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Kara M. Montalvo, Director
Environmental Services
Mail Stop PAB359 |P.O. 52025
Phoenix, AZ 85072-2025
P: (602) 236-5256
Kara.Montalvo@srpnet.com

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Via Electronic Comment Submittal:
https://cara.fs2c.usda.gov/Public/CommentInput?Project=51592

Attn: Michiko Martin, Regional Forester and Objection Reviewing Officer,
Southwestern Region, U.S. Forest Service
333 Broadway Blvd SE
Albuquerque, NM 87102

Re: Salt River Valley Water Users' Association and Salt River Project Agricultural Improvement and Power District's Objection under 36 C.F.R. § 219.54 to the Tonto National Forest Final Land Management Plan, Final Environmental Impact Statement, and Draft Record of Decision; Nos. MB-R3-12-13, MB-R3-12-14, and MB-R3-12-15 (Neil Bosworth, Responsible Officer, Tonto National Forest Supervisor)

Dear Ms. Martin:

Pursuant to 36 C.F.R. § 219.54, the Salt River Valley Water Users' Association ("Association") and the Salt River Project Agricultural Improvement and Power District ("District"), hereinafter collectively ("SRP") submit this objection to the Tonto National Forest Land Management Plan ("Forest Plan"), Final Environmental Impact Statement ("FEIS"), and Draft Record of Decision for the Tonto National Forest Land Management Plan ("Draft ROD").[1] SRP is one of the nation's oldest federal reclamation projects and a significant portion of SRP's water and power infrastructure is situated within a corridor of lands in the Tonto National Forest ("TNF"). This corridor, along the Salt and Verde Rivers, which the Secretary of the Interior withdrew for reclamation purposes ("Reclamation Withdrawn Lands"),[2] is critically important to SRP in meeting its responsibility to the United States to care for, operate, and maintain the Salt River Federal Reclamation Project ("Reclamation Project").

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[1] *See* Tonto National Forest Land Management Plan (March 2022); *see also* Final Environmental Impact Statement for the Land Management Plan (March 2022); and Draft Record of Decision for the Tonto National Forest Land Management Plan (March 2022).

[2] As the Forest Service is aware, before the creation of the TNF, Reclamation withdrew from public entry a corridor of lands along the Salt River for development of water and power infrastructure associated with the Reclamation Project.

SRP acknowledges the TNF's considerable effort to develop a Forest Plan that provides a balanced direction for the management, protection, and use of the forest. SRP is supportive of a Forest Plan that "fulfill[s] its stewardship responsibilities to best meet the current and future needs of the people and communities" of Arizona. Nevertheless, SRP objects to TNF's selection of the Coronado Mesa Recommended Wilderness Area ("CMRWA") as suitable for Congressional wilderness area designation. The CMRWA is located adjacent to the Reclamation Project and Reclamation Withdrawn Lands, downstream of Roosevelt Dam.[3] As discussed below, designation of this site as recommended wilderness will inhibit future Reclamation Project operations.

SRP is currently investigating the potential to increase the amount of long duration energy storage capacity (known as pumped storage) for the Reclamation Project to meet future power demand with renewable power sources such as solar and wind resources. In a 2014 study, Reclamation identified a site called "Alternative Apache 1B" ("Apache Lake PSP Site") as valuable for the development of pumped storage hydropower infrastructure ("2014 Reclamation PSP Study" attached hereto as Attachment B).[4] The Apache Lake PSP Site is located in the CMRWA. Development of a pumped storage project at the Apache Lake PSP Site would allow SRP to: (1) reliably provide power for future demand in an energy scarce environment; (2) replace existing fossil fuel generating resources with renewable power; and (3) meet its goals to reduce its carbon emissions. The TNF designation of the CMRWA in its final Forest Plan would frustrate SRP's efforts to investigate and eventually develop a pumped storage project at the Apache Lake PSP Site. The removal of this area from potential carbon-free power facility development is not in the best interest of the American public. Given the critical importance of the CMRWA to future pumped storage hydropower development, SRP requests that the Forest Service revise the Forest Plan to exclude the CMRWA from its recommendations for wilderness designations. SRP is supportive of recommended wilderness areas in other areas of the TNF that are in the public interest and do not adversely impact SRP's obligations for the care, operation, and maintenance of the Reclamation Project.

A. SRP's Objection is Founded in and Supported by, its Participation in Each Step of the Forest Plan Revision Process, Including in Person Meetings and the Submission of Written Comments

SRP has participated in each step of the Plan Revision Process and has submitted comments to the TNF on eight occasions.[5] In those comments, SRP urged the TNF to consider the operation and maintenance needs of existing and future SRP water and power infrastructure within the Forest. As required by 36 C.F.R. § 229.54, a summary of the subject matter of our previous comments is set forth here.

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[3] The CMRWA and its proximity to existing Reclamation Project works and Reclamation Withdrawn Lands is shown in Attachment A.

[4] *See* Reclamation-Wide Pumped Storage Screening Study, U.S. Department of Interior, Bureau of Reclamation Power Resources Office (September 2014) ("2014 Reclamation PSP Study, Attachment B).

[5] The TNF began revising its Forest Plan in 2014 using the 2012 Planning Rule for the National Forest System (herein the "Plan Revision Process").

- SRP first submitted comments on May 18, 2017, in response to TNF's Notice of Intent ("NOI") to revise the Forest Plan and prepare an Environmental Impact Statement ("EIS").[6] Those comments explained SRP's longstanding interest in the Forest Plan, its relationship to Reclamation Project operation and maintenance and the importance of considering water and power infrastructure needs going forward in the development of a revised plan.

- On June 5, 2017, SRP submitted comments regarding the TNF's wild and scenic river eligibility process.[7] SRP raised concerns regarding the criteria used to identify proposed wild and scenic river designations that would impact existing and future water and power operations and infrastructure.

- On October 10, 2017, SRP submitted comments regarding the TNF's wilderness recommendation process.[8] The comments highlighted conflicts between the boundaries of recommended wilderness areas and existing and future water and power infrastructure. At that time, the CMRWA site had not yet been singled out for recommendation; nevertheless, SRP's comment expressed concerns about the impact of any designation on the operation and maintenance of water and power infrastructure, as well as future power development.

- On January 10, 2018, SRP submitted comments regarding the TNF's proposed land and resource management plan.[9] SRP requested that the plan provide the needed flexibility for operation and maintenance of Reclamation Project water and power infrastructure. SRP expressed concerns regarding restoration of natural flow regimes and water-based recreation and took issue with aspects of the plan affecting access to water and power infrastructure, wildfires, and utility corridors. Finally, SRP requested that the plan consider SRP's ongoing commitments to conserve species and habitat pursuant to incidental take permits issued to SRP under Section 10(a)(1)(B) of the Endangered Species Act. This letter also summarized SRP's participation in the planning process to date.

- On February 12, 2018, SRP submitted comments regarding the TNF's draft evaluation map.[10] SRP identified conflicts between recommended wilderness areas and water and power infrastructure and access roads.

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[6] *See* SRP Comments on the Notice of Intent to Revise the Tonto National Forest Land and Resource Management Plan and Preparation of the Associated Environmental Impact Statement (May 18, 2017).
[7] *See* SRP Comments on the Proposal to Provide Special Designations for Water Bodies on the Tonto National Forest (June 5, 2017).
[8] *See* SRP Comments on the Tonto National Forest Draft Inventory Map for the Wilderness Recommendation Process (October 10, 2017).
[9] *See* SRP Comments on the Tonto National Forest Preliminary Proposed Land and Resource Management Plan (January 10, 2018).
[10] *See* SRP Comments on the Tonto National Forest Draft Evaluation Map for Wilderness Recommendation Process (February 12, 2018).

- On May 22, 2018, SRP submitted comments regarding the TNF's wilderness recommendation process, after meeting with the agency in person to voice concerns about how the recommendations might interfere with present and future water and power operations and infrastructure development.[11] Through its written comments, SRP requested that the TNF recognize existing land use authorizations, including Reclamation Land Withdrawals and other areas within the project influence, for water and power infrastructure.[12] Again, at the time of these comments, the CMRWA site had not been singled out by the TNF as a recommended wilderness area.[13]

- On March 12, 2020, SRP submitted comments regarding the TNF's Draft Land Management Plan and draft EIS.[14] The draft EIS included alternatives that proposed, for the first time, that the CMRWA site be recommended for wilderness designation. SRP's comments on the draft EIS expressed concerns regarding proposed special management areas and the direction of the Forest Plan and specifically requested that the CMRWA be excluded from the recommended wilderness areas.

- On May 24, 2022, SRP submitted an objection under 36 C.F.R. § 219.54 to the final TNF Forest Plan, EIS, and Draft ROD.[15] SRP's objection expressed concern that the inclusion of the CMRWA site in the National Wilderness Preservation System in the Draft ROD would inhibit the Reclamation Project's ability to achieve Congressionally authorized purposes, including the addition of long duration and low carbon energy storage assets necessary to support a transition to renewable energy sources. SRP's objections specifically requested that the CMRWA site be excluded from Alternative B, as selected in the Draft ROD, and replaced with alternative TNF lands meeting the wilderness criteria outlined in the TNF planning documents.

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[11] *See* SRP Comments on the Tonto National Forest Wilderness Recommendation Process (May 22, 2018).

[12] Regarding areas on the TNF "surrounding or adjacent to" Reclamation Project reservoirs (Roosevelt, Apache, Canyon, Saguaro, Bartlett, and Horseshoe), the comments requested that these "be eliminated from consideration for Wilderness designation under the wilderness criteria (apparent naturalness, solitude, and manageability)."

[13] A "final evaluation map" posted to the TNF website in May 2018 depicted more than 100 potential wilderness sites within the TNF, including the lands within the subsequently designated CMRWA. At this stage, the TNF had not yet identified which areas would be carried forward for further evaluation as wilderness. During "Step 3" of TNF's process, the agency subsequently reviewed the entirety of the evaluated sites and made internal decisions about what to carry forward into alternatives in the draft EIS. Those decisions were not revealed to the public until publication of the draft environmental impact statement ("EIS") for the Forest Plan.

[14] *See* SRP Comments on the Tonto National Forest Draft Land Management Plan and Draft Environmental Impact Statement (March 12, 2020).

[15] *See* SRP Objection under 36 C.F.R. § 219.54 to the Tonto National Forest Final Land Management Plan, Final Environmental Impact Statement, and Draft Record of Decision; Nos. MB-R3-12-13, MB-R3-12-14, and MB-R3-12-15 (May 24, 2022).

B. Statement of Interest

SRP and TNF have a longstanding, mutual interest in and responsibility for ensuring that Forest management activities do not frustrate Reclamation Project purposes, including the development of pumped storage hydropower resources such as on the Apache Lake PSP Site. The following sections describe the respective roles and responsibilities of TNF, Reclamation and SRP, and briefly summarize the laws and agreements that necessitate collaborative decision-making among these entities regarding Forest management. Chief among these agreements is the Management Memorandum among SRP, the Forest Service, and Reclamation dated April 27, 1979 ("Tri-Party Agreement"), discussed in Section B.3, below.

1. The Reclamation Project was Authorized by Congress to Provide Reliable, Sustainable Water and Power Supplies to Central Arizona Through the Construction, Care, Operation and Maintenance of Infrastructure that is Largely Situated on TNF Lands.

SRP is one of the nation's largest public power utilities and one of the largest raw-water suppliers in Arizona. The Association is a private corporation formed in 1903 under the laws of the Territory of Arizona by local farmers within the Salt River Valley to contract with Reclamation for the construction and repayment of the costs incurred in building and acquiring the works of the Reclamation Project. The District is an agricultural improvement district organized in 1937 under the laws of the State of Arizona for the purpose, in part, of providing financial support to the Association.[16] Under contract between the Association and the District, and approved by the United States, the District and the Association collectively and collaboratively operate the Reclamation Project.

In 1917, the United States turned over the care, operation, and maintenance of the Reclamation Project to the Association.[17] The United States continues to hold title to all Reclamation Project facilities and has a supervisory role over such facilities. The Reclamation Project includes dams, reservoirs, a diversion dam, canals and laterals, and other associated facilities. Reclamation Project Dams include Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Dams on the Salt River; Horseshoe and Bartlett Dams on the Verde River; and C.C. Cragin Dam on East Clear Creek. Reservoirs include Roosevelt, Apache, Canyon and Saguaro on the Salt River; Horseshoe and Bartlett on the Verde River, and C.C. Cragin on East Clear Creek. The Granite Reef Diversion dam is located on the Salt River below its confluence with the Verde.[18] Hydroelectric generation facilities are located at Roosevelt, Horse Mesa, Mormon Flat and Stewart Mountain Dams. The hydropower generating facilities at Horse Mesa and Mormon Flat dams include pumped storage capability that have been used for safe and reliable energy storage since the 1970's.

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[16] *See Id.*

[17] See Contract between United States of America and Salt River Valley Water Users' Association (September 6, 1917).

[18] *See Id*.

Water stored in Reclamation Project reservoirs drains from the 13,000 square mile Salt and Verde River watershed and the 70 square mile East Clear Creek watershed. A majority of the Verde River watershed and portions of the Salt River and East Clear Creek watersheds are located within the TNF. These watersheds supply water to the Reclamation Project that is delivered to agricultural lands and municipal water treatment plants that serve potable water to millions of people throughout the Phoenix Metropolitan area and Northern Gila County.

