Siltstone	9	4848	4839	1.6	25	1.5
		9	4848	4839	2	50	1.3
DH-5	Tuffaceous	44	4838	4882	31	25	8.0
	conglomerate	44	4838	4882	34.5	50	6.5
		44	4838	4882	37.4	100	4.6
		43	4772	4729	11.3	25	3.0
		43	4772	4729	13.7	100	1.7
DH-9	Interlayered silt	43	5074	5117	25	25	6.5
	and gravel	43	5074	5117	37	100	4.6
DH-102	Gravel	10	4884	4894	8	25	6.8
		10	4884	4894	13.6	50	8.4
		10	4884	4894	19	100	7.7
		14	4879	4893	9	25	5.9
		14	4879	4893	12	50	5.7
		14	4879	4893	20.6	100	6.4
		20	4725	4745	7	25	3.4
		20	4725	4745	10.6	50	3.8
		20	4725	4745	13.4	100	3.1
DH-651	Tuff, gravel, and clay	40	4732	4772	35	10	16.9

Using the water pressure testing data and correlative hydraulic conductivities, potential downward leakage through the floor of the Lane Lake reservoir into the sediments was estimated. Exhibit 3-22 provides a summary of potential minimum and maximum leakage based on various hydraulic conductivity values, reservoir depth, and surface area for a given depth. The potential losses were calculated as acre-feet per day, because the depth of the reservoir is likely to vary significantly as the pool elevation fluctuates. However, the lithology, layering, and fracturing in the sediments that underlie the proposed Lane Lake site are not known, and may or may not be consistent with the sediments tested beneath the Teton Dam. Site-specific investigations must be conducted to confirm the properties of the sediments.

Loess deposits that consist of silt, clay, and fine silty sand cover the floor of the proposed reservoir area. In contrast to most bedded sediments, loess can have higher vertical conductivity than horizontal conductivity due to vertical fracturing. However, loess can hydro-compact under water which could decrease the vertical conductivity. The permeability of loess is an elusive property because the structure changes when saturated. It breaks down, becomes denser, and its permeability is decreased. This would have a positive effect by limiting downward leakage of water through the reservoir floor.

EXHIBIT 3-22
Summary of Seepage Estimates Downward through Sediment Beneath Proposed Lane Lake

Water Surface Elevation (ft)	Head (ft)	Seepage Per Unit Area (cfs/acre)		Reservoir Area (acres)	Seepage Range, Q (cfs)		Seepage Range, Q (acre-ft/day)	
		High	Low	High	High	Low	High	Low
5605	151	0.22	0.02	1720	380	38	752	75
5600	146	0.22	0.02	1692	365	36	722	72
5590	136	0.20	0.02	1586	324	32	642	64
5580	126	0.19	0.02	1450	280	28	554	55
5570	116	0.18	0.02	1300	235	24	466	47
5560	106	0.17	0.02	1167	197	20	390	39
5550	96	0.16	0.02	1039	162	16	332	32
5540	86	0.14	0.01	910	130	13	257	26
5530	76	0.13	0.01	759	98	10	193	19
5520	66	0.11	0.01	581	66	7	131	13
5510	56	0.10	0.01	414	41	4	81	8
5500	46	0.08	0.01	257	21	2	42	4
5490	36	0.07	0.01	118	8	1	16	2
5480	26	0.05	0.00	55	3	0	5	1
5470	16	0.03	0.00	13	0	0	1	0

Assumptions:
- Ignore loess covering bottom of reservoir.
- Head is the depth of water in the reservoir.
- Length is the depth of water plus the thickness of permeable material.
- Gradient (i) is the hydraulic gradient (head/length).
- Q is flow rate from the Darcy Equation where Q = k*i*A
- A = unit area of one acre
- k = horizontal hydraulic conductivity, range determined from Teton Dam pressure testing data in rhyolite; vertical conductivity in sediments is lower (possibly order of magnitude) than horizontal conductivity.
- Worst case: reservoir head is from water surface to *lowest point* in reservoir bottom.
- High seepage rate is based on a hydraulic conductivity of 4.70E-04 cm/sec; low seepage rate is based on a hydraulic conductivity of 4.70E-05 cm/sec.

3.3.5.3 Seepage Summary

In summary, the sediments that underlie the proposed Lane Lake Dam foundation could potentially provide a cutoff layer and limit downward vertical seepage through the floor of the reservoir. However, the following limitations must be taken into consideration:

- Highly fractured zones and lateral lithologic variation in the sediments will control horizontal and vertical permeability and seepage pathways, and these will be dependent on fracture density, steep faulting, and continuity of low-permeability layers.
- Weak zones could be subject to a high amount of deformation which could result in secondary permeability.

- Vertical clastic dikes could be subject to piping and vertical leakage if infilled with weak, porous material.

The relatively horizontal bedding and laterally extensive fine-grained confining beds could be advantageous for providing a lower-permeability vertical cutoff to limit vertical leakage. However, the deformation and fractures due to tectonic forces in the Hog Hollow area are concerns that must be investigated further.

Exhibit 3-23 provides a combined estimate of seepage potential through the abutments and sediments at Lane Lake.

EXHIBIT 3-23
Summary of Combined Seepage Potential through the Abutments and Bottom Sediments at Lane Lake

Water Surface Elevation (ft)	Seepage Range, Q (cfs)		Seepage Range, Q (acre-ft/day)	
	High	Low	High	Low
5605	409	49	810	98
5600	392	46	774	93
5590	345	41	683	80
5580	296	34	586	68
5570	247	29	490	56
5560	206	23	407	46
5550	168	18	344	37
5540	134	15	264	29
5530	100	11	197	21
5520	67	7.0	133	14
5510	41	4.0	81	8.0
5500	21	2.0	42	4.0
5490	8.0	1.0	16.0	2.0
5480	3.0	0.0	5.0	1.0
5470	0.0	0.0	1.0	0.0

See Exhibits 3-17 and 3-22 for assumptions.

As presented in Exhibit 3-23, expected seepage losses from the reservoir may range from 98 to 810 af per day at full pool. Although the reservoir is unlikely to be held at full pool for long durations, that rate of loss is likely unacceptable given the high demand for water in the region. As described previously, several mitigation measures could be utilized to limit seepage losses:

- Foundation cutoff wall
- Extensive pressure grouting
- Cleaning and filling of cracks
- Placement of slurry grout and concrete
- Placement of filters
- Placement of a low permeability blanket

A future in-depth geotechnical evaluation will be necessary to establish a detailed seepage mitigation strategy (refer to Section 3.3.6), but a cursory estimate of potential mitigation costs was incorporated into the overall construction cost estimate for the project. An escalated foundation cost factor was included to help account for potential seepage remedies. The escalated foundation factor may underestimate required mitigation costs, especially if seepage occurs through cracks and facture systems in the exposed bedrock of the rhyolite tuff in areas around the perimeter of the reservoir. An additional cost specifically for a continuous seepage cutoff wall was also incorporated, but further investigations to determine seepage cutoff requirements would be necessary during future phases of this study.

3.3.6 Future In-Depth Geotechnical Site Investigation and Evaluation

The proposed Lane Lake reservoir and dam is located in Hog Hollow, which is a fault-bounded valley formed by extension and faulting. The faults are termed "rootless" because the depth of the faulting extends only to a limited depth within the underlying sediments. Numerous northwest trending fault lines bisect the ridge separating the Lane lake reservoir in Hog Hollow from the Teton Canyon to the south. The unconsolidated near-surface sediments in the Hog Hollow valley are not anticipated to be saturated and some zones could potentially be highly permeable. However, the valley sediments appear to be mantled by the loess sediments which may tend to limit the amount of infiltration and water loss that occurs where the water within the reservoir is underlain by the tertiary age sediments.

Within the higher elevations of the proposed reservoir, the water is likely to be in contact with the fractured rhyolite tuff bedrock. In these areas, the seepage could be substantially higher than in the valley areas that are underlain by sediments. However, the duration of inundation at these higher elevations may be relatively short depending on reservoir operations. Additional considerations that must be investigated for the dam and reservoir include the possibility of excessive seepage, especially from the fractures in the exposed bedrock.

In many areas, the bedrock is overlain by silty loess soils. Although the silt can be expected to reduce the seepage, the silt, if in direct contact with the underlying bedrock, may not meet filter criteria with cracks in the bedrock. This could result in:

- Excessive seepage and loss of water from the reservoir
- Unstable conditions and headward erosion (piping) at discharge points
- Potential for developing sinkholes in the reservoir foundation that may need attentive maintenance
- Development of unstable conditions at the seepage exit points
- Global instability of the dam or areas of the reservoir

Seepage and wetting of the underlying sediments could also result in global instability. Slickensides in the rock and in the underlying sediments may be an indication that the design may need to consider residual strength within the underlying clay soils.

A detailed geotechnical evaluation would be required to confirm suspected conditions at the proposed Lane Lake reservoir site. The two primary areas of focus for the evaluation would include:

- Foundation: Evaluate potential seepage paths through embankment; under embankment through sediments, including permeable materials such as gravel, ash, and cinders; and through tectonically fractured zones in the sandstone and basalt within the sediments.
- Abutments: Evaluate potential seepage paths through rock fractures at the abutment/dam contact.