SRP also provides electric power, including hydropower produced by the Salt River Dams, to more than one million residential, commercial, industrial, and agricultural customers in the Phoenix Metropolitan area and northern Pinal County, as well as large mining, commercial and industrial customers in east-central Arizona. In addition, SRP operates, and maintains 380 miles of high voltage transmission and distribution lines, including substations, communications sites, microwave sites, radio towers, as well as an extensive array of stream monitoring gages, precipitation gages, and snow monitoring equipment on National Forest System ("NFS") lands related to its power and water operations. A significant portion of the Reclamation Project's power transmission infrastructure is located within the TNF. Authorization for the construction, operation, and maintenance of these facilities on TNF-managed lands has been pursuant to congressional legislation, license, agreement, and Special Use Permits. For more than a century, SRP has collaborated with the TNF to access, maintain and operate these critical systems in a manner consistent with the multiple use management objectives of the Forest Service.

2. TNF was Created by President Theodore Roosevelt in Furtherance of the Water and Power Supply Purposes of the Reclamation Project.

The creation of the Reclamation Project, pursuant to the Reclamation Act of 1902 ("Reclamation Act"), led to the creation of the TNF.[19] It was one of Reclamation's first multipurpose undertakings, designed to provide flood control, water storage, and hydroelectric power. Prior to the creation of the TNF, the U.S. Secretary of the Interior withdrew certain Reclamation Withdrawn Lands under Section 3 of the Reclamation Act encompassing the Salt and Verde Rivers for the benefit of the Reclamation Project.[20] Following these Reclamation Land Withdrawals, on October 3, 1905, President Theodore Roosevelt withdrew lands for the purpose of establishing the Tonto Forest Reserve, the precursor to the TNF.[21] The withdrawal was made subject to a savings clause that specifically omitted the Reclamation Withdrawn

[19] *See* Reclamation Act of 1902, 43 U.S.C. § 371 et seq. (Chap. 1093, 32 Stat. 388).
[20] See First Form Withdrawal on March 2, 1903 ("the channel of [the] Salt River from the mouth of Tonto Creek to the mouth of Verde River, and all land lying within one mile thereof" from public entry."; See First Form Withdrawal on July 20, 1905 (the Acting Secretary of the Interior withdrew public lands "[t]hree miles from [the] Salt River on the south side, from the mouth of Tonto Creek to the mouth of the Verde River."); See First Form withdrawal on July 27, 1903 (the Acting Secretary of the Interior withdrew land surrounding the Horseshoe Dam site; See First Form withdrawal on December 14, 1904 (the Acting Director withdrew a "strip of land one mile wide on each side of the Verde River" stretching from the Fort McDowell Yavapai Reservation to Fossil Creek.
[21] *See* Proclamation No. 598, 34 Stat. 3166 (October 3, 1905).

Lands previously withdrawn for the Reclamation Project.[22] Twelve years later, on February 5, 1917, the United States issued Water Power designations. Among them, Water Power Designation No. 8 reserved for water power development and hydroelectric use the area that encompasses the lower Salt River dams, including Apache Lake and upstream to Roosevelt Dam.

The fundamental purpose of the Tonto Forest Reserve is to protect the water supply of the Reclamation Project.[23] The Forest Plan itself recognizes that "[t]he Tonto National Forest was created in 1905 to protect the Salt River Watershed…and the creation of the national forest to protect [the Reclamation Project] and provide water to Phoenix and Mesa were critical elements in the political process that gave statehood to Arizona."[24] Over a hundred years later, the TNF continues to be an important source of water for communities within the Salt River Valley served by the Reclamation Project. Today, the TNF produces an average of 350,00 acre-feet of water each year, while the Reclamation Project has capacity to store more than 2 million acre-feet.[25] In 2015, 56 percent of the water used by the City of Phoenix came from the Salt and Verde Rivers, and the Tonto National Forest.[26] In keeping with its purpose, the TNF must be managed to maximize the productivity of the watershed, facilitate ongoing Reclamation Project operations and maintenance and enable SRP to meet water and energy supply needs and challenges through the development of innovative water and hydropower solutions.

3. The Agreements among SRP, TNF and Reclamation are Intended to Ensure that the Purposes of the Reclamation Project will be Furthered, Integrated with, and Not Compromised by Forest Management Activities.

The 2017 Master Interagency Agreement Number 86-SIE-004 between Reclamation and the Forest Service ('2017 Master Agreement") requires that the TNF and Reclamation collaborate on planning, developing, operating, and maintaining Reclamation projects and related programs *located on or affecting* lands and resources administered by the Forest Service.[27] The 2017 Master Agreement further provides for Forest Service planning and implementation of activities on NFS lands within the total area of Reclamation project influence.[28] The Tri-Party Agreement likewise requires the TNF, Reclamation and SRP to collaborate regarding forest management.[29] The specific purpose of the Tri-Party Agreement is to set guidelines for coordinating the activities of SRP, Reclamation, and the TNF, and thereby ensure that multiple uses, public recreation, aesthetic protection, enhancement of wildlife, planning,

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[22] *See Id* ("Excepting from the force and effect of this proclamation all lands which may have been, prior to the date hereof, embraced in any legal entry or covered by any lawful filing duly of record in the proper United Stated Land Office.").
[23] *See* Forest Plan, at 4.
[24] *Id*.
[25] *Id*.
[26] *See Id*.
[27] The 2017 Master Agreement replaced and succeeded similar agreements between the Forest Service and Reclamation in 1948 and 1972.
[28] *See* 2017 Master Agreement.
[29] *See* Tri-Party Agreement.

management, environmental compatibility, public access and use, and security of Reclamation Project works, will be undertaken and maintained consistent with the responsibilities of each of the parties.

In its previously filed comments, SRP urged the TNF to refrain from encumbering withdrawn or adjacent lands with management designations that would preclude Reclamation and SRP from exercising their authority under the Reclamation Act, the 1917 Agreement, or the Tri-Party Agreement in furtherance of Reclamation Project purposes. As we noted in our comments, Reclamation Project infrastructure and facilities located within withdrawn and adjacent areas are essential to the reliable and sustainable operation of water storage facilities and electric power generation and transmission. Unencumbered access to these areas is essential to performing these functions and will only become more important in the coming decades as the Reclamation Project facilities on the Salt River enter their second century of service.

SRP appreciates the Forest Plan's exclusion of withdrawn lands within the TNF from wilderness recommendations and "wild and scenic" classifications. At the same time, the Forest Plan recommends the CMRWA site as wilderness. The recommendation does not properly consider the importance of these "adjacent areas" to the fulfillment of the Congressionally authorized Reclamation Project purposes. As explained in this objection, we remain concerned that the recommendation of the CMRWA site as "wilderness" will interfere with the maintenance of Reclamation Project facilities. Equally important, the recommendation imposes insurmountable obstacles to the Reclamation Project's development of power infrastructure that would increase the generation of renewable and carbon free energy. The recommendation conflicts with the original intent of Congress in authorizing the Reclamation Project and would hinder the ongoing efforts of the White House, U.S. Department of Agriculture ("USDA"), Forest Service, Reclamation and SRP to reduce carbon emissions.

4. The Continued Development of Hydropower and Power Infrastructure is Critical to the Fulfillment of the Congressionally Authorized Reclamation Project Purposes, particularly at a Time When Arizona's Water and Power Resources are in Short Supply and Climate Change is Worsening this Shortage.

The water and power industry in Arizona and the Southwest is constantly evolving. Reclamation and SRP need flexibility to access, operate, and maintain Reclamation Project facilities on TNF-managed lands. Increased demand for renewable energy generation, coupled with projected growth in SRP's reservoir district will require SRP to upgrade and replace aging infrastructure or develop new infrastructure. Moreover, expansion of Reclamation Project infrastructure, including the potential development of additional pumped storage capacity, on "adjacent" lands managed by the TNF should be expected. SRP is committed to working with the TNF and other stakeholders to ensure that the Reclamation Project's essential water storage and power generation functions will serve Arizona's resource needs. However, SRP is concerned that the Forest Plan will restrict SRP's ability to develop, operate, and maintain hydropower generation and power infrastructure necessary to meet the growing population and changing climate of Arizona in the future.

As SRP transitions to renewable generation resources, the expansion of the Reclamation Project to incorporate larger capacities of pumped storage is crucial. Reclamation has recognized that pumped storage is "one of the most useful methods for regulating intermittent renewable generation resources such as wind and solar."[30] Wind and solar energy sources are subject to natural variability that can create challenges for integration into the larger power grid. Wind and solar generation can change suddenly which affects moment-to-moment power output and increases the balancing requirements of dispatchable resources. Peak wind and solar generation also typically occur during off-peak demand periods and are not sufficient during the hours of SRP's peak load. Pumped storage is an efficient means to store energy when power is available and to generate power with the stored energy when it is needed. The Reclamation Project currently includes a 119 MW pump-back storage unit at Horse Mesa Dam and a 57 MW pump-back storage unit at Mormon Flat Dam. However, increasing the pumped storage capacity on the Reclamation Project would allow SRP to increase the use of renewable energy to meet customer energy demands, replace existing fossil fuel generating facilities, improve grid reliability, and avoid potential interruptions in energy supply.

In the 2014 Reclamation PSP Study, Reclamation sought to identify locations at Reclamation-owned reservoirs where a pumped storage project may be technically, environmentally, and economically viable and could contribute to meeting renewable energy and greenhouse gas reduction objectives in the future. The study identified two locations within the TNF utilizing Apache Reservoir, including the Apache Lake PSP Site as a top ranked option. The Apache Lake PSP Site has the potential to generate between 1,100 and 2,200 MW of pumped storage hydropower capacity for an energy storage duration of 10-12 hours. Reclamation owns 348 reservoirs across 17 western states. Reclamation first screened the 348 reservoirs for potential pumped storage projects based on the size of the active storage pool and topography. Reclamation identified 203 alternatives at 60 sites and developed conceptual layouts, cost opinions, operational, regulatory, and environmental screenings, and economic evaluations for 108 alternatives. The Apache Lake PSP Site, which is located in the CMRWA, was ranked third out of 108 alternatives (See Figure 1, below). SRP urges the TNF to adopt a plan that enables Reclamation and SRP to evaluate and, if feasible, develop pumped storage infrastructure at the Apache Lake PSP Site, to support the reliable expansion of renewable energy for central Arizona. As discussed in Section C, these efforts would stall if the CMRWA site is retained in the TNF Plan as recommended wilderness.

[30] *See* 2014 Reclamation PSP Study.

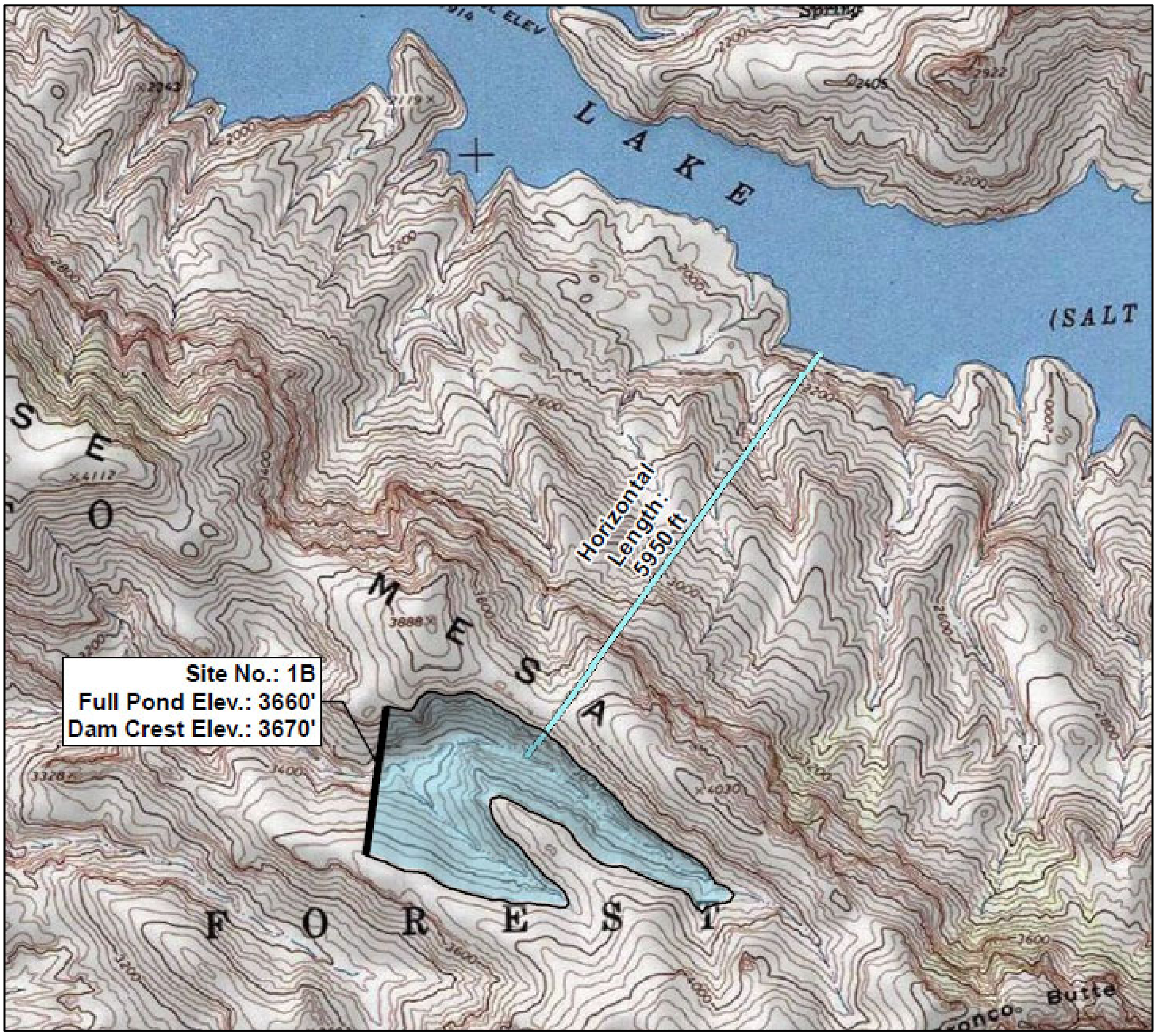

Figure 1. Apache Lake PSP Site (Apache 1B Site Configuration)

Figure 1 depicts the general location of the upper reservoir for the Apache Lake PSP Site (Apache 1B pump storage configuration considered by Reclamation in the 2014 Reclamation PSP Study. Portions of the Apache Lake PSP Site and surrounding area necessary for access fall within the CMRWA.

5. SRP Shares the Goals of the White House, USDA, Forest Service, and Reclamation to reduce Carbon Emissions over time as a Strategy, in part, to address the Impacts of Climate Change; Areas such as the CMWRA are key to SRP meeting those Goals.

The Biden Administration has placed a high priority on interagency efforts to reduce carbon emissions and increase resilience to the effects of climate change through the deployment of "clean energy technologies and infrastructure."[31] In keeping with that prioritization, the recently passed Inflation Reduction Act incentivizes stand-alone energy storage projects such as the pumped storage project under

[31] Exec. Order No. 14008, 86 Fed. Reg. 7619 (February 1, 2021).

consideration.[32] Responding to these directives, the Department of the Interior continues to prioritize the decarbonization of the nation's economy and the full transition to a clean energy future.[33] The USDA has expressed similar intentions to increase climate resiliency in the West by improving watersheds and water supply in rural areas. [34] Likewise, the Department of Energy has recommended an analysis of incentives for modernizing the "existing hydropower fleet, powering non-powered dams, and development of pumped storage hydropower" to aid in the clean energy revolution.[35]

Cohesive climate action across multiple agencies markedly intersects with SRP's longstanding hydroelectric power production. SRP is committed to expanding its renewable energy resources and to reduce its fossil fuel energy resources to reduce carbon emissions in ways consistent with this comprehensive federal agenda addressing the climate crisis. SRP expects to transform its power generation resource portfolio over the coming decade and beyond to address climate challenges and achieve the sustainability goals established by SRP's Board of Directors. SRP's sustainability goals include reducing carbon intensity of its generation portfolio by 90% from 2005 levels by the year 2050, reducing waste and improving sustainability of its supply chain, and enhancing customer programs and options while maintaining grid reliability and customer satisfaction. In addition to addressing sustainability concerns, the anticipated changes to SRP's power resource portfolio are driven by the significant increase in demand expected in SRP's service territory.

SRP will achieve these twin objectives through multiple initiatives, including the retirement of aging carbon-emitting generation resources and the coordinated deployment of renewable generating resources and grid-scale energy storage. To date, SRP has retired 1,300 MW of baseload coal generation from its portfolio, and SRP has committed to retiring an additional 1,300 MW by 2032. SRP's latest Resource Plan also includes nearly 7,000 MW of solar generation and over 6,000 MW of 4-hour battery storage online by 2033 to ensure grid reliability. As SRP retires baseload resources and adds significantly more solar to its power system, there will be a need for longer-duration energy storage to conserve excess solar generated during the day and dispatch it overnight, thereby ensuring reliable electric service around the clock. SRP hydroelectric generation in the TNF through the implementation of pumped storage projects thus furthers the mutual interests of the Reclamation Project and the federal agencies in climate resiliency and renewable energy technology.

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[32] *See* National Hydropower Association Statement on Passage of Inflation Reduction Act (August 16, 2022) https://www.hydro.org/news/nha-statement-on-passage-of-inflation-reduction-act/.

[33] Press Release, Interior Department Outlines Roadmap for Continued Renewable Energy Progress on Public Lands, (Apr. 20, 2022) Interior Department Outlines Roadmap for Continued Renewable Energy Progress on Public Lands | U.S. Department of the Interior (doi.gov); Department-Wide Approach to the Climate Crisis and Restoring Transparency and Integrity to the Decision-Making Process, Sec. Order No. 3399, (Apr. 16, 2021) SO 3399 Climate Crisis Transparency and Integrity to Decision-Making Processes (doi.gov).

[34] Press Release No. 0240.21, U.S. Dept. of Agriculture, Statement from Agriculture Secretary Tim Vilsack on the Passage of the Infrastructure Investment and Jobs Act, (Nov. 6, 2021) Statement from Agriculture Secretary Tom Vilsack on the Passage of the Infrastructure Investment and Jobs Act | USDA.

[35] DEPT. OF ENERGY, AMERICA'S STRATEGY TO SECURE THE SUPPLY CHAIN FOR A ROBUST CLEAN ENERGY TRANSITION, U.S. DEPARTMENT OF ENERGY RESPONSE TO EXECUTIVE ORDER 14017, "AMERICA'S SUPPLY CHAINS" (Feb. 24, 2022) America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition FINAL.docx 0.pdf.

C. SRP's Objections to the Forest Plan's Designation of the CMRWA as a Special Management Area.

1. The Recommendation to Designate the CMRWA as Recommended "Wilderness" Would Inhibit SRP's Efforts to Develop the Apache Lake PSP Site for Pumped Storage Hydropower in Furtherance of Congressionally Authorized Reclamation Project Purposes and Compromise SRP's Efforts to Maintain and Improve Aging Water and Power Infrastructure in or Adjacent to the Site.

SRP previously submitted comments to the TNF regarding Recommended Wilderness Areas ("RWA") during the Plan Revision Process. As indicated in its previous comments, SRP generally supports the recommendation for additional wilderness areas within the TNF and the TNF's selection of Alternative B (modified) in the Draft ROD.[36] However, SRP believes that the inclusion of the CMRWA in the National Wilderness Preservation System ("NWPS") would inhibit the ability of the Reclamation Project to achieve Congressionally authorized purposes, including the addition of long duration energy storage assets at the Apache Lake PSP Site. Fundamental to the TNF's purpose is the management of TNF lands to enable the fulfillment of the Reclamation Project's purpose, as provided in the 1905 Presidential Proclamation and management agreements among SRP, TNF and Reclamation. As the 2014 Reclamation PSP Study emphasizes, the Apache Lake PSP Site (located with the CMRWA) presents one of the best opportunities for pumped storage development across Reclamation's 348 reservoirs in the western United States. SRP also believes there are strong alternative TNF lands to the CMRWA site that meet the criteria for wilderness outlined by the TNF planning documents. For these reasons, SRP requests that the TNF revise the Draft ROD to exclude the CMRWA site from selected Alternative B (modified). TNF may consider adding alternative Wilderness Area recommendations considered through the Forest Planning Process.

The Draft ROD should be revised to omit the CMRWA from the selected Alternative B (modified) because inclusion of the area in the NWPS is inconsistent with the management direction of the Forest Plan.[37] As described in the Forest Plan, the TNF intends to manage Recommended Wilderness Areas ("RWA") to retain or improve the wilderness characteristics of these areas if and until they are considered for designation by Congress. They are, in effect, to be managed as designated wilderness areas until such time as Congress acts on a formal designation. Given the restrictive management of RWAs, recommending the CMRWA for inclusion in the NWPS would inhibit furthering feasibility investigations at Horse Mesa within the Apache Lake PSP Site.

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[36] *See* Draft ROD at 10. (Recommending five Recommended Wilderness Areas (106,441 acres) for inclusion in the National Wilderness Preservation System: (1) Gun Creek Recommended Wilderness; (2) Boulder Recommended Wilderness (3) Coronado Mesa Recommended Wilderness; (4) Red Creek Recommended Wilderness; and (5) Mullen Mesa Recommended Wilderness)

[37] *See* Draft ROD at 12.

The Multiple–Use Sustained–Yield Act ("MUSYA") and the National Forest Management Act ("NFMA") require the TNF to manage lands for multiple uses.[38] The Draft ROD expresses an intention to balance multiple uses, including recreation opportunities, natural resource management, economic contributions, partnerships, and designated and recommended management areas. The inclusion of the CMRWA in Alternative B (modified) deviates from this objective. The decision to recommend the CMRWA is not in the best interest of the American public as it would frustrate SRP's efforts to increase deployment of renewable resources and reduce carbon emissions. We submit that a modification by the TNF to remove the recommendation of CMRWA site would be more consistent with the MUSYA and NFMA objectives.

The Forest Plan identifies the Desired Conditions (RWMA-DC), Standards (RWMA-S) and Guidelines (RWMA-G) ("DCSGs") for the management of RWA in the TNF.[39] RWMA-S-03 states that "[n]ew energy developments or authorizations shall not be permitted within recommended wilderness areas."[40] And RWMA-G-08 states that "[n]ew permanent improvements should not be authorized in recommended wilderness areas unless necessary for public health and safety, resource protection, or viability of valid existing rights and authorized uses."[41] If the CMRWA site is required to be managed under these constraints, the permissions required from the TNF to further investigate the feasibility of the Apache Lake PSP Site, regardless of any other considerations will be inhibited. Consequently, the direct benefits to central Arizona of such a pumped storage project in enabling large-scale solar development and the broader benefits to the American public of reduced carbon emissions would be inhibited by the Forest Plan, which would likely prohibit TNF from authorizing SRP to construct a pumped storage project within the CMRWA or any other future improvements to the Reclamation Project itself within the CMRWA. Given the CMRWA's proximity to the Reclamation Project works on the Salt River and other facilities along the Apache Trail, this scenario is deeply concerning to SRP.

Climate change, together with the growing demand for water and renewable electric power in central Arizona, are requiring SRP to evaluate upgrades of the water and power infrastructure within or adjacent to the CMRWA. The existing Reclamation Project facilities have been in operation since the first half of the 20th century and the next century of successful service will require continued maintenance and upgrade of facilities. To continue to meet the Congressionally authorized purposes of the Reclamation Project, including potential upgrades to water and power infrastructure, such as the contemplated development of the Apache Lake PSP Site, it is likely that construction activities, infrastructure placement, and the expansion of existing rights-of-ways ("ROW"), within the CMRWA would be required.

SRP recognizes that these activities could require a National Environmental Policy Act ("NEPA") process and special use permits, depending on the relationship of such infrastructure to the Reclamation

[38] *See* 16 U.S.C. §§ 528–31; *see also* 16 U.S.C. §§ 1600–14.
[39] *See* Forest Plan at 136.
[40] *Id.* at 137.
[41] *Id*.

Project. However, these types of facilities already exist in the vicinity of the CMRWA and are critically important to the continued economic vitality of the Salt River Valley. Once constructed, these facilities would require regular maintenance, reconstruction, and upgrades in the future. A buffer between the CMRWA and existing infrastructure simply is not adequate to make possible the future construction of a pumped storage project to combat climate change or other expansion needs along this very essential power line corridor. Thus, SRP believes that the inclusion of the CMRWA in Alternative B (modified) is inconsistent with the decision rationale articulated in the Draft ROD and requests that the entirety of the CMRWA be removed as a recommendation.

2. The CMRWA does not Support a Wilderness Recommendation Considering the Specific Information Provided Herein about the Apache Lake PSP Site and Applying the Wilderness Characteristics Criteria

SRP also suggests that TNF's evaluation of the CMRWA's wilderness characteristics should yield a different result considering the information provided about the Apache Lake PSP Site. Chapter 70 of the Forest Service Land Management Planning Handbook ("FSH") 1909.12 describes the process and criteria used by TNF to determine whether the CMRWA site should be recommended for "wilderness" designation and inclusion in the NWPS pursuant to the Wilderness Act.[42] The process has four steps: (1) inventory; (2) evaluation; (3) analysis; and (4) recommendation. In Spring 2017, the TNF began an inventory of lands within the forest that "may be suitable for inclusion in NWPS." In October 2017, the TNF evaluated the areas identified in the inventory and ranked the areas based on their wilderness characteristics. The criteria used by the TNF to evaluate and rank the areas were derived from the "definition of Wilderness provided in the Wilderness Act of 1964," identified in FSH 1909.12, Chapter 70, Section 72.1. TNF also utilized input from the TNFs resource specialist and the public.[43] Each polygon was assigned an "overall ranking of the wilderness characteristic it possesse[d]: HIGH, MODERATE, LOW, or NO."[44] Rankings were determined using a point system based on the "apparent naturalness, opportunities for solitude or unconfined recreation, and manageability" of each polygon.[45]

For the CMRWA (polygon 32), the TNF determined that the area had a "HIGH" level of wilderness characteristics based on a perfect score of 12 points.[46] SRP submits that applying such criteria to the CMRWA based on the specific information provided in this letter, including the areas the proximity to existing project works, Reclamation Withdrawn Lands, and the potential for use of the Apache Lake PSP Site for a pumped storage project, supports a conclusion that the CMRWA should not be designated as recommended wilderness.