In the foundation, a series of boreholes would be established in the sediments to evaluate the lithology and engineering characteristics in detail, and permeability tests including infiltration/packer tests beneath the proposed dam foundation would be conducted. At the dam abutments, field mapping to determine fracture characteristics such as density, aperture (opening width), and persistence (length), would facilitate more refined evaluation of seepage potential and requirements for reducing seepage. A series of boreholes to evaluate the rock mass properties at depth, the permeability of the rock mass using hydraulic pressure testing, and deeper boreholes to evaluate the thickness of the tuff at the dam abutments where it overlies the sediments would also be critical.

Specific elements of the site investigation and evaluation would include:

- Instrumentation such as piezometers, downhole flow meters, and downhole cameras.
- Field mapping to characterize abutment conditions and rock mass parameters.
- Subsurface exploration to evaluate foundation conditions such as layering in sediments, impermeable and or permeable layers, rock layers, and perched water. Focus at abutments would be to evaluate rock strength, rock mass quality, and fracture characteristics like density and apertures.
- Field testing would include downhole-borehole imaging, well geophysical logging, dye and tracer studies, test grouting program, packer testing in fractured rock, and borehole infiltration testing.
- Seismic refraction to evaluate rock characteristics at abutments such as seismic velocity, fracture density, and layers in the foundation area.
- A laboratory testing program to evaluate soil and rock engineering behavior properties. This program would include strength testing of soil like materials, intact rock, and along rock discontinuities and testing for deformation and settlement properties,
- Because of high ash content, conduct tests for dispersive soils, clay content, and ashy erosive layers.
- A borrow source investigation including durability testing of the proposed source materials including the Huckleberry Ridge Tuff and the nearby basalt flows for suitability as rock fill.

Additional objectives of the site investigation and evaluation would include:

- Assess potential settlement that could occur during and following construction of embankments.
- Assess global stability of the embankment during all loading conditions, particularly if the site is underlain by soft, low strength sediments.
- Determine the thickness and variation of the loess deposits that would underlie the dike on the bench on the south side of the main dam.
- Determine seepage cutoff wall requirements.
- Examine characteristics and variability of the bedrock and characteristics of exposed fractures by digging a test trench into the exposed abutment areas.

3.3.7 Hydropower Potential

As presented in Exhibit 3-24, hydropower potential associated with Lane Lake would be approximately 1,500 kW.

EXHIBIT 3-24
Enlarged Lane Lake Hydropower Potential

Sub-Alternative	Design Flow (cfs)	Penstock Length (mi)	Head (ft)	Power Potential (kW)
All	151	0[1]	145	1,500

[1] – It is assumed that turbines are located at the bottom of the outlet works. Therefore, no penstocks are needed.

3.4 Cost Estimate

A summary of the cost per acre-foot of water stored for each sub-alternative is presented in Exhibit 3-25. The exhibit presents costs with and without hydropower facilities. The site may also be prone to high seepage rates, so an escalated foundation factor was included in the cost estimate to help account for measures intended to limit seepage. An additional cost specifically for a continuous seepage cutoff wall was also incorporated.

EXHIBIT 3-25
Lane Lake Sub-Alternative Cost Estimates[1]

Hydropower	Sub-Alternative	Storage Volume (af)	Total Construction Cost	Cost Per Unit Yield ($/af)
No Hydropower	LL-T-2	101,000	$530,940,000	5,300
	LL-CoF-2	101,000	$466,230,000	4,600
	LL-F-2	101,000	$462,020,000	4,600
With Hydropower Facilities	LL-T-2	101,000	$538,160,000	5,300
	LL-CoF-2	101,000	$473,460,000	4,700
	LL-F-2	101,000	$469,250,000	4,600

[1] – Total estimated construction costs were rounded to the nearest $10,000 and unit costs were rounded to the nearest $100.

3.5 Basin Water Needs

The storage provided by Lane Lake would enhance the in-basin water budget by diverting 101,000 af during the annual high flow period and storing that water until more critical, higher demand periods during the summer and early fall. Water stored in the reservoir could help satisfy unmet irrigation demands in the Egin Bench (more water available in the Henrys Fork because of reduced need for diversions into the Crosscut Canal) and Lower Watershed irrigated regions (Reclamation, 2012). Reservoir releases would also be used to enhance ecological in-stream flows (see Section 3.7.2 – *Change in Connectivity*).

The out-of-basin water budget would be temporarily reduced by up to 101,000 af during the annual high flow period when water is diverted to the reservoir, but some or all of that quantity may be available at a later time for numerous out-of-basin uses, including needs resulting from climate change; agricultural needs; domestic, municipal, and industrial needs; ecological needs; and for recharge of the ESPA (Reclamation, 2012).

3.6 Legal, Institutional, or Policy Constraints

Legal, institutional, and policy constraints that may affect the implementation of this alternative are described in Section 2.5 – *Legal, Institutional, or Policy Constraints* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012.

3.7 Environmental Benefits and Impacts

3.7.1 Impacted River Segments

River segments potentially impacted by various sub-alternatives include the Teton River, Conant Creek, and Falls River, as identified in Exhibit 3-26.

			Connectivity		State Aquatic Species of Special Concern			Special Designation[a]				
Surface Storage Site	Sub-Alternative	Impacted River Segments	Flow Decrease (Supply Source)	Flow Increase (Receives Reservoir Releases)	Yellowstone Cutthroat Trout (YCT) Presence	Rainbow Trout (RBT) Priority Fishery[b]	YCT Conservation and Management Tier[c] and RBT Fishery Rating	BLM/USFS Eligible Stream	State Natural River	State Recreational River	Designated Wilderness[d]	Rating
Lane Lake	LL-T-2	Teton River	•	•	•		YCT Conservation	•				Eligible Federal
Lane Lake	LL-CoF-2	Conant Creek	•		•		YCT Conservation		•	•		State
		Falls River	•		•		YCT Conservation	•		•		State/ Eligible Federal
		Teton River		•	•		YCT Conservation	•				Eligible Federal
Lane Lake	LL-F-2	Falls River	•		•		YCT Conservation	•		•		State/ Eligible Federal
		Teton River		•	•		YCT Conservation	•				Eligible Federal

Notes:

[a]Special designations noted in this exhibit apply to the river reach impounded, diverted for water supply, or directly receiving return flows (if applicable).

[b]Based on personal communications with IDFG, rainbow trout are the primary focus in the Henrys Fork Watershed, whereas YCT are the primary focus in the Teton Watershed.

[c]Three tiers for prioritizing YCT conservation and management options per Montana Fish Wildlife & Parks database (2009) supplemented with anticipated data revisions per personal communications with IDFG.

1) **core conservation** populations composed of > 99 percent cutthroat trout genes;
2) **conservation** populations that generally "have less than 10 percent introgression, but in which introgression may extend to a greater amount depending upon circumstances and the values and attributes to be preserved"; and
3) **sport** populations of cutthroat trout that, "at a minimum, meet the species phenotypic expression defined by morphological and meristic characters of cutthroat trout."

[d]Per the 1997 Revised Forest Plan - Targhee National Forest.

Legend

State Aquatic Speices of Special Concern (YCT and RBT)

YCT Core / RBT Priority	Core Conservation Population of YCT or Priority RBT Fishery
YCT Conservation	Conservation Population of YCT
YCT Sport / None	None or Sport Population of YCT

Special Designation

Federal	Federal Wild and Scenic River (WSR) or Wilderness Area
State/ Eligible Federal	State Protected (Natural and Recreational) or eligible Federal WSR
None	None

EXHIBIT 3-26

Impacts to Connectivity, State Aquatic Species of Special Concern, and Special River Designations for Affected River Reaches

3.7.2 Change in Connectivity

Potential impacts to river connectivity consist of decreased flow (diversions to the reservoir) for river segments providing reservoir supply and increased flow for river segments receiving reservoir releases. As described in Section 2.2.1.3 – *Potentially Available Water* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012, diversions would likely occur during the excess spring runoff period and reservoir releases would likely occur during more critical low flow periods. Potential impacts to connectivity of each impacted river segment are identified in Exhibit 3-26. In addition to the segments listed in Exhibit 3-26, increased flow would be experienced in other downstream river segments, including the North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork, which have all been identified as having additional ecological streamflow needs (Van Kirk et al., 2011).

3.7.3 State Aquatic Species of Special Concern

The reservoir inundation area is not in Yellowstone cutthroat trout habitat. However, potential modifications to the hydrology of Conant Creek, Falls River, and the Teton River would impact conservation populations, which are defined as having less than 10 percent genetic introgression from other species. State Aquatic Species of Special Concern in potentially impacted river segments are indicated in Exhibit 3-26.