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[42] *See* 16 U.S.C. §§ 1131–36 (The "Wilderness Act").
[43] The criteria used to evaluate inventoried areas within the TNF are described in the "Final Evaluation Process Documentation and Criteria for the Tonto National Forest Wilderness Recommendation Process." (herein "Evaluation Criteria").
[44] *See* Evaluation Criteria at 6
[45] "NO = 0-2.99, LOW = 3-5.99, MODERATE = 6-8.99, HIGH = 9+. *See Id*.
[46] Twelve points is the maximum score possible.

D. Conclusion

SRP recognizes the tremendous effort that has gone into TNF Plan Revision Process and greatly appreciates the opportunity to comment on the Forest Plan, FEIS, and Draft ROD. The development of this Forest Plan is very important to SRP due to our operation of the Reclamation Project and the many laws and agreements that define the collaborative relationship among SRP, Reclamation and the TNF. Our objection focuses on the specific aspects of the Forest Plan that we believe would frustrate the fulfillment of Reclamation Project purposes, specifically, the development and delivery of reliable, sustainable water and power. If you or your team have any questions, please do not hesitate to contact Kara Montalvo, Director Environmental Services, at 602-236-5256 (Kara.Montalvo@srpnet.com) or Ron Klawitter, Senior Principal Water System Projects, at 602-236-2182 (Ronald.klawitter@srpnet.com) for technical questions.

Very truly yours,

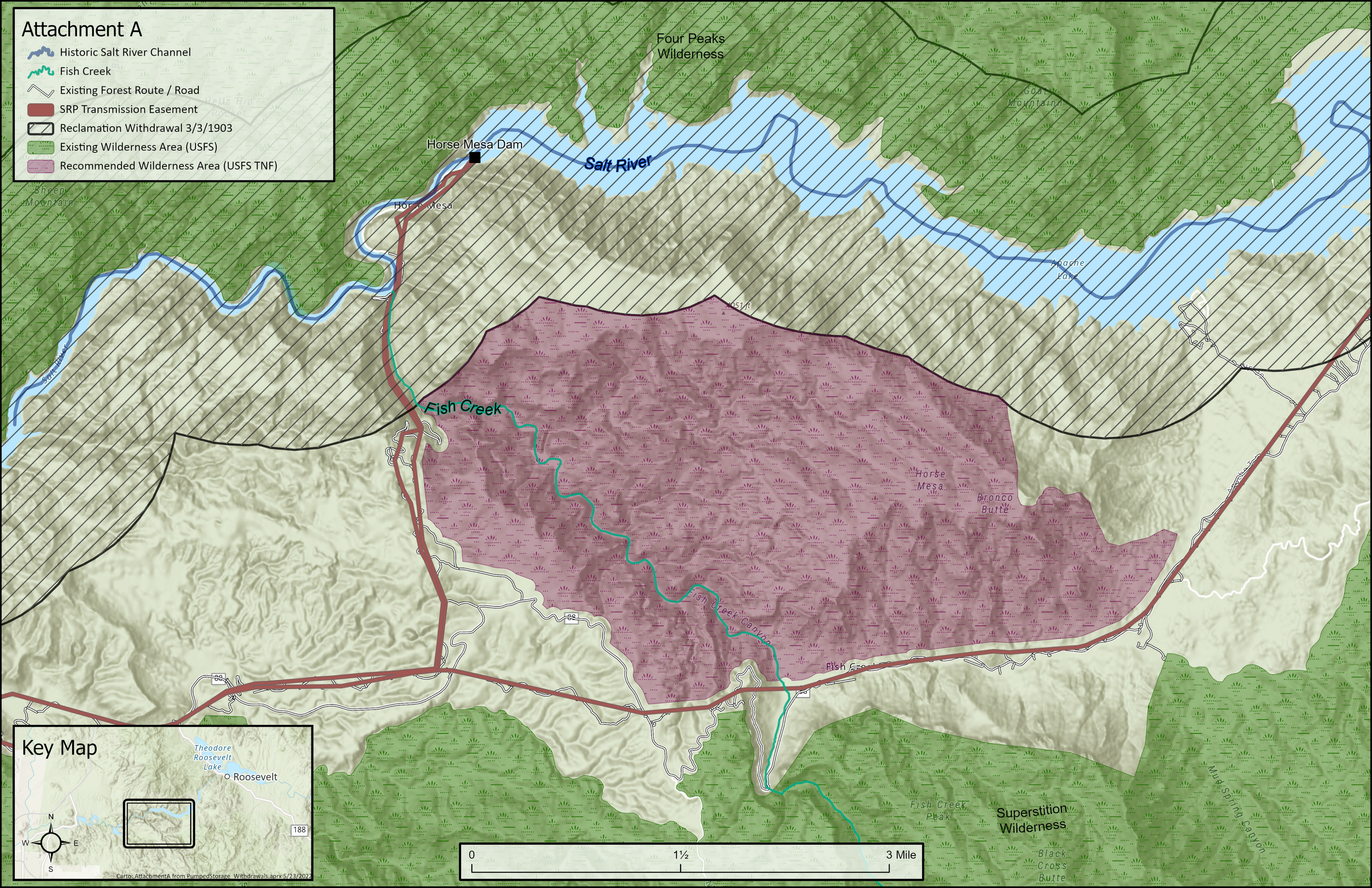
Kara M. Montalvo
Director Environmental Services

Enclosures

cc:
Alex Smith, Deputy Area Manager, Bureau of Reclamation

Attachment A

Map of CMRWA and Proximity to Project Works and Reclamation Withdrawn Lands



Attachment A
Historic Salt River Channel
Fish Creek
Existing Forest Route / Road
SRP Transmission Easement
Reclamation Withdrawal 3/3/1903
Existing Wilderness Area (USFS)
Recommended Wilderness Area (USFS TNF)
Four Peaks Wilderness
Goat Mountain
Horse Mesa Dam
Salt River
Sheep Mountain
Horse Mesa
Apache Lake
Salt River
Fish Creek
Horse Mesa
Bronco Butte
Fish Creek Canyon
88
88
Key Map
Theodore Roosevelt Lake
Roosevelt
188
N
W
E
S
Fish Creek Peak
Superstition Wilderness
Mud Spring Canyon
Black Cross Butte
0
1½
3 Mile
Carto: AttachmentA from PumpedStorage_Withdrawals.aprx 5/23/2022

Attachment B

Reclamation-Wide Pumped Storage Screening Study

Final Report

September 2014

Bureau of Reclamation

RECLAMATION
Managing Water in the West

Reclamation-Wide Pumped Storage Screening Study

Final Report

U.S. Department of the Interior
Bureau of Reclamation Power Resources Office
Denver, Colorado

September 2014

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

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

Reclamation-Wide Pumped Storage Screening Study

Final Report

Prepared by

HDR-CDM Joint Venture

Prepared for

United States Department of the Interior
Bureau of Reclamation
Power Resources Office

U.S. Department of the Interior
Bureau of Reclamation Power Resources Office
Denver, Colorado

September 2014

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Errata to

Reclamation-Wide Pumped Storage Screening Study

Final Report

The errata corrections listed below apply to the Reclamation-Wide Pumped Storage Screening Study Final Report.

Errata	Page(s)	Location(s)	Summary of Change(s)
1.1	ES-7	Table ES-1	Table has been revised to reflect updated overall ranking of the top 15 pumped storage alternative sites
1.1	4-6	Table 4-3	Table has been revised to reflect updated Power Plant Equipment and subsequent costs for Lower Colorado Region alternative sites
1.1	6-2 through 6-4	Table 6-1	Table has been revised to reflect updated cost ranking of all 108 pumped storage alternative sites
1.1	7-2 through 7-4	Second paragraph and Table 7-1	Text and table have been revised to reflect updated $/MW installed capacity and overall ranking of all 108 alternative sites
1.1	7-5 through 7-7	First paragraph and Table 7-3	Text and table have been revised to reflect updated top 10 ranked alternative sites
1.1	7-8	Second paragraph	Text has been revised to reflect updated Yellowtail 5A alternative ranking from "8th" to "2nd"
1.1	7-10	First bullet list entry	Text has been revised to correct the typo of "our" to "or" and update the table number reference of "4.3" to "4-6"
1.1	7-13 through 7-22	Table 7-2	Table has been revised to reflect updated construction cost, $/MW installed capacity, cost ranking, and overall ranking of all 108 pumped storage alternative sites
1.1	B-21	Table B-39	Table has been revised to reflect updated power equipment costs for the Lower Colorado alternative sites
1.2	A	Table A	Inclusion of Pacific Northwest Site Location and Layout Maps

U.S. Department of the Interior
Bureau of Reclamation Power Resources Office
Denver, Colorado

September 2020

Executive Summary

ES.1 Background

The Bureau of Reclamation (Reclamation) is the largest water supplier in the United States, owning and operating 187 projects across the western states with dams, reservoirs, canals, and other distribution infrastructure. Reclamation is the second largest producer of hydropower in the United States, behind the United States Army Corps of Engineers (USACE), and owns and operates 53 hydropower plants that produce over 40,000,000 megawatt hours (MWh) of generation each year. Reclamation is interested in the potential to use existing facilities as the lower pool and new off stream upper impoundments to act as the upper pool to develop pumped storage projects. Pumped storage is recognized as one of the most useful methods for regulating intermittent renewable generation resources such as wind and solar.

ES.2 Purpose of this Study

Reclamation has undertaken this Reclamation-Wide Pumped Storage Screening Study to investigate the potential for pumped storage projects at existing Reclamation-owned reservoirs. This study is a resource assessment to identify locations throughout Reclamation's service area where a pumped storage project may be technically, environmentally and economically viable and could contribute to meeting renewable energy objectives in the future. It represents a preliminary screening level of analysis and is not a feasibility level investigation. Reclamation can use these study results in the future to initiate further study of a particular site or sites if there is sufficient interest to develop pumped storage and market conditions are supportive.

ES.3 Sites Identified for Study

Reclamation owns 348 reservoirs across 17 western states. Reclamation first screened the 348 reservoirs for potential pumped storage projects based on the size of the active storage pool and topography. The lower existing reservoir must allow for frequent fluctuations of water levels for pumped storage without affecting existing operations for water supply, hydropower, environmental, or other reservoir uses. Reclamation defined a minimum active storage volume of 100,000 acre-feet (AF) for a lower reservoir to avoid any impacts to existing water uses while supporting pumped storage operations. The second preliminary screening criteria was that surrounding topography must support an upper reservoir site and allow for an adequate water conduit length (L) to operating head (H) ratio for pumped storage operations. Reclamation completed a preliminary analysis of topography and L/H ratio using Geographic Information Systems (GIS) to screen the sites for potential pumped storage. Applying these two criteria reduced the number of potential sites for pumped storage from 348 existing reservoirs to 60 reservoir sites. These 60 reservoir sites are the subject of the screening evaluation described in this study.

The reservoirs are spread across Reclamation's five regions: Great Plains (11 sites), Upper Colorado (13 sites), Lower Colorado (8 sites), Mid-Pacific (13 sites), and Pacific Northwest (15 sites) regions. Figure ES-1 shows the reservoirs evaluated in this study.

ES.4 Site Evaluation

As described above, Reclamation initially identified 60 existing reservoirs for a potential pumped storage project. Reclamation then implemented the following steps to further evaluate the sites for pumped storage.

Identify Preliminary Alternatives

Reclamation identified a range of potential pumped storage alternatives at each existing reservoir site. Each alternative includes an upper reservoir site and associated pumped storage infrastructure. Upper reservoir sites were selected to avoid urban and populated areas and use topographic features suitable for dam construction and reservoir impoundment. Each upper reservoir site was sized based on existing active reservoir storage and volume, surrounding topography, historic lake elevations, dam characteristics and additional existing data. The number of alternatives for each reservoir varies based on available topography for an upper reservoir site. If topography did not allow for an upper reservoir or the upper reservoir was too far away and did not provide sufficient operating head, then the existing reservoir did not have any alternatives and was dropped from the analysis. There were 203 total alternatives developed for all reservoirs. Figure ES-1 lists the number of alternatives initially developed for each reservoir (the first number listed after the reservoir name).