3.7.4 Other Environmental Factors

The proposed Lane Lake inundation area contains both winter range and migration corridors for big game, according to Trout Unlimited (TU), Friends of the Teton River (FTR), American Rivers (AR), and the Idaho Department of Fish and Game (IDFG). The United States Fish and Wildlife Service (USFWS) tracks one federally listed threatened species, the grizzly bear, and one candidate species, the wolverine, in the area. The bald eagle, sandhill crane, sharp-tailed grouse, and trumpeter swan, considered at-risk by the Bureau of Land Management (BLM) and the United States Forest Service (USFS), also make their homes here. Data from the National Wetlands Inventory (NWI) indicate construction at this site would have minimal impact on mapped wetlands, affecting an area less than one acre in size. Potential impacts along the canal and pipeline routes were not assessed during this evaluation and would require further investigation during future phases of the study. Hydrologic changes to the water source brought about by the proposed construction would also have indirect impacts on a stretch of Teton River that is eligible for Wild and Scenic River status designation and on Conant Creek that is designated as a State Natural and Recreational River.

Potential wildlife habitat impacts, federally listed species, and wetlands habitat impacts within the reservoir inundation area are summarized in Exhibit 3-27, while State of Idaho aquatic species of special concern (Yellowstone cutthroat trout and rainbow trout) and special river designations for all potentially impacted river segments are summarized in Exhibit 3-26.

3.8 Land Management, Recreation and Infrastructure impacts and benefits

Lane Lake is located on private land, has a low recreation and economic rating, and is rated as having few potential infrastructure impacts, as summarized in Exhibit 3-28.

Surface Storage Site	Wildlife Habitat[a]			Federally Listed Species			Wetland/Habitat Value	
	Big Game Winter Range	Big Game Migration Corridors	Rating	At-Risk (USFS & BLM sensitive species, and Idaho Species of Greatest Conservation Need)[b]	Threatened, Endangered, Candidate and Experimental Nonessential Species[c]	Rating	NWI Wetlands	Rating
Lane Lake	•[1]	•[2]	Winter Range	bald eagle, sandhill crane, sharp-tailed grouse, trumpeter swan	grizzly bear, wolverine[b]	Federal Terrestrial / Sensitive	•	Minimal

Notes:

[a]Sources of Wildlife Habitat data

[1]Per review comments from Trout Unlimited, Friends of the Teton River, and American Rivers.

[2]Per personal communications with IDFG on the Sand Creek and Teton Canyon winter ranges.

[3]Per the USFS 1997 Revised Forest Plan - Targhee National Forest.

[b]Per IDFG special species February 2011 GIS dataset (1-mile buffer area) and personal communications with the Henrys Fork Foundation.

[c]Threatened and Endangered and Candidate species list obtained from USFWS; however, location specific information based on data compiled by Trout Unlimited, Friends of the Teton River, and American Rivers (unless otherwise specified, some identified in the IDFG February 2011 dataset).

Legend

Wildlife Habitat

Winter Range	Winter Range Habitat
Migration	Migration Corridor
None	None

Federally Listed Species

Federal Aquatic/ Prime Conservation	Federally Listed Aquatic Species and Prime Conservation Area
Federal Terrestrial/ Sensitive	Federally Listed Terrestrial Species and State Species of Greatest Conservation Need
None	None

Wetland and Habitat Values

Extensive	Extensive wetland impacts (> 200 Acres)
Moderate	Moderate wetland impacts (>1 - 200 Acres)
None/Minimal	<1 Acre

EXHIBIT 3-27
Impacts to Wildlife Habitat, Federally Listed Species, and Wetland Habitat at the Reservoir Site

	Land Management Data[a]					Recreation/Economic Value								Infrastructure[d]				
Surface Storage Site	Private	Federal	State	Conservation Easements[b]	Rating	Boating	Fishing	Yellowstone National Park	Guiding/ Outfitting	Scenic/ Natural Features[c]	Cultural/ Historic Resources[c]	Land Recreation[c]	Rating	Roads	Structures	Habitation	Additional Infrastructure Notes	Rating
Lane Lake	•				Private								Low	•		•		Few

Notes:

[a]Land management data per the BLM Idaho Surface Management Agency (2010). For federal government lands, the data displays the managing agency which may or may not be the same as the agency that "owns" the land.

[b]Per feedback from Trout Unlimited, Friends of the Teton River, American Rivers, and the Henry's Fork Foundation.

[c]Per the Resource Evaluation (IWRB 1992)

[d]Preliminary impacts based on cursory review of aerial photography.

Legend

Land Management

Federal/ Conservation	Federal, Conservation Easement
State	State
Private	Private

Recreation/Economic Value

High	Significant Impacts to Recreation/ Economic Values
Moderate	Moderate Impacts to Recreation/ Economic Values
Low	Minimal Impacts to Recreation/ Economic Values

Infrastructure

High	Impacts to major infrastructure/development
Moderate	Moderate impacts to human environment
Few	Few impacts to human environment

EXHIBIT 3-28

Land Management Implications and Impacts to Recreation/Economic Value and Infrastructure at the Reservoir Site

3.9 Assumptions and Limitations

General assumptions and limitations applicable to all of the surface-storage alternatives are described in Section 2.8 – *Key Assumptions and Limitations* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012. Additional assumptions and limitations specific to this alternative are listed below:

- Excavation for the open spillway would likely be in colluvial soils and/or rock. It is possible that the spillway may be in soft erodible materials and if an open channel spillway is used, it may require concrete or rock linings that are suitable to match the intended spillway flows. A lined concrete spillway was assumed for costing purposes. Alternative spillway approaches should also be investigated once the inflow design flow has been established and local site conditions are better understood.
- Since the natural watershed is only slightly larger than the reservoir itself, natural runoff from the watershed would be very low.

3.10 Evaluation Criteria

3.10.1 Stakeholder Group Measurable Criteria

There are four Stakeholder Group Measurable Criteria, with results summarized in Exhibit 3-29:

- Water Supply: The net change for in basin and out of basin water budgets in af is described above in Section 3.5 and summarized in Section 3.2.
- Water Rights: Water rights were not specifically addressed during this level of study, but known legal, institutional, and policy constraints are summarized in Section 3.6.
- Environmental Considerations: Environmental benefits and impacts are summarized in Section 3.7.
- Economics: The estimated reconnaissance-level field cost to construct the project is summarized in Section 3.4.

EXHIBIT 3-29
Stakeholder Group Measurable Criteria Summary

Stakeholder Group Measurable Criteria	Criteria Characterization
Water Supply (in-basin water transfer potential)	101,000 af/yr
Water Supply (out-of-basin water transfer potential)	101,000 af/yr
Legal, Institutional, or Policy Constraints (yes, no)	Yes
Environmental Considerations (net positive, negative or neutral)	Negative to Positive[1]
Economics (reconnaissance-level field costs for implementation)	\$462,020,000 - \$530,940,000 (no hydropower) \$469,250,000 - \$538,160,000 (with hydropower)

[1] – Net environmental impact would depend on water sources and reservoir operations; further analysis required in future phase of study.

3.10.2 Federal Viability Tests

The four federal viability tests used to evaluate potential projects are listed below:

- **Acceptability**
- **Effectiveness** (extent to which basin needs are met)
- **Completeness** (extent to which all needs are met)
- **Efficiency** (relative construction/implementation cost per af)

For alternatives that are carried forward to future phases of the Basin Study, the information needed to evaluate each of the criteria listed above will be further developed and refined.

SECTION 4

Teton Dam

4.1 Alternative Description

4.1.1 Overview

The Teton Dam alternative features a proposed new 300-foot-tall dam and a 265,000 acre-feet (af) reservoir. The dam site is located on the Teton River approximately 16 miles upstream of the City of Rexburg (at the site of the old Teton Dam), and would require no secondary water sources. When full, Teton Reservoir could provide a roughly 285-foot drop to a proposed new hydropower facility at the base of the dam.

4.1.2 Alternative Variations

Only a single dam concept was carried through cost development.

4.1.3 Operational Assumptions

Detailed operations have not been evaluated or distinguished by alternative. Preliminary, generalized, non-binding operational assumptions were described in Sections 2.2 and 2.3 of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012, to evaluate potential water availability and design flow to identify sub-alternatives and develop relative costs.

4.2 Key Findings

Teton Reservoir, formed by water impounded by a new dam at the site of the former Teton Dam which failed in 1976, would provide additional storage water for the Teton Basin, effectively enhancing water supply by capturing excess peak flows and redistributing that water during periods of higher demand. The available storage would enhance the in-basin water budget by impounding up to 265,000 af (if the reservoir was initially empty) during the annual high flow period and storing that water until more critical, higher demand periods. This storage water could help satisfy unmet irrigation demands in the Lower Watershed and Egin Bench irrigated regions. Reservoir releases during low flow periods would increase flow in downstream river segments, including the North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork of the Snake River (Lower Henrys Fork), which have all been identified as having additional ecological streamflow needs. Storage would typically occur during periods when connectivity is not an issue, but nonetheless may be expected to impact conservation populations of Yellowstone cutthroat trout in the Teton River. Teton Dam would function as a barrier and limit connectivity between upstream and downstream reaches. The out-of-basin water budget would be temporarily reduced by up to 265,000 af during the annual high flow period when water is diverted to the reservoir, but some or all of that quantity may be available at a later time for numerous out-of-basin uses, including needs resulting from climate change; agricultural needs; domestic, municipal, and industrial needs; ecological needs; and for recharge of the Eastern Snake Plain Aquifer (ESPA). The site may be prone to high seepage rates, and measures intended to maintain stability and limit seepage led to elevated estimated construction costs. Exhibit 4-1 provides a tabular summary of the key findings.

EXHIBIT 4-1
Key Findings from the Reconnaissance Evaluation

Estimated Cost per af	Impact on In-Basin Water Budget	Impact on Out-of-Basin Water Budget	Change in Connectivity of Impacted River Segment
$1,900 - $2,000	265,000 af, to be diverted during the annual high flow	265,000 af reduction during the annual high flow period, in accordance with priority rights. Part or all of this quantity	Improvement in connectivity of downstream river segments, including

EXHIBIT 4-1
Key Findings from the Reconnaissance Evaluation

Estimated Cost per af	Impact on In-Basin Water Budget	Impact on Out-of-Basin Water Budget	Change in Connectivity of Impacted River Segment
	period and released during high demand periods.	would be available later for out-of-basin needs.	North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork. Potential impacts to the Teton River (supply source), which contains a conservation population of Yellowstone cutthroat trout.

4.3 Engineering Results

4.3.1 Hydrology

The Teton River would be impounded by Teton Dam, and the river was the only water supply source evaluated (Exhibit 4-2). Exhibit 4-3 presents a summary of potentially available water based on analyses using StreamStats (USGS, 2011; see Section 2.2.1 – *Hydrology*).

EXHIBIT 4-3
Water Potentially Available for Storage at Teton Reservoir

Source	Watershed Area (sq. mi)	Quantity (af/year)
Teton River	849	345,400

4.3.2 Conveyance

Since Teton Dam would impound the river and no alternative water supply sources were evaluated, no conveyance infrastructure (pressurized pipelines, canals, siphons, stream diversions, intakes, or fish screens) were required for this alternative.

4.3.3 Dam Site Geology

4.3.3.1 Area Geology

The Teton Dam site is in the Teton River Canyon, which is dissected into the Rexburg Bench. The Rexburg Bench is entirely formed in the Huckleberry Ridge Tuff. This tuff erupted from the Henrys Fork Caldera of the Yellowstone Plateau. The tuff flowed over irregular topography containing at least one large lake, west-flowing streams, basaltic lava flows, and older rhyolitic rocks. Large-scale gravity sliding and deformation occurred within the lake and stream deposits shortly after the tuff flowed over them. A minimum of 0.6 mile of horizontal movement caused significant deformation in the partially-fluid tuff sheet. Numerous open joints, shear zones, large overturned asymmetric antiforms, and an extensional valley (Hog Hollow, located nearby) were created prior to the complete welding of the ignimbritic tuff.

The basalt of Moody Creek erupted from a vent to the south of the Teton Dam site and produced at least three lava flows. This basalt likely temporarily dammed the Teton River. Downdropping of the Snake River Plain and Teton Basin resulted in the Rexburg Bench being incised by the Teton River between the deposition of the Huckleberry Ridge tuff and the Moody Creek Basalt.

A thick mantle of loess (windblown silt) was deposited over the area after glaciation of the Yellowstone region. The proposed Teton Reservoir would be built within the Teton River Canyon. Exhibit 4-4 shows a geologic map of the proposed dam site. The geologic profile was developed based on available geologic mapping (Embree et al., 2011), geologic data post-failure reports, available water well logs in the area, and geologic site observations. The following is a description of the geologic units at the site, based on published data (Embree et al., 2011), results of geotechnical site investigations conducted before construction of the original dam, and site observations. The geologic unit abbreviations are consistent with Exhibit 4-4.

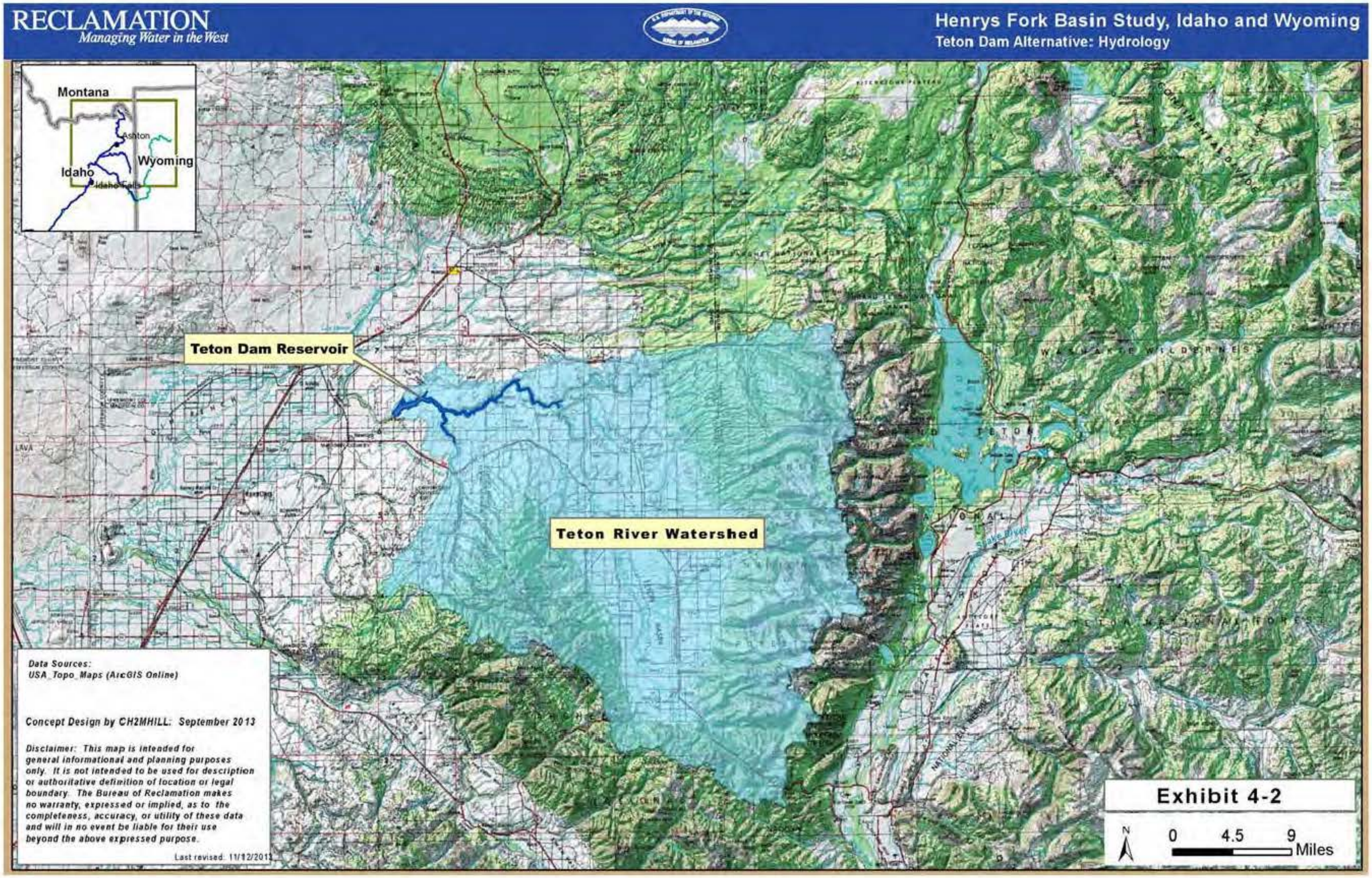

EXHIBIT 4-2
Teton Dam Alternative: Hydrology

4.3.3.2 Stratigraphy

Qyh –The Huckleberry Ridge tuff is the first rhyolitic welded ash-flow tuff of the Yellowstone volcanic group. This tuff unit was deposited over nearly 6,000 square miles and is approximately 1.9 to 2.0 million years old. This unit consists of crystal-rich, grayish-pink to light gray, rhyolitic welded ash-flow tuff and ash layers with phenocrysts of sanidine and quartz. The major part of this unit, exposed in the walls of the Teton Canyon, is composed of light-gray to grayish-pink, densely welded, devitrified tuff. This tuff is highly permeable and jointed. The thickness of this unit is highly variable and ranges from 35 to 760 feet in the vicinity. This unit is exposed in cliffs on the north and south sides of the Teton River Canyon at both proposed dam abutments.

Qbm – The basalt of Moody Creek is a medium-gray, fine-grained basalt with sparse phenocrysts of plagioclase and olivine. The thickness of this basalt flow ranges from 60 to 140 feet. Pillows within the basalt flows indicate underwater emplacement, which suggests that these flows temporarily dammed the Teton River at some point in the past.