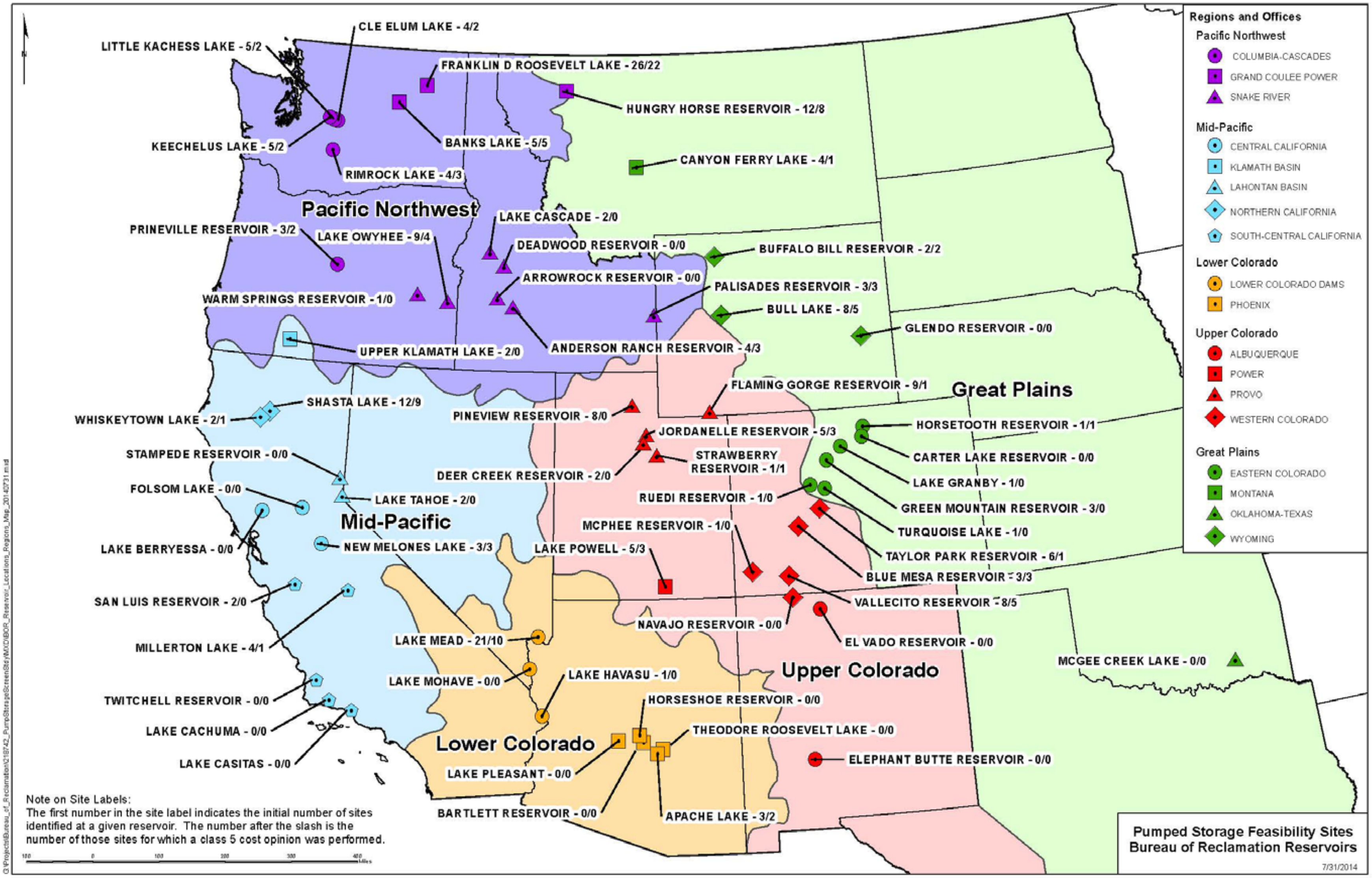

Figure ES-1 Potential Pumped Storage Reservoirs and Alternatives

Screen Preliminary Alternatives

After the initial list of alternatives were identified and sized, the project team screened the alternatives relative to technical criteria, such as:

- L/H ratio: the L/H ratio examines the relationship between the length of the conduit between reservoirs (L) and the head difference (H). Larger L/H ratios are less efficient for pumped storage operations.
- Energy storage: Energy storage created by the project must be large enough for consideration. Alternatives that offered relatively small potential energy storage were screened out.
- Resulting installed capacity: Similar to energy storage, the resulting installed capacity (measured in megawatts (MW)) must be large enough for consideration. Alternatives with relatively small installed capacity were screened out.
- Estimated dam volume: The estimated dam volume needs to be reasonable relative to the general size of the project because larger facilities increase costs and environmental effects. Larger dams were screened out.

This step also included a fatal flaw screening for environmental or operations issues based on discussions with Reclamation staff at each area office. Sites where the upper reservoir is a large percentage of the lower reservoir have a greater potential to cause operational and environmental impacts; therefore, these sites were screened out. A total of 108 alternatives remained after this screening step. Figure ES-1 lists the number of remaining alternatives for each reservoir (the second number listed after the reservoir name).

Prepare Preliminary Cost Opinions

The project team further developed the remaining alternatives and completed preliminary cost opinions in order to develop a relative comparison of costs among the alternatives. Cost opinions were developed for major project elements assuming variable-speed technology. Variable speed technology was selected over single speed technology due to its unique ability to integrate intermittent renewable generation resources in both the generation and pump mode.

Evaluate Operations, Environmental, and Regulatory Impacts

For those alternatives that passed the initial screening, the project team collected information on operations criteria, regulatory setting, environmental resources, and existing stakeholder issues. The operations evaluation considered the potential to cause water supply or water quality impacts, which would generally be greater when the size of the upper reservoir is a larger percentage of the lower reservoir. Additionally, the evaluation considered whether the lower reservoir was part of a larger interconnected system that could be affected by a new pumped storage facility. The environmental and regulatory evaluation considered potential effects to environmental resources, existing land uses, cultural and historic resources, and Indian Trust Assets from the construction and operation of pumped storage at each site. The team evaluated each alternative relative to qualitative rating scales that allow for a ranking of how these factors could challenge development of an alternative.

Assess Economic Viability

The economic evaluation is a cost effectiveness comparison and a qualitative evaluation of some economic or market characteristics, such as project location relative to an existing market for ancillary services and the potential for integration of renewable resources. Ancillary services, including regulation, generally provide the most revenue from a pumped storage facility relative to energy arbitrage. Therefore, pumped storage facilities will be more economically viable in areas with wind and solar generation, demand for renewable power, and have existing (or potential future) ancillary power markets. The cost effectiveness analysis uses the estimated dollar per megawatt ($/MW) for each alternative as a comparison.

Combine Technical, Environmental, and Economic Evaluations

The project team developed a summary table to compare how alternatives perform relative to the technical, operations, environmental, and regulatory criteria. Some alternatives appeared to better meet the suite of criteria relative to others. The alternatives were also ranked based on cost effectiveness alone and the entire suite of screening criteria. This ranking will facilitate Reclamation to make future decisions on potential pumped storage investigations. Table ES-1 shows the information for the 15 alternatives based on the overall screening evaluation.

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Table ES-1. Top 15 Ranked Pumped Storage Alternatives

Region	Lower Co.	Pacific NW	Lower Co.	Pacific NW	Pacific NW	Upper Co.	Upper Co.	Mid-Pacific	Lower Co.	Lower Co.	Pacific NW	Pacific NW	Lower Co.	Pacific NW	Lower Co.
Site	**Mead**	**Hungry Horse**	**Apache**	**Little Kachess**	**Hungry Horse**	**Flaming Gorge**	**Lake Powell**	**Shasta**	**Mead**	**Mead**	**Hungry Horse**	**Franklin D Roosevelt**	**Mead**	**Owyhee**	**Apache**
Alternative	2D	1B	1B	3B	7B	2F	1B	5A	7D	9C	9B	4	3	5	1C
Technical Screening															
Upper Reservoir Usable Vol (AF)	12,000	15,700	11,600	10,550	5,700	14,800	12,700	18,900	14,500	7,400	23,000	24,600	12,800	7,300	9,300
Lower Reservoir Usable Vol (AF)	17,350,000	29,982,026	245,138	239,000	29,982,026	3,515,500	320,000	3,970,000	17,350,000	17,350,000	5,185,000	5,185,000	17,350,000	715,000	245,138
Upper Reservoir/Lower Reservoir (%)	0	1	5	4	0	0	4	0	0	0	0	0	0	1	4
Approx. Static Head (ft) (<2650 ft)	1,653	1,142	1,723	2,735	2,312	1,473	900	1,352	1,250	2,365	1,089	976	1,210	1740	1,713
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	1,745	2,285	1,759	2,539	2,328	1,918	2,210	2,248	1,595	1,540	2,085	2,650	1,363	1,118	1,402
Energy Storage (MWh)	17,453	15,778	17,588	25,393	11,597	19,178	10,058	22,478	15,953	15,402	22,031	21,128	13,632	11,177	14,019
Estimated Dam Volume (CY)	2,307,992	7,036,719	6,176,494	6,277,805	1,111,263	7,038,706	10,573,317	14,391,874	6,639,662	6,143,288	4,413,021	9,014,091	4,468,372	1,625,340	5,284,243
Maximum Dam Height (ft) (<400 ft)	294	317	347	236	126	132	399	297	330	330	226	399	400	96	326
L/H Ratio	5.81	7.7	4.56	3.72	6.15	4	10.43	4.94	5.87	4.92	8.67	7.7	5.19	4.25	4.58
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	0	0	< 12	< 12	< 12
Assumed Distance to Transmission (mi.)	5	5	30	5	5	20	50	10	5	5	40	40	5	25	30
Cost Opinions															
Construction Cost (million)	$2,399	$3,222	$2,546	$3,541	$3,414	$2,795	$3,226	$3,309	$2,462	$2,400	$3,202	$4,191	$2,158	$1,690	$2,266
$/MW Installed Capacity	$1,374,313	$1,410,023	$1,447,357	$1,394,322	$1,466,793	$1,457,510	$1,459,878	$1,472,148	$1,543,407	$1,557,980	$1,536,110	$1,581,488	$1,583,239	$1,512,410	$1,616,500
Cost Ranking based on$/MW	1	3	4	2	7	5	6	8	11	12	10	13	14	9	17
Operations and Environmental Criteria															
Water Supply and Release Requirements															
Water Quality/Temperature Requirements															
System Reoperation															
Special Status and Sport Fisheries															
Special Status Terrestrial Species/Sensitive Habitat															
Recreation															
Cultural and Historic Resources															
Native American Resources															
Land Use/Regulatory Designations															
Access/Construction Impacts															
Stakeholder Issues															
Environmental Ranking	3	3	3	7	3	6	6	6	3	3	6	4	3	9	3
Summary															
Overall Ranking	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Qualitative Criteria Rating Scale
"Green" indicates effects can likely be coordinated, avoided or mitigated
"Yellow" indicates effects might pose challenges
"Orange" indicates more serious potential for effects are not fatal flaws at this point in the analysis

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Comparison to Yellowtail, Seminoe, and Trinity Potential Pumped Storage Sites

In 2013, Reclamation completed an analysis of potential pumped storage projects at Yellowtail, Seminoe, Pathfinder, and Trinity reservoirs. The study involved two phases: Phase 1 was a screening evaluation similar to this Reclamation-wide pumped storage evaluation; and Phase 2 was a more detailed evaluation of technical, operations, and environmental aspects of the potential projects. Phase 2 focused on Yellowtail, Seminoe, and Trinity reservoirs. Based on the $/MW, Yellowtail 5A alternative ranks 8th among the Reclamation-wide sites, and the remaining sites rank outside of the top 15 sites. The cost for Yellowtail 5A alternative was $1.38 million/MW and the remaining four alternatives had costs ranging from $1.74 million/MW to $2.21 million/MW.

Considerations for Further Study

Prior to initiating more definitive studies on any of the sites, Reclamation should consider the following factors:

- Cost – The target $/MW cost for economically viable pumped storage projects should be in the range of equal to or less than $1.5 million to $2.0 million per MW. For comparison purposes, costs of past projects that have been implemented in the range of $0.8 million to $1.7 million per MW using single-speed technology. Variable speed technology is more expensive than single speed technology, but also provides increased benefits for renewable energy integration.

- Market Conditions – Monitoring market conditions and energy utilities short- and long-term plans is needed to understand an area's demand for a pumped storage project. In general, areas with higher demand for a pumped storage project include places where utilities are developing large-scale wind or solar projects that require energy storage, states with emerging or developed ancillary service markets, states with increasing renewable energy standards that will result in more wind and solar coming online in the future, and areas where utilities are anticipating substantial increases in energy demand. These are all changing conditions that affect the timing of a pumped storage project.

- Stakeholder Support – It is important to understand both support and opposition to a potential project. Projects could be in a regulatory environment with stakeholders that will not be supportive of a project. This could be for biological, fisheries, tribal, cultural, recreation or other purposes. Coordination with Reclamation area offices will help to understand local response to a potential pumped storage project.

- Agency Partnerships – There will be operations and environmental challenges in implementing any pumped storage project. Reclamation should first consider projects that have local interest and could provide mutual benefits to other state, federal, or local agencies. Other agencies could include local energy utilities, water districts, or state and federal agencies working to progress renewable energy development.