Ts – This unit consists of older alluvial and lacustrine sediments exposed in the cores of anticlines in the Teton Canyon. These consist of a thick sequence of light gray and yellow, weakly cemented, strongly deformed tuffaceous and arkosic sandstone, siltstone, and conglomerate that is locally interbedded with tuff, diatomite, basalt, and rhyolite. Metamorphic and granitic clasts, arkosic sandstones, and diatomite beds suggest deposition in fluvial and lacustrine environments. In geothermal wells in the vicinity, this unit consists of 60 feet of gravel beneath about 100 feet of clay and arkosic sand.

Qel – This unit is thick loess on the upland areas of the Rexburg Bench and overlies the Huckleberry Ridge Tuff and the Moody Creek basalt. Loess consists of wind-blown silt, clay, and very fine sand that ranges from light gray to light brown to tan. The thickness of this material ranges from less than 5 to 44 feet thick.

Qc – This unit is colluvium that consists of unconsolidated angular blocks of tuff in a silty tuffaceous matrix and soil deposits that mantle steep canyon walls along the Teton River Canyon.

Qa – This is the alluvium of the Teton River that consists primarily of unconsolidated clayey silt, silty sand, and gravel. This unit underlies the Teton River valley in the vicinity of the dam site. Based on site investigations and Teton Dam reports, this unit is as much as 110 feet thick.

Qtfb – This unit is boulder gravel mixed with cobbles and pebbles and open-work boulders deposited during the Teton Dam flood. The boulders are angular to sub-rounded and are as large as 36 by 26 by 13 feet in dimension and weigh as much as 896 tons. These are composed of Huckleberry Ridge Tuff and the basalt of Moody Creek and derived from talus or bedrock in the Teton River Canyon. These are mapped up to 1,600 feet downstream of the Teton Dam site.

Qtfg – This unit is gravel including pebbly gravel and sand to cobble gravel and includes material derived from the Teton Dam fill, gravel in road fills, and irrigation canals and was deposited during the Teton Dam flood. These deposits form pendant bars up to 33 feet thick in the canyon downstream from bedrock projects.

Qls – This unit includes landslides that resulted from rapid drawdown of the Teton Reservoir after failure of the dam, with failure surfaces near the contact of the overburden on the slopes and the underlying Huckleberry Ridge Tuff. Where the overburden was thicker, the slides began as rotation slumps and evolved into earth and debris flows. The slides mostly occurred at or below the maximum reservoir elevation reached prior to failure.

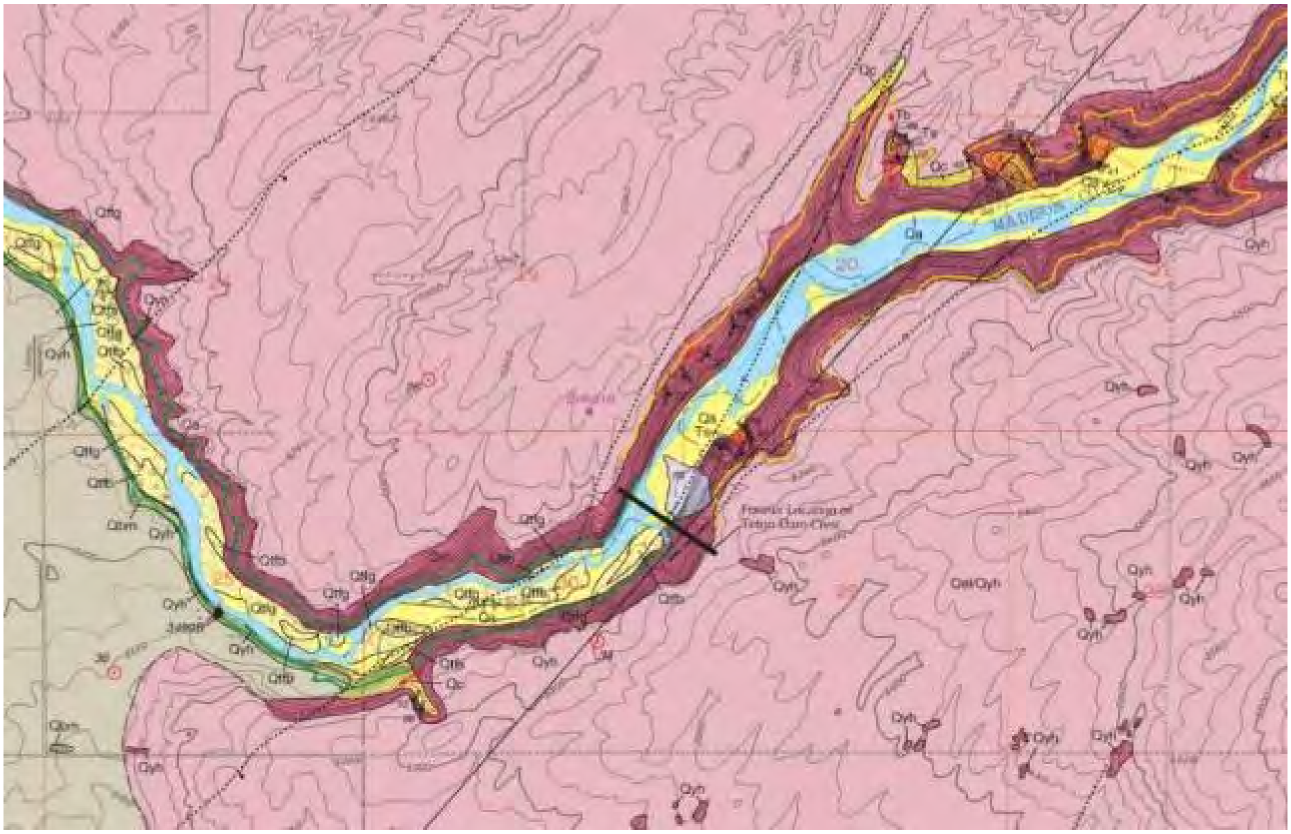

EXHIBIT 4-4
Geologic Map of the Teton Dam Area (adapted from Embree et Al., 2011)

Exhibit 4-5 shows a geologic profile, or cross-section, of the interpreted subsurface conditions beneath the proposed dam.

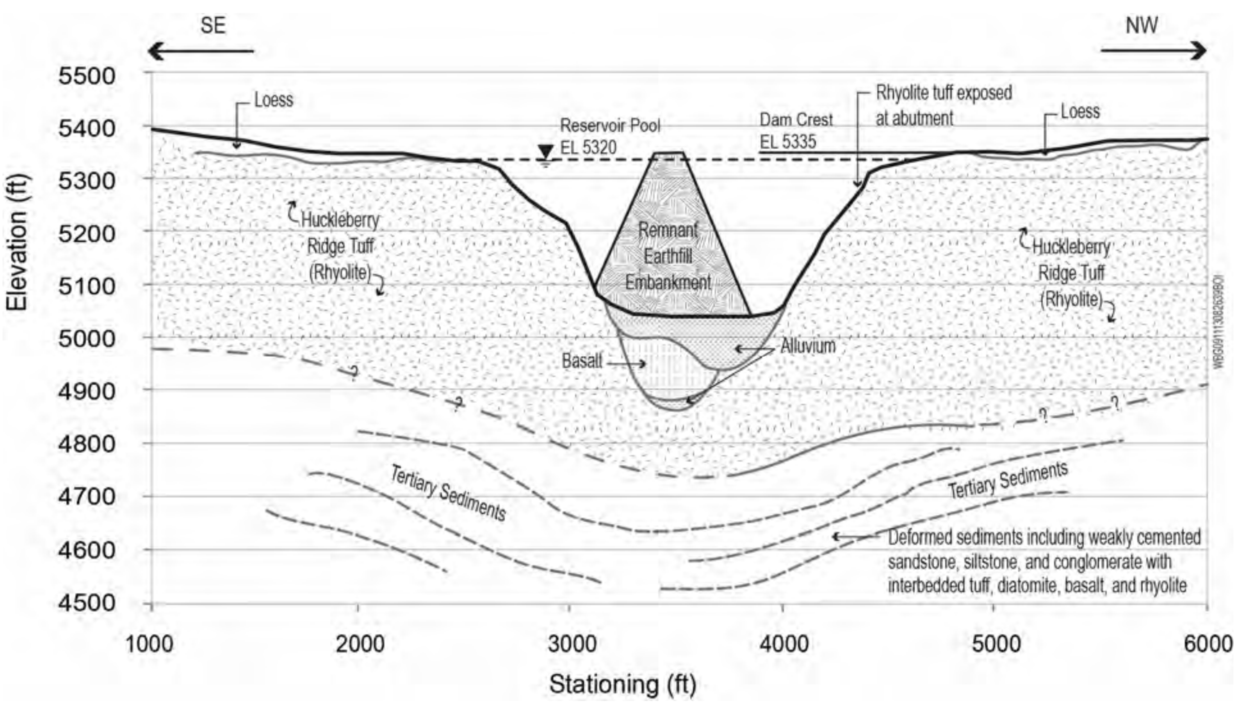

EXHIBIT 4-5
Teton Dam Geologic Profile

4.3.3.3 Structural Geology

The Huckleberry Ridge tuff has been deformed for a variety of reasons. These include: 1) fissures and voids formed in the ash-flow sheet during secondary flowage likely caused by differential compaction settling over irregular topography, and 2) steep cooling joints possibly subject to enlargement and widening farther by horizontal tectonic extension and gravitational creep.