Contents

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Tables

Figures

Appendices

Abbreviations and Acronyms

AACE	American Association of Cost Estimators
ACEA	Area of Critical Environmental Concern
AF	Acre-Feet
AK	Alaska
Alt.	Alternative
AZ	Arizona
AZPS	Arizona Public Service Company
BLM	Bureau of Land Management
BMPs	Best Management Practices
BPA	Bonneville Power Administration
C	Rated Generating Capacity (MW)
CA	California
CFS	Cubic Feet per Second
CO	Colorado
CT	Connecticut
CY	Cubic Yard
D	Water Conduit Diameter (ft.)
DT	Draft Tube
EIR	Environmental Impact Report
Elev	Elevation
EPRI	Electrical Power Research Institute
ESA	Endangered Species Act
EST	Estimated
ft	Feet
FERC	Federal Energy Regulatory Commission
GA	Georgia
GC Power	Grand Coulee Power
GWh	Gigawatt Hour
GIS	Geographic Information System
H	Static Head
HVAC	Heating, Ventilation and Air Conditioning
IDPC	Idaho Power Company
km^2	kilometers
kV	Kilovolts

kW	Kilowatts
L	Conduit Length
m	Meters
MA	Massachusetts
MI	Michigan
mi	Miles
MO	Missouri
MSL	Mean Sea Level
MT	Montana
MW	Megawatts
MWD	Metropolitan Water District
MWh	Megawatt Hour
NC	North Carolina
NEPA	National Environmental Policy Act
NJ	New Jersey
NPS	National Park Service
NRA	National Recreation Area
NREL	National Renewable Energy Laboratory
NY	New York
O&M	Operations and Maintenance
OK	Oklahoma
PA	Pennsylvania
PG	Pacific Gas and Electric
PSCO	Public Service of Colorado
Q	Generating Discharge (cfs)
Reclamation	Bureau of Reclamation
ROD	Record of Decision
RPS	Renewable Portfolio Standard
SC	South Carolina
SCE	Southern California Edison
sec	Second
TN	Tennessee
TRRP	Trinity River Restoration Program
TSGT	Tri State G&T
TW	Tailwater
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service

YR	Year
V	Generating Velocity (ft./sec.)
VA	Virginia
Vol.	Volume
WA	Washington
WAPA	Water and Power Authority
$	Dollar
%	Percent
>	Greater Than
<	Less Than

Chapter 1 Introduction

1.1 Background

The Bureau of Reclamation (Reclamation) is the largest water supplier in the United States, owning and operating 187 projects across the western states with dams, reservoirs, canals, and other distribution infrastructure. Reclamation is the second largest producer of hydropower in the United States, behind the United States Army Corps of Engineers (USACE), and owns and operates 53 hydropower plants that produce over 40,000,000 megawatt hours (MWh) of generation each year. Reclamation is interested in the potential to use existing facilities as the lower pool and new off stream upper impoundments to act as the upper pool to develop pumped storage projects.

Pumped storage is recognized as one of the most useful methods for regulating intermittent renewable generation resources such as wind and solar. Wind and solar energy sources are subject to natural variability that can create challenges for integration into the larger power grid. Wind generation can change suddenly which affects moment-to-moment power output and increases the balancing requirements of dispatchable resources. Peak wind generation also typically occurs during off-peak demand periods and cannot support peak loads. Pumped storage is an efficient means to store energy when the demand for power is low and to generate power with the stored energy when the demand is high. Increased energy storage would also improve grid reliability, avoid transmission congestion periods, and avoid potential interruptions in energy supply.

In addition to providing energy storage, pumped storage can provide power immediately and can be rapidly adjusted to respond to changes in energy demands. These benefits are part of a large group of benefits, known as ancillary services. Reclamation has indicated that a primary objective for the proposed pumped storage projects would be to market ancillary services.

1.2 Purpose of this Study

Reclamation has undertaken this Reclamation-Wide Pumped Storage Screening Study to investigate the potential for pumped storage projects at existing Reclamation-owned reservoirs. This study is a resource assessment to identify locations throughout Reclamation's service area where a pumped storage project may be technically, environmentally and economically viable and could contribute to meeting renewable energy objectives in the future. It represents a preliminary screening level of analysis and is not a feasibility level investigation. Reclamation can use these study results in the future to initiate further study of a particular site or sites if there is sufficient interest to develop pumped storage and market conditions are supportive.

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1.4 Evaluation Methods

As described above, Reclamation initially identified 60 existing reservoirs for a potential pumped storage project. Reclamation then implemented the following steps to further evaluate the sites for pumped storage.

1. *Identify potential pumped storage alternatives and complete preliminary sizing.* This step involves identifying a range of potential pumped storage alternatives at each existing reservoir site. Each alternative includes an upper reservoir site and associated pumped storage infrastructure. Alternatives were sized based on existing active reservoir storage and volume, surrounding topography, historic lake elevations, dam characteristics and additional existing data. The number of alternatives for each reservoir varies based on available topography for an upper reservoir site. If topography did not allow for an upper reservoir or the upper reservoir was too far away and did not provide sufficient operating head, then the existing reservoir did not have any alternatives and was dropped from the analysis.

2. *Screen identified alternatives based on various technical criteria for pumped storage.* After the initial list of alternatives were identified and sized, the project team screened the alternatives relative to technical criteria, such as L/H ratio, reservoir depth, minimum head/maximum head ratio and other physical and operating characteristics. This step also included a fatal flaw screening for environmental or operations issues based on discussions with Reclamation staff at each area office.

3. *Prepare preliminary cost opinions for remaining alternatives.* The project team completed preliminary cost opinions for the remaining alternatives in order to develop a relative comparison of costs among the alternatives. Cost opinions were developed for major project elements assuming variable-speed technology. Variable speed technology was selected over single speed technology due to its unique ability to integrate intermittent renewable generation resources in both the generation and pump mode.

4. *Conduct a qualitative analysis for operations, environmental, and regulatory constraints.* For those alternatives that passed the technical screening, the project team collected information on operations criteria, regulatory setting, environmental resources, and existing stakeholder issues. The team evaluated each alternative relative to qualitative rating scales that allow for a ranking of how operations, environmental, or regulatory features that could challenge development of an alternative.

5. *Assess the economic characteristics of alternatives.* The economic evaluation is a cost effectiveness comparison and a qualitative evaluation of some economic or market characteristics, such as project location relative to an existing market for ancillary services and the potential for integration of renewable resources. The cost effectiveness analysis uses the estimated dollar per megawatt ($/MW) for each alternative as a comparison.

6. *Summarize evaluation results and rank alternatives for future analysis.* The project team developed a summary table to compare how alternatives perform relative to the technical, operations, environmental, regulatory, and economic criteria. Some alternatives appeared to better meet the suite of criteria relative to others. The alternatives were also ranked based on cost effectiveness alone and the entire suite of screening criteria. This ranking will facilitate Reclamation to make future decisions on potential pumped storage investigations.

1.5 Report Contents

In addition to this Introduction, this report includes the following chapters:

- **Chapter 2 Site Identification, Preliminary Sizing, and Technical Screening –** discusses how a wide range of pumped storage alternatives were initially identified and the first screening step to narrow the alternatives.

- **Chapter 3 Conceptual Layout and Cost Evaluation** – describes methods to develop conceptual layouts, including sizing, performing quantity take-offs, and generating Class 5 cost opinions for major project elements.

- **Chapter 4 Cost Opinions –** presents the cost opinions, including total construction costs, for each alternative.

- **Chapter 5 Operations, Regulatory, and Environmental Screening–** presents the methods and results for the operations, regulatory and environmental screening.

- **Chapter 6 Economic Evaluation –** summarizes the cost effectiveness of the alternatives and discusses market conditions to support a pumped storage project.

- **Chapter 7 Summary and Recommendation –** summarizes the screening results and presents a ranking of the alternatives for potential future pumped storage investigations.

- **Chapter 8 References –** lists the references used in development of this report.

- **Appendix A Site Location and Layout Maps**

- **Appendix B Cost Opinion Details**

- **Appendix C Variable Speed vs Single Speed Technology**

- **Appendix D Reclamation Area Office Comment Summary**

- **Appendix E Operations, Environmental, and Regulatory Descriptions**

- **Appendix F Operations, Environmental, and Regulatory Evaluations**

Chapter 2
Site Identification, Preliminary Sizing, and Technical Screening

This chapter describes how the initial pumped storage alternatives for each reservoir were identified and evaluated. A range of alternatives were developed at each of the reservoirs. This chapter also presents the results of the first screening step to identify the alternatives to be carried forward for cost opinions, operations, environmental, regulatory, and economic screening.

Each alternative includes the construction of a new upper reservoir to serve as a forebay. An existing reservoir would be used as an afterbay. This concept requires a pump-turbine/generator motor system, a new (upper) reservoir and other appurtenant facilities and equipment. For the purpose of this study, variable speed technology was assumed appropriate for grid integration of intermittent renewable generating resources such as wind and solar due to its unique ability to regulate in both the generation and pump mode.

2.1 Reservoir Data Collection

The following information for each of the 60 existing reservoirs was needed to identify alternatives:

- Surrounding Topography (GIS)
- Top of Active Reservoir Storage (feet [ft])
- Top of Inactive Reservoir Storage (ft)
- Active Reservoir Volume (ft)
- Historical Lake Elevations (ft)

2.2 Alternatives Identification

Based on the physical and project-related data that was collected, the project team performed topographic and reconnaissance screening studies to evaluate pump-generation potential. Using topographic and satellite maps, the project team began identifying potential alternatives based on the following key site criteria:

- Upper reservoir sites evaluated on the operating H and water L;
- Avoiding, where possible, urban and populated areas; and

- Topographic features suitable for dam construction and reservoir impoundment.

Some of the 60 reservoirs did not have any alternatives for upper reservoir sites based on the above criteria. These sites were dropped from the analysis. Figure 2-1 shows the number of alternatives identified for each of the reservoirs and the number of alternatives that moved on to the second screening step. There were 203 total alternatives developed for all the reservoirs. Appendix A includes site identification maps that show site locations and layouts for each reservoir and alternative.

For reservoirs with one or more alternatives identified, the project team completed preliminary sizing on these alternatives to help determine if they would be technically feasible. Alternatives were initially sized for various run times based on preliminary information such as usable reservoir volume and head differential, estimated based on the top of the active reservoir, top of inactive reservoir and historical lake elevations.

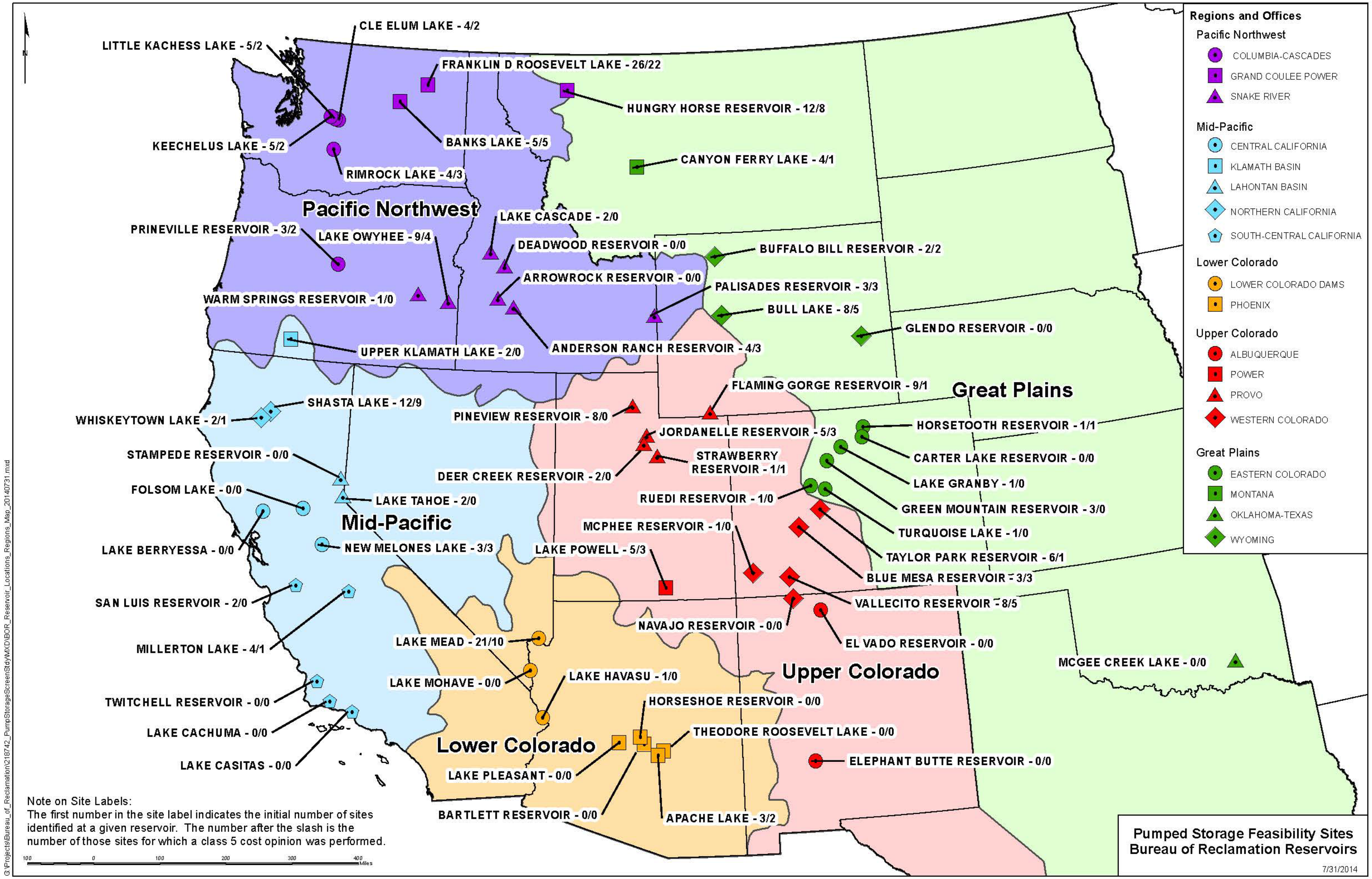

Figure 2-1. Potential Pumped Storage Reservoirs and Alternatives

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2.3 Preliminary Resource Sizing (MWh and MW)

To assist with screening each of the potential alternatives, the project team considered various upper reservoir locations and estimated the following characteristics for each:

- Embankment volumes
- Reservoir area-volume curves
- Reservoir drawdown characteristics and active storage
- Energy storage
- Installed capacities

These characteristics were examined using the methods listed below.