The Huckleberry Ridge tuff just upstream of the Teton Dam site is locally folded into large-scale overturned antiforms. This deformation occurred when the tuff flowed over the existing unconsolidated, water-saturated sediments and basalt flows. The secondary flow occurred after the upper part of the tuff had welded and jointed but prior to devitrification, with caused the joint walls to pull apart and form numerous open fissures as much as 3 feet wide. Lower in the unit, subhorizontal shear zones reflect the transition from brittle to ductile deformation during devitrification. These joint and shear zones form an extensive and interconnected system of fractures.

Very long, through-going extensional fractures and strike-slip faults have been mapped in the area (Embree and Phillips, 2011; Prostka, 1977). The Snake River Plain has been undergoing regional tectonic stress from late Miocene time (5 million years ago) to present. Tectonic extension in the Rexburg-Teton Bench as been most active since the late Pliocene (after deposition of the Huckleberry Ridge tuff), and the northwest trend of fissures at Teton Dam site is consistent with the predominant northwest trend of Quaternary fissure zones in the Snake River Plain, such as the Great Rift and active normal faults in the area. Also, several northeast-trending strike-slip faults have been mapped in the vicinity. These faults accommodate the lateral extension. These faults are mapped from the Teton canyon all the way to Hog Hollow, which indicates the potential for long, through-going geologic structures that could result in seepage paths.

Platy joints appear to have resulted from depositional layering and flattening and collapse of the ash-flow sheet. During secondary flowage, they formed horizontal zones a few inches to about 1 foot thick of closely-spaced imbricate joints.

4.3.4 Dam Configuration

A potential new dam at the site of the former Teton Dam, which failed in 1976, requires special attention. Possible dam types worth consideration at the Teton Dam site include a concrete faced rock fill dam (CFRD), a roller compacted concrete dam (RCC), or an earth or asphalt core rock fill dam (ECRD or ACRD) having a central or sloping impervious core. Both the CFRD and RCC dams would need to be constructed on a bedrock foundation, but it may be possible to construct an ECRD on the alluvial sediments. In either case, questions still remaining about possible seepage through the underlying bedrock would require any of the dam types to be constructed in combination with a continuous deep seepage barrier (cutoff) extending well into the bedrock. The final configuration of the dam section is beyond the scope of this phase of the study and will continue to evolve as the study progresses. However, possible concepts for seepage cutoff through the dam and cutoff within the foundation (continuous deep cutoff wall) are presented, and a CFRD is presented as a preferred concept for this evaluation. The CFRD would be founded on the underlying bedrock foundation and have a continuous cutoff wall excavated deep into the bedrock to control seepage. Use of filters and relief wells was assumed to be necessary to control seepage that could occur within the foundation.

The bottom of the valley at the proposed dam location is at an approximate elevation of 5,030 feet and the top of the dam would be at an approximate elevation of 5,330 feet for a maximum height of about 300 feet above the present valley bottom (about 410 feet above the estimated bedrock foundation at its deepest location). The length of the dam at this elevation would be about 2,300 feet. The resulting reservoir would have about 265,000 acre-feet of storage with a maximum surface area of 1,370 acres. Exhibit 4-6 shows the general locations for the dam, appurtenant structures, and existing emergency spillway (which would be enlarged), and Exhibit 4-7 presents a typical dam configuration section.