2.3.1 Dam Volume Estimates

The type of embankment structure is site specific and general the product of an in depth study that includes the following variables:

- Topography
- Geology and Foundation Conditions
- Material Availability
- Constructability
- Seismic Consideration
- Functional Requirements
- Appearance
- Schedule
- Costs

For the purpose of this study, all of the embankments were assumed to be rockfill concrete face structures because they function well in high seismic areas and rapid drawdown conditions. All dams are assumed to be constructed with a crest width of 30 ft. on slopes of 1.75H:1 volume (V) with 10 ft. of freeboard and 20 ft. of foundation preparation. The maximum allowable dam height was approximately 400 ft. The actual composition and geometry of embankments would be determined via more detailed and rigorous study efforts. All dam volumes were estimated from GIS-based digital topography.

2.3.2 Upper Reservoir Area-Volume

Upper reservoir area-volumes and drawdown were estimated from GIS-based digital topography.

2.3.3 Upper Reservoir Active Storage

Active storage was determined via topography information obtained from GIS-based digital topography.

Where necessary, the active volumes, heads, and reservoir operational limits were governed by the operational restrictions of pump-turbine design criteria to limit the minimum to maximum gross head ratio to 70 percent for variable speed technology.

2.3.4 Upper Reservoir Energy Storage

Energy storage within the upper reservoir was estimated using the following relationship:

$$E = 0.88\ HS \times 10^{-3}$$

Where: E = Energy Storage (Megawatt hours [MWh])

H = Average Gross Head (ft)

S = Active Storage (AF)

2.3.5 Capacity

Approximate generating capacity (MW) was estimated using the following relationship for hours of storage ranging from 10 to 40 hours:

C = E/Hours of Storage

Where: C = Rated Generating Capacity (MW)

E = Energy Storage (MWh)

2.4 Technical Screening

As part of the initial screening process, the project team compiled the following preliminary site characteristics for each alternative. Alternatives that appeared to offer the most development potential were then selected to move forward with conceptual layouts and Class 5 cost opinions. The following technical criteria were used for screening:

- Maximum L/H Ratio (Electric Power Research Institute [EPRI] Document No. GS-6669 [1990]) – For the purpose of site identification and initial screening, EPRI offers the following criteria utilizing the following relationship between operating H and water L. These criteria are guidelines and do not mean that if the L/H ratio is slightly more, the pumped storage project is infeasible. If the L/H ratio was close and other technical features of the option looked favorable, the alternative was not screened out.

Operating Head (ft.)	Maximum L/H Ratio
200 – 300	<5
300 – 500	<7
500 – 750	<10
750 and greater	<12

- Operating Range of Pump-Turbine Units (Minimum head/Maximum head) – For the purposes of this study, the minimum to maximum head ratio was limited to a value of 70 percent or greater reflecting an assumed maximum operating range of the turbines in the pump mode. The operational flexibility of the units in the generation mode is much greater. It should be noted that variable-speed unit technology was utilized for the purpose of developing conceptual layouts and capital cost opinions due to the availability and abundance of historical parametric cost data. The actual selection of a preferred unit technology is generally the product of more in-depth studies with consideration given to operational objectives, costs, and benefits.

- Energy Storage – Energy storage is the potential power generation of the project, measured in MWh. Energy storage created by the alternative must be large enough for consideration. Energy storage potential was generally compared across alternatives and to existing pump-generation projects.

- Resulting Installed Capacity – Installed capacities for each alternative were provided for run times of 10, 20, 30, and 40 hours. For the purposes of screening, a 10-hour run time was assumed. Such a run time would reflect daily cycling and integration of intermittent renewable generation resources. For comparison purposes, Table 2-1 provides a summary of data for pumped storage projects constructed in the United States before 1991. Similar to energy storage, the resulting installed capacity must be large enough for consideration. Alternatives with relatively small installed capacity were screened out. Alternatives were generally sized in the range of 1,000 MW to 2,000 MW for comparison purposes, to reduce dam volume sizes, and to be relative to existing pumped storage projects. Initial alternatives that resulted in installed capacities much larger than 2,000 MW were resized to fall within the 1,000 MW to 2,000 MW range. This can be further evaluated in future investigations of potential sites.

- Estimated Dam Volume – The estimated dam volumes (in cubic yards) were estimated for each alternative. Projects having similar energy storage values but with excessively large dams volumes were generally screened out on a comparative basis. In general, a very large dam volume means higher costs, more construction effects, and more environmental effects.

Tables 2-2 through 2-6 summarize the preliminary site characteristics and technical screening results. Alternatives that passed the technical screening move forward to the second screening step, which includes performing cost opinions, conceptual layouts, operations, environmental, regulatory and economic screening.

Table 2-1. Summary of Plant Data

Plant Name	Plant Location: Nearest Town, State	Plant Capacity MW	First Commercial Power	Number of Reversible Units	Number of Main Conduits	Surge Tanks	Static Head: Max, Min (ft.) Max/Min Ratio	Storage Capacity Generation Hours	Length of Waterways ft.	L/H Ratio
Bad Creek	Salem, SC	1,000	1991	4	1	none	1,230, 1,040 Ratio: 1.18	24	9,519	8.3
Balsam Meadow (Now Eastwood)	Shaver Lake, CA	200	1987	1	1	downstream	1,352, 1,316 Ratio: 1.03	8	12,488	10.0
Bath County	Warm Springs, VA	2,100	1985	6	3	upstream	1,260, 1,080 Ratio: 1.17	11	9,117	7.7
Bear Swamp (Now Cockwell)	Rowe, MA	600	1974	2	2	none	770, 680 Ratio: 1.13	6	1,834	2.4
Blenheim-Gilboa	Blenheim and Gilboa, NY	1,000	1973	4	4	none	1,143, 1,097 Ratio: 1.04	12	3,895	3.5
Cabin Creek	Georgetown, CO	300	1967	2	2	none	1,226, 1,095 Ratio: 1.12	5	4,300	3.7
Carters	Chatsworth, GA	258	1976	2	2	none	406, 315 Ratio: 1.29	7	838	2.4
Castaic	Castaic, CA	1,250	1973	6	1	upstream	1,098, 800 Ratio: 1.37	10	41,275	38.6
Clarence Cannon	Center, MO	31	1984	1	1	none	117, 59 Ratio: 1.98	9	70	0.9
De Gray	Arkadelphia, AK	28	1971	1	1	none	206, 146 Ratio: 1.41	7	1,570	9.2
Edward Hyatt	Oroville, CA	293	1967	3	2	none	675, 500 Ratio: 1.35		581	0.9
Fairfield	Jenkinsville, SC	512	1978	8	4	none	169, 155 Ratio: 1.09	8	1,095	7.3
Flatiron	Loveland, CO	9	1954	1	1	upstream	298, 153 Ratio: 1.95		7,392	25.5
Gianelli San Luis	Los Banos, CA	400	1968	8	4	none	324, 117 Ratio: 2.77	1,274	2,146	10.9
Grand Coulee	Grand Coulee, WA	314	1973	6	6	none	363, 267 Ratio: 1.36	35	716	2.7
Helms	Shaver Lake, CA	1,206	1984	3	1	upstream and downstream	1,745, 1,470 Ratio: 1.19	153	19,803	12.3
Hiwassee-Unit 2	Murphy, NC	68	1956	1	1	none	255, 173 Ratio: 1.47	4,228	190	1.0
Horse Mesa #4	Tortilla Flat, AZ	97	1972	1	1	none	258, 236 Ratio: 1.10	245	187	0.8
Jocassee	Salem, SC	610	1973	4	4	none	335, 310 Ratio: 1.08	94	1,636	5.0

Table 2-1. Summary of Plant Data

Plant Name	Plant Location: Nearest Town, State	Plant Capacity MW	First Commercial Power	Number of Reversible Units	Number of Main Conduits	Surge Tanks	Static Head: Max, Min (ft.) Max/Min Ratio	Storage Capacity Generation Hours	Length of Waterways ft.	L/H Ratio
Kinzua Seneca	Warren, PA	350	1970	2	2	none	813, 644 Ratio: 1.26	11	2,802	4.3
Lewiston	Lewiston, NY	240	1961	12	12	none	113, 66 Ratio: 1.71	20	152	2.0
Ludington	Ludington, MI	1,979	1973	6	6	none	364, 295 Ratio: 1.23	9	1,299	3.6
Mormon Flat #2	Tortilla Flat, AZ	47	1971	1	1	none	139, 126 Ratio: 1.10	59	175	1.4
Mt. Elbert	Leadville, CO	200	1981	2	2	upstream	475, 400 Ratio: 1.19	12	3,000	6.7
Muddy Run	Drumore, PA	800	1967	8	8	none	415, 361 Ratio: 1.15	14	1,290	3.7
Northfield Mountain	Northfield & Erving, MA	1,080	1972	4	4	upstream and downstream	828, 735 Ratio: 1.13	10	6,320	8.5
Raccoon Mountain	Chattanooga, TN	1,530	1978	4	4	downstream	1,042, 900 Ratio: 1.16	21	3,600	4.0
Rocky Mountain	Armuchee, GA	760	1995	3	3	none	690, 613 Ratio: 1.13	8	2,984	4.6
Rocky River	New Milford, CT	32	1929	1	1	upstream	230, 210 Ratio: 1.10	837	1,677	7.5
Richard G. Russel	Elberton, GA	360	1987	4	4	none				
Salina	Salina, OK	260	1968	6	6	none	245, 225 Ratio: 1.09	10	640	2.8
Smith Mountain	Sandy Level, VA	240	1965	3	3	none	195, 174 Ratio: 1.12	14	170	0.9
Taum Sauk	St. Louis, MO	350	1963	2	2	none	875, 764 Ratio: 1.15	8	7,250	9.2
Thermalito	Oroville, CA	115	1968	4	4	none	101, 85 Ratio: 1.19		118	1.3
Wallace	Eatonton, GA	209	1979	4	6	none	96, 89 Ratio: 1.08	1,020	172	1.8
Yards Creek	Blairstown, NJ	360	1965	3	1	none	760, 688 Ratio: 1.11	8	3,500	4.8

.

Table 2-2. Pumped Storage Alternative Preliminary Site Characteristics – Great Plains Region

Great Plains Alternative	Buffalo Bill	Buffalo Bill	Bull	Bull	Bull	Bull	Bull	Bull	Bull	Bull	Canyon Ferry	Canyon Ferry	Canyon Ferry	Granby
	1	2	1A	1B	2A	2B	2C	3	4	5	1	2	3	1
Max Upper Reservoir Elev (msl)	6,960	6,850	7,440	7,390	7,790	7,750	7,700	7,300	7,390	7,490	4,560	5,200	4,600	9,280
Min Upper Reservoir Elev (msl)	6,830	6,700	7,230	7,230	7,600	7,600	7,600	7,250	7,320	7,430	4,420	5,030	4,450	9,200
Estimated Dam Fill Volume (CY)	5,000,000	3,900,000	6,375,000	4,541,696	13,700,000	10,122,657	6,679,841	2,700,000	2,308,473	4,066,862	5,700,000	13,400,000	8,700,000	2,650,000
Lower Reservoir Maximum Elev (msl)	5,394	5,394	5,805	5,805	5,805	5,805	5,805	5,805	5,805	5,805	3,800	3,800	3,800	8,280
Lower Reservoir Minimum Elev (msl)	5,300	5,300	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	3,770	3,770	3,770	8,200
Upper Reservoir Drawdown (ft.)	130	150	210	160	190	150	100	50	70	60	140	170	150	80
Min Head / Max Head Ratio (>.70)	0.87	0.84	0.84	0.87	0.88	0.90	0.92	0.93	0.92	0.93	0.78	0.86	0.78	0.85
Approx. Static Head (ft.) (<2650 ft.)	1,548	1,428	1,558	1,533	1,918	1,898	1,873	1,498	1,578	1,683	705	1,330	740	1,000
Maximum Dam Height (ft.) (<400ft)	304	404	393	343	373	333	283	168	174	218	280	351	315	133
Horiz. Dist. Intake-Discharge (ft.)	8,000	10,600	11,682	11,682	11,882	11,882	11,882	7,482	5,886	5,886	8,400	13,303	6,800	6,920
Estimated Submergence Below TW (ft.)	166	155	169	164	204	200	195	155	164	174	79	143	83	108
Est. Conveyance Length (L)	9,714	12,183	13,409	13,379	14,004	13,980	13,950	9,135	7,628	7,743	9,184	14,776	7,623	8,028
Conveyance Length (L) / Static Head (H)	6.28	8.53	8.61	8.73	7.30	7.37	7.45	6.10	4.84	4.60	**13.03**	11.11	**10.30**	8.03
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 10	< 12
Upper Reservoir Usable Vol. (AF)	11,700	15,000	22,900	14,700	31,600	22,100	12,400	4,000	4,600	6,600	21,500	16,400	17,100	19,100
Lower Reservoir Usable Vol. (AF)	601,404	601,404	151,700	151,700	151,700	151,700	151,700	151,700	151,700	151,701	1,506,597	1,506,597	1,506,597	466,000
Upper Reservoir/Lower Reservoir (%)	2	2	**15**	10	**21**	**15**	8	3	3	4	1	1	1	4
Energy Storage (MWh)	15,938	18,850	31,387	19,824	53,322	36,903	20,433	5,271	6,386	9,772	13,339	19,195	11,136	16,808
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,594**	**1,885**	**3,139**	1,982	**5,332**	**3,690**	**2,043**	**527**	**639**	**977**	**1,334**	**1,919**	**1,114**	**1,681**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	21	22	20	20	20	20
Resulting Installed Capacity (MW)	797	942	1,569	991	2,666	1,845	1,022	264	304	444	667	960	557	840
Assumed Hours of Storage	30	30	30	30	30	30	30	30	31	32	30	30	30	30
Resulting Installed Capacity (MW)	531	628	1,046	661	1,777	1,230	681	176	206	305	445	640	371	560
Assumed Hours of Storage	40	40	40	40	40	40	40	40	41	42	40	40	40	40
Resulting Installed Capacity (MW)	398	471	785	496	1,333	923	511	132	156	233	333	480	278	420
Assumed Distance to Transmission (mi.)	30	30	50	50	50	50	50	50	50	50	20	20	20	50
Voltage of Nearby Transmission (kV)	230	230	230	230	230	230	230	230	230	230	500	500	500	230
Transmission Ownership	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	BPA	BPA	BPA	PRPA