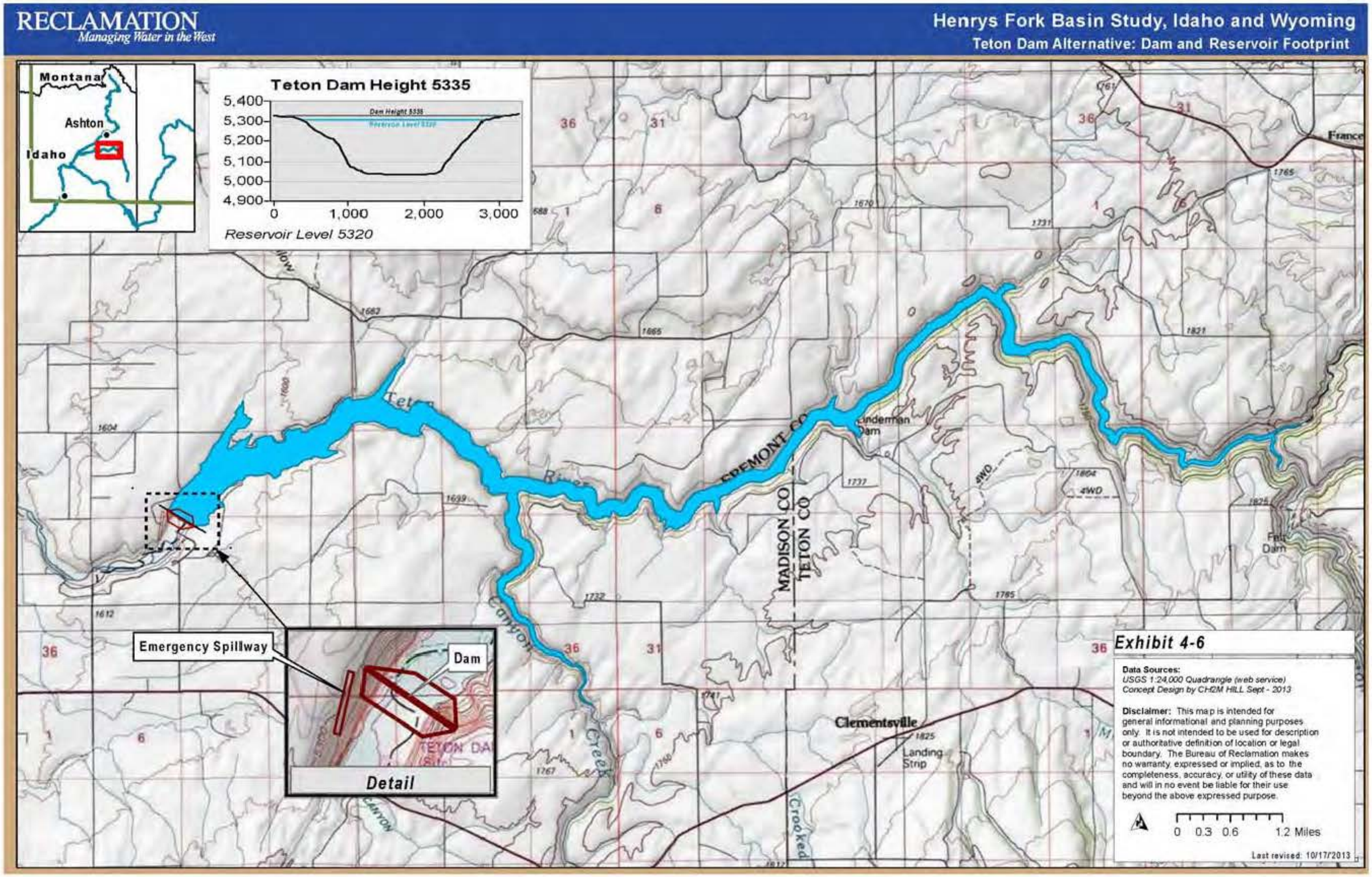

EXHIBIT 4-6
Teton Dam and Reservoir Layout

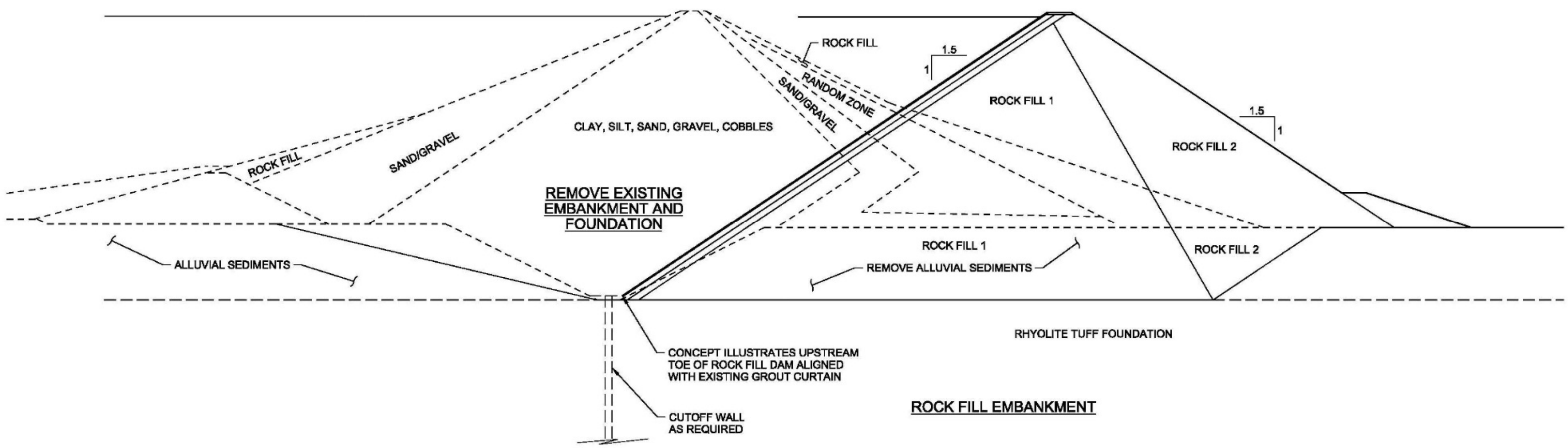

EXHIBIT 4-7
Teton Dam Existing and Proposed Cross-Sections

The Teton dam site is underlain by rhyolitic ash-flow tuff bedrock. The Teton River occupies a steep-walled canyon incised into the rhyolite tuff with steep rock slopes on each of the canyon walls with exposed jointing that is typical in the rhyolite. Extensive joints are common in this rhyolite tuff and are particularly numerous near the surface of the dam abutments where stress relief has allowed opening of the joints. Deep key trenches were previously excavated into the abutments under the existing remnant dam embankment, and substantial initial grouting and exploration previously occurred along the base of this existing key trench alignment. A canyon basalt flow, although not visible from the present configuration of the valley, occupies a portion of the valley bottom underlying the valley sediments. It was deposited on top of the underlying rhyolite tuff and it also overlies variable thicknesses of older alluvium also composed of silt, sand, gravel, and cobbles. The basalt may have been naturally exposed at about the existing ground surface along the left bank of the canyon bottom prior to construction of the Teton dam in 1970s. Alluvial sediments overlie most of the existing basalt flow and presently exist in the bottom of the valley, consisting of up to about 100 feet of silt, sand and gravel, and cobbles.

During the post-failure investigations of the original dam foundation, significant grout takes were demonstrated in several of the grout holes, and it was found that the grout injection in two exploratory drill holes alone exceeded the originally estimated take for the entire dam pressure grouting program. Final quantities injected into these two holes were nearly 16,000 sacks of cement and nearly 18,000 cubic feet of sand. Because of this extremely high grout take, the complex foundation conditions, the difficult history of the Teton Dam project, and other complex challenges, an ECRD or ACRD built on the alluvial soil foundation is not recommended. A dam founded on the bedrock with a deep positive cutoff wall extending well into the bedrock is considered the most appropriate means to safely control seepage. The cutoff seepage barrier system presented herein therefore assumes the new dam would be a CRFD constructed on a prepared bedrock foundation throughout the entire length of the dam. A positive cutoff wall such as a diaphragm or trench remixing deep (TRD) wall would be utilized and would extend well into the bedrock in order to adequately control seepage through the underlying bedrock. The TRD wall system used by Hayward Baker on other domestic projects and the cutoff wall constructed at Twin Buttes Dam in San Angelo, Texas, by Bencor Corporation are examples of similar cutoff walls (barriers) that have been used on other dam projects in the United States. The Twin Buttes Dam utilized a 115 feet deep cutoff wall constructed in highly cemented materials (with compressive strengths up to 15,000 pounds per square inch) and in sedimentary rock. Other similar deep cutoff walls in bedrock have been used successfully on past projects.

If a CFRD turns out to be feasible, it is essential that the sloping concrete barrier constructed on the face of the rockfill dam be founded on a concrete plinth that is anchored securely to the bedrock foundation. The plinth would be integral with and constructed over the top of the cutoff wall and would form the platform upon which the sloping barrier would rest. In order to attain the desired flexibility to allow the facing to accommodate movement of the rock fill, the concrete facing panels would normally be constructed in 50 or 60 foot square panels. Around the periphery or in areas where more differential settlement is anticipated, the panels would be narrower to provide flexibility where bending due to settlement would be most severe. Granular filter layers are required under the concrete slab to transition between the concrete barrier and the underlying rockfill. In order to further evaluate the foundation rock and to minimize settlement of the concrete facing, alluvial sediments above the foundation would need to be removed. Filter layers consisting of gravel or other materials may be required on the bedrock foundation to assure that seepage conditions can be controlled.

The final grading at the toe of the dam assumes that the excavation upstream of the toe of the concrete barrier and plinth would be left open and that a reasonably flat slope would be constructed upstream from the dam to transition to the top of the adjacent alluvial sediments. This allows complete inspection of the concrete barrier in the future if the water level is drawn down and avoids imposing additional loading over the top of the concrete barrier which could result in additional settlement within the underlying rock fill. Alternatively, if settlement can be shown to be minimal and acceptable, this zone could be backfilled with a low permeability soil to further lengthen potential seepage paths near the upstream toe of the dam.

Backfilling above the toe of the dam may be most advantageous at the location of the existing steep key trench at the abutments of the existing dam. Partially filling the key trenches with a low permeability soils above the barrier would reduce the rock cuts into the abutments.

A likely source of rock fill for the new dam is the rhyolite tuff that exists throughout the region. Because the specific gravity of the rhyolite is low, unconfined compressive strengths can be low compared to other rock types, and because the degree of welding within its rock fabric varies, a conservative slope of 1.5 horizontal to 1 vertical is assumed for the rockfill dam. Additional investigation is required to determine the feasibility of these slopes.

4.3.5 Hydropower Potential

As presented in Exhibit 4-8, hydropower potential associated with Teton Reservoir would be approximately 7,700 kW.

EXHIBIT 4-8
Teton Hydropower Potential

Sub-Alternative	Design Flow (cfs)	Penstock Length (mi)	Head (ft)	Power Potential (kW)
N/A	396	0[1]	285	7,700

[1] – It is assumed that turbines are located at the bottom of the outlet works. Therefore, no penstocks are needed.

4.4 Cost Estimate

A summary of the cost per acre-foot of water stored for this alternative is presented in Exhibit 4-9. The exhibit presents costs with and without hydropower facilities. The site may also be prone to high seepage rates, so an escalated foundation factor was included in the cost estimate to help account for measures intended to limit seepage. An additional cost specifically for a continuous seepage cutoff wall was also incorporated.

EXHIBIT 4-9
Teton Sub-Alternative Cost Estimates[1]

Hydropower	Sub-Alternative	Storage Volume (af)	Total Construction Cost	Cost Per Unit Yield ($/af)
No	N/A	265,000	$492,210,000	$1,900
Yes	N/A	265,000	$520,410,000	$2,000

[1] – Total estimated construction costs were rounded to the nearest $10,000 and unit costs were rounded to the nearest $100.

4.5 Basin Water Needs

The storage provided by Teton Reservoir would enhance the in-basin water budget by impounding 265,000 af during the annual high flow period and storing that water until more critical, higher demand periods during the summer and early fall. Water stored in the reservoir could help satisfy unmet irrigation demands in the Egin Bench (more water available in the Henrys Fork because of reduced need for diversions into the Crosscut Canal) and Lower Watershed irrigated regions (Reclamation, 2012). Reservoir releases would also be used to enhance ecological in-stream flows (see Section 4.7.2 – *Change in Connectivity*).

The out-of-basin water budget would be temporarily reduced by up to 265,000 af during the annual high flow period when water is impounded in the reservoir, but some or all of that quantity may be available at a later time for numerous out-of-basin uses, including needs resulting from climate change; agricultural needs; domestic, municipal, and industrial needs; ecological needs; and for recharge of the ESPA (Reclamation, 2012).

4.6 Legal, Institutional, or Policy Constraints

Legal, institutional, and policy constraints that may affect the implementation of this alternative are described in Section 2.5 – *Legal, Institutional, or Policy Constraints* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012.

4.7 Environmental Benefits and Impacts

4.7.1 Impacted River Segments

River segments potentially impacted by this alternative (providing supply or receiving releases) are limited to the Teton River, as identified in Exhibit 4-10. However, the lower portions of Canyon and Bitch Creeks would also be impounded by Teton Reservoir.

4.7.2 Change in Connectivity

Potential impacts to river connectivity consist of decreased flow (impoundment in the reservoir) for the river segment providing reservoir supply and increased flow for the river segment receiving reservoir releases. Teton Dam would function as a barrier and limit connectivity between upstream and downstream reaches. As described in Section 2.2.1.3 – *Potentially Available Water* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012, impoundment would likely occur during the excess spring runoff period and reservoir releases would likely occur during more critical low flow periods. Potential impacts to connectivity of each impacted river segment are identified in Exhibit 4-10. In addition to the segments listed in Exhibit 4-10, increased flow would be experienced in other downstream river segments, including the North Fork Teton River, South Fork Teton River, and the Lower Henrys Fork, which have all been identified as having additional ecological streamflow needs (Van Kirk et al., 2011).

4.7.3 State Aquatic Species of Special Concern

Yellowstone cutthroat trout are present in the proposed reservoir inundation area. The reservoir would impact the Teton River’s conservation population, which is defined as having less than 10 percent genetic introgression from other species. State Aquatic Species of Special Concern in potentially impacted river segments are indicated in Exhibit 4-10.

4.7.4 Other Environmental Factors

The proposed Teton Reservoir inundation area contains both winter range and migration corridors for big game, according to Trout Unlimited (TU), Friends of the Teton River (FTR), American Rivers (AR), and the Idaho Department of Fish and Game (IDFG). The United States Fish and Wildlife Service (USFWS) tracks one candidate species, the wolverine, in the area. The bald eagle, trumpeter swan, and Wyoming ground squirrel, considered at-risk by the Bureau of Land Management (BLM) and the United States Forest Service (USFS), also make their homes here. Data from the National Wetlands Inventory (NWI) indicate construction at this site would have an extensive impact on mapped wetlands, affecting an area greater than 200 acres. Hydrologic changes to the water source brought about by the proposed construction would also have direct impacts on a stretch of Teton River that is eligible for Wild and Scenic River status designation.

Potential wildlife habitat impacts, federally listed species, and wetlands habitat impacts within the reservoir inundation area are also summarized in Exhibit 4-11, while State of Idaho aquatic species of special concern (Yellowstone cutthroat trout and rainbow trout) and special river designations for all potentially impacted river segments are summarized in Exhibit 4-10.

Surface Storage Site	Sub-Alternative	Impacted River Segments	Connectivity: Flow Decrease (Supply Source)	Connectivity: Flow Increase (Receives Reservoir Releases)	State Aquatic Species of Special Concern: Yellowstone Cutthroat Trout (YCT) Presence	State Aquatic Species of Special Concern: Rainbow Trout (RBT) Priority Fishery[b]	State Aquatic Species of Special Concern: YCT Conservation and Management Tier[c] and RBT Fishery Rating	Special Designation[a]: BLM/USFS Eligible Stream	Special Designation[a]: State Natural River	Special Designation[a]: State Recreational River	Special Designation[a]: Designated Wilderness[d]	Special Designation[a]: Rating
Teton	N/A	Teton River	•	•	•		YCT Conservation	•				Eligible Federal

Notes:

[a]Special designations noted in this exhibit apply to the river reach impounded, diverted for water supply, or directly receiving return flows (if applicable).

[b]Based on personal communications with IDFG, rainbow trout are the primary focus in the Henrys Fork Watershed, whereas YCT are the primary focus in the Teton Watershed.

[c]Three tiers for prioritizing YCT conservation and management options per Montana Fish Wildlife & Parks database (2009) supplemented with anticipated data revisions per personal communications with IDFG.

1) **core conservation** populations composed of > 99 percent cutthroat trout genes;
2) **conservation** populations that generally "have less than 10 percent introgression, but in which introgression may extend to a greater amount depending upon circumstances and the values and attributes to be preserved"; and
3) **sport** populations of cutthroat trout that, "at a minimum, meet the species phenotypic expression defined by morphological and meristic characters of cutthroat trout."

[d]Per the 1997 Revised Forest Plan - Targhee National Forest.

Legend

State Aquatic Speices of Special Concern (YCT and RBT)

YCT Core / RBT Priority	Core Conservation Population of YCT or Priority RBT Fishery
YCT Conservation	Conservation Population of YCT
YCT Sport / None	None or Sport Population of YCT

Special Designation

Federal	Federal Wild and Scenic River (WSR) or Wilderness Area
State/ Eligible Federal	State Protected (Natural and Recreational) or eligible Federal WSR
None	None

EXHIBIT 4-10

Impacts to Connectivity, State Aquatic Species of Special Concern, and Special River Designations for Affected River Reaches

Surface Storage Site	Wildlife Habitat[a]			Federally Listed Species			Wetland/Habitat Value	
	Big Game Winter Range	Big Game Migration Corridors	Rating	At-Risk (USFS & BLM sensitive species, and Idaho Species of Greatest Conservation Need)[b]	Threatened, Endangered, Candidate and Experimental Nonessential Species[c]	Rating	NWI Wetlands	Rating
Teton	•[1,2]	•[2]	Winter Range	bald eagle, trumpeter swan, wyoming ground squirrel	wolverine	Federal Terrestrial/ Sensitive	•	Extensive

Notes:

[a]Sources of Wildlife Habitat data

[1]Per review comments from Trout Unlimited, Friends of the Teton River, and American Rivers.

[2]Per personal communications with IDFG on the Sand Creek and Teton Canyon winter ranges.

[3]Per the USFS 1997 Revised Forest Plan - Targhee National Forest.

[b]Per IDFG special species February 2011 GIS dataset (1-mile buffer area) and personal communications with the Henrys Fork Foundation.

[c]Threatened and Endangered and Candidate species list obtained from USFWS; however, location specific information based on data compiled by Trout Unlimited, Friends of the Teton River, and American Rivers (unless otherwise specified, some identified in the IDFG February 2011 dataset).

Legend

Wildlife Habitat

Winter Range	Winter Range Habitat
Migration	Migration Corridor
None	None

Federally Listed Species

Federal Aquatic/ Prime Conservation	Federally Listed Aquatic Species and Prime Conservation Area
Federal Terrestrial/ Sensitive	Federally Listed Terrestrial Species and State Species of Greatest Conservation Need
None	None

Wetland and Habitat Values

Extensive	Extensive wetland impacts (> 200 Acres)
Moderate	Moderate wetland impacts (>1 - 200 Acres)
None/Minimal	<1 Acre

EXHIBIT 4-11

Impacts to Wildlife Habitat, Federally Listed Species, and Wetland Habitat at the Reservoir Site

4.8 Land Management, Recreation and Infrastructure impacts and benefits

Teton Dam and Reservoir would be located on public and private land, has a high recreation and economic rating, and is rated as having few potential infrastructure impacts, as summarized in Exhibit 4-12.

4.9 Assumptions and Limitations

General assumptions and limitations applicable to all of the surface-storage alternatives are described in Section 2.8 – *Key Assumptions and Limitations* of Technical Series Report No. PN-HFS-002 – New Surface Storage Alternatives, dated November 2012.

	Land Management Data[a]					Recreation/Economic Value								Infrastructure[d]				
Surface Storage Site	Private	Federal	State	Conservation Easements[b]	Rating	Boating[b,c]	Fishing[c]	Yellowstone National Park	Guiding/ Outfitting[c]	Scenic/ Natural Features[c]	Cultural/ Historic Resources[c]	Land Recreation[c]	Rating	Roads	Structures	Habitation	Additional Infrastructure Notes	Rating
Teton	•	•			Federal	•	•		•			camping	High					Few

Notes:

[a]Land management data per the BLM Idaho Surface Management Agency (2010). For federal government lands, the data displays the managing agency which may or may not be the same as the agency that "owns" the land.

[b]Per feedback from Trout Unlimited, Friends of the Teton River, American Rivers, and the Henry's Fork Foundation.

[c]Per the Resource Evaluation (IWRB 1992)

[d]Preliminary impacts based on cursory review of aerial photography.

Legend

Land Management

Federal/ Conservation	Federal, Conservation Easement
State	State
Private	Private

Recreation/Economic Value

High	Significant Impacts to Recreation/ Economic Values
Moderate	Moderate Impacts to Recreation/ Economic Values
Low	Minimal Impacts to Recreation/ Economic Values

Infrastructure

High	Impacts to major infrastructure/development
Moderate	Moderate impacts to human environment
Few	Few impacts to human environment

EXHIBIT 4-12

Land Management Implications and Impacts to Recreation/Economic Value and Infrastructure at the Reservoir Site

4.10 Evaluation Criteria

4.10.1 Stakeholder Group Measurable Criteria

There are four Stakeholder Group Measurable Criteria, with results summarized in Exhibit 4-13:

- Water Supply: The net change for in basin and out of basin water budgets in af is described above in Section 4.5 and summarized in Section 4.2.
- Water Rights: Water rights were not specifically addressed during this level of study, but known legal, institutional, and policy constraints are summarized in Section 4.6.
- Environmental Considerations: Environmental benefits and impacts are summarized in Section 4.7.
- Economics: The estimated reconnaissance-level field cost to construct the project is summarized in Section 4.4.

EXHIBIT 4-13
Stakeholder Group Measurable Criteria Summary

Stakeholder Group Measurable Criteria	Criteria Characterization
Water Supply (in-basin water transfer potential)	265,000 af/yr
Water Supply (out-of-basin water transfer potential)	265,000 af/yr
Legal, Institutional, or Policy Constraints (yes, no)	Yes
Environmental Considerations (net positive, negative or neutral)	Negative to Positive[1]
Economics (reconnaissance-level field costs for implementation)	$492,210,000 (no hydropower) $520,410,000 (with hydropower)

[1] – Net environmental impact would depend on water sources and reservoir operations; further analysis required in future phase of study.

4.10.2 Federal Viability Tests

The four federal viability tests used to evaluate potential projects are listed below:

- **Acceptability**
- **Effectiveness** (extent to which basin needs are met)
- **Completeness** (extent to which all needs are met)
- **Efficiency** (relative construction/implementation cost per af)

For alternatives that are carried forward to future phases of the Basin Study, the information needed to evaluate each of the criteria listed above will be further developed and refined.