Table 2-2. Pumped Storage Alternative Preliminary Site Characteristics – Great Plains Region

Great Plains Alternative	Green Mountain	Green Mountain	Green Mountain	Horsetooth	Ruedi	Turquoise
	1	2	3	1	1	1
Max Upper Reservoir Elev (msl)	8,600	8,850	10,040	6,360	9,710	11,000
Min Upper Reservoir Elev (msl)	8,450	8,700	9,840	6,200	9,510	10,925
Estimated Dam Fill Volume (CY)	6,600,000	10,600,000	12,030,000	10,600,000	6,500,000	4,300,000
Lower Reservoir Maximum Elev (msl)	7,950	7,950	7,950	5,430	7,766	9,869
Lower Reservoir Minimum Elev (msl)	7,860	7,860	7,860	5,300	7,680	9,800
Upper Reservoir Drawdown (ft.)	150	150	200	160	200	75
Min Head / Max Head Ratio (>.70)	**0.68**	0.76	0.87	0.73	0.86	0.88
Approx. Static Head (ft.) (<2650 ft.)	**620**	870	2,035	915	1,887	1,128
Maximum Dam Height (ft.) (<400 ft.)	255	321	335	400	400	171
Horiz. Dist. Intake-Discharge (ft.)	6,653	10,853	24,250	6,970	16,400	7,131
Estimated Submergence Below TW (ft.)	74	99	218	106	203	120
Est. Conveyance Length (L)	7,347	11,822	26,503	7,991	18,490	8,379
Conveyance Length (L) / Static Head (H)	**11.85**	**13.59**	**13.02**	8.73	9.80	7.43
L/H General Acceptance Criteria	< 10	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	38,700	51,000	23,800	8,800	17,000	6,800
Lower Reservoir Usable Vol (AF)	112,794	112,794	112,794	139,135	101,280	120,478
Upper Reservoir/Lower Reservoir (%)	**34**	**45**	**21**	6	17	6
Energy Storage (MWh)	21,115	39,046	42,621	7,086	28,230	6,750
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**2,111**	**3,905**	**4,262**	**709**	**2,823**	**675**
Assumed Hours of Storage	20	20	20	20	20	20
Resulting Installed Capacity (MW)	1,056	1,952	2,131	354	1,411	337
Assumed Hours of Storage	30	30	30	30	30	30
Resulting Installed Capacity (MW)	704	1,302	1,421	236	941	225
Assumed Hours of Storage	40	40	40	40	40	40
Resulting Installed Capacity (MW)	528	976	1,066	177	706	169
Assumed Distance to Transmission (mi.)	20	20	20	10	20	20
Voltage of Nearby Transmission (kV)	230	230	230	230-345	230	230
Transmission Ownership	WAPA	WAPA	WAPA	PSCO/TSGT	PSCO	PSCO

Table 2-3. Pumped Storage Alternative Preliminary Site Characteristics – Upper Colorado Region

Upper Colorado Alternative	Blue Mesa			Flaming Gorge									Lake Powell				
	1A	1B	1C	1A	1B	1C	2A	2B	2C	2D	2E	2F	1A	1B	2A	2B	2C
Max Upper Reservoir Elev (msl)	8,470	8,480	8,490	7,750	7,725	7,700	7,560	7,550	7,540	7,530	7,520	7,510	5,010	5,000	4,400	4,430	4,470
Min Upper Reservoir Elev (msl)	8,450	8,450	8,450	7,660	7,660	7,660	7,480	7,480	7,480	7,480	7,480	7,480	4,950	4,950	4,360	4,360	4,360
Estimated Dam Fill Volume (CY)	2,720,669	3,943,186	5,274,318	16,556,478	11,369,161	7,376,816	18,659,075	15,823,373	13,254,848	10,943,858	8,882,089	7,038,706	12,626,820	10,478,812	1,822,579	3,618,992	8,141,476
Lower Reservoir Maximum Elev (msl)	7,520	7,520	7,520	6,035	6,035	6,035	6,035	6,035	6,035	6,035	6,035	6,035	3,700	3,700	3,700	3,700	3,700
Lower Reservoir Minimum Elev (msl)	7,440	7,440	7,440	6,010	6,010	6,010	6,010	6,010	6,010	6,010	6,010	6,010	3,550	3,550	3,550	3,550	3,550
Upper Reservoir Drawdown (ft)	20	30	40	90	65	40	80	70	60	50	40	30	60	50	40	70	110
Min Head / Max Head Ratio (>.70)	0.90	0.89	0.89	0.93	0.95	0.96	0.93	0.94	0.94	0.95	0.96	0.96	0.86	0.86	0.78	0.75	0.72
Approx. Static Head (ft) (<2650 ft)	980	985	990	1,683	1,670	1,658	1,498	1,493	1,488	1,483	1,478	1,473	1,355	1,350	755	770	790
Maximum Dam Height (ft) (<400ft)	65	75	85	182	157	132	182	172	162	152	142	132	141	131	136	166	206
Horiz. Dist. Intake-Discharge (ft)	8,841	8,841	8,841	4,267	4,267	4,267	4,267	4,267	4,267	4,267	4,267	4,267	5,052	5,052	5,052	5,052	5,052
Estimated Submergence Below TW (ft)	103	104	105	174	172	169	155	154	153	152	151	150	146	145	85	88	92
Est. Conveyance Length (L)	9,924	9,930	9,936	6,124	6,109	6,094	5,920	5,914	5,908	5,902	5,896	5,890	6,553	6,547	5,892	5,910	5,934
Conveyance Length (L) / Static Head (H)	10.13	10.08	10.04	3.64	3.66	3.68	3.95	3.96	3.97	3.98	3.99	4.00	4.84	4.85	7.80	7.68	7.51
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	8,800	14,300	20,540	26,200	16,700	8,700	46,425	39,800	33,000	26,600	20,400	14,800	23,500	18,600	4,600	10,800	22,100
Lower Reservoir Usable Vol (AF)	748,500	748,500	748,500	3,515,500	3,515,500	3,515,500	3,515,500	3,515,500	3,515,500	3,515,500	3,515,500	3,515,500	20,320,000	20,320,000	20,320,000	20,320,000	20,320,000
Upper Reservoir/Lower Reservoir (%)	1	2	3	1	0	0	1	1	1	1	1	0	0	0	0	0	0
Energy Storage (MWh)	7,589	12,395	17,894	38,792	24,542	12,690	61,179	52,273	43,197	34,702	26,524	19,178	28,021	22,097	3,056	7,318	15,364
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**759**	**1,240**	**1,789**	**3,879**	**2,454**	**1,269**	**6,118**	**5,227**	**4,320**	**3,470**	**2,652**	**1,918**	**2,802**	**2,210**	**306**	**732**	**1,536**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	379	620	895	1,940	1,227	634	3,059	2,614	2,160	1,735	1,326	959	1,401	1,105	153	366	768
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	253	413	596	1,293	818	423	2,039	1,742	1,440	1,157	884	639	934	737	102	244	512
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	190	310	447	970	614	317	1,529	1,307	1,080	868	663	479	701	552	76	183	384
Assumed Distance to Transmission (mi)	10	10	10	20	20	20	20	20	20	20	20	20	60	60	60	60	60
Voltage of Nearby Transmission (kV)	345	345	345	230	230	230	230	230	230	230	230	230	230	230	230	230	230
Transmission Ownership	WAPA	WAPA	WAPA	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	WAPA	WAPA	WAPA	WAPA	WAPA

Table 2-3. Pumped Storage Alternative Preliminary Site Characteristics – Upper Colorado Region

Upper Colorado Alternative	Blue Mesa			Deer Creek		Jordanelle					Pineview							
	1A	1B	1C	1	2	1	2A	2B	2C	2D	1A	1B	1C	1D	2A	2B	2C	2D
Max Upper Reservoir Elev (msl)	8,470	8,480	8,490	6,040	6,110	7,120	7,730	7,700	7,680	7,660	5,710	5,690	5,670	5,650	5,940	5,920	5,900	5,880
Min Upper Reservoir Elev (msl)	8,450	8,450	8,450	5,895	5,950	6,950	7,550	7,550	7,550	7,550	5,500	5,500	5,500	5,500	5,750	5,750	5,750	5,750
Estimated Dam Fill Volume (CY)	2,720,669	3,943,186	5,274,318	15,859,517	10,463,444	10,573,317	20,750,748	16,400,720	13,913,144	11,713,590	10,991,865	9,148,952	7,906,099	6,780,668	9,033,634	7,719,716	6,678,460	5,739,462
Lower Reservoir Maximum Elev (msl)	7,520	7,520	7,520	5,418	5,418	6,160	6,160	6,160	6,160	6,160	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900
Lower Reservoir Minimum Elev (msl)	7,440	7,440	7,440	5,360	5,360	6,110	6,110	6,110	6,110	6,110	4,850	4,850	4,850	4,850	4,850	4,850	4,860	4,860
Upper Reservoir Drawdown (ft)	20	30	40	145	160	170	180	150	130	110	210	190	170	150	190	170	150	130
Min Head / Max Head Ratio (>.70)	0.90	0.89	0.89	0.70	0.71	0.78	0.86	0.87	0.89	0.90	0.70	0.71	0.73	0.75	0.78	0.79	0.82	0.83
Approx. Static Head (ft) (<2650 ft)	980	985	990	579	641	900	1,505	1,490	1,480	1,470	730	720	710	700	970	960	945	935
Maximum Dam Height (ft) (<400ft)	65	75	85	394	324	399	399	369	349	329	396	368	348	328	393	373	353	333
Horiz. Dist. Intake-Discharge (ft)	8,841	8,841	8,841	6,082	6,082	8,386	11,575	11,575	11,575	11,575	7,238	7,238	7,238	7,238	10,540	10,540	10,540	10,540
Estimated Submergence Below TW (ft)	103	104	105	68	75	101	162	159	157	155	86	84	82	80	109	107	104	102
Est. Conveyance Length (L)	9,924	9,930	9,936	6,729	6,798	9,387	13,242	13,224	13,212	13,200	8,054	8,042	8,030	8,018	11,619	11,607	11,589	11,577
Conveyance Length (L) / Static Head (H)	10.13	10.08	10.04	**11.63**	**10.61**	10.43	8.80	8.88	8.93	8.98	**11.03**	**11.17**	**11.31**	**11.45**	**11.98**	**12.09**	**12.26**	**12.38**
L/H General Acceptance Criteria	< 12	< 12	< 12	< 10	< 10	< 12	< 12	< 12	< 12	< 12	< 10	< 10	< 10	< 10	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	8,800	14,300	20,540	31,700	22,800	12,700	25,400	19,600	16,000	12,800	51,600	42,300	34,100	27,000	39,400	31,700	25,100	19,400
Lower Reservoir Usable Vol (AF)	748,500	748,500	748,500	149,700	149,700	320,000	320,000	320,000	320,000	320,000	110,150	110,150	110,150	110,150	110,150	110,150	110,150	110,150
Upper Reservoir/Lower Reservoir (%)	1	2	3	21	15	4	8	6	5	4	47	38	31	25	36	29	23	18
Energy Storage (MWh)	7,589	12,395	17,894	16,138	12,861	10,058	33,640	25,700	20,838	16,558	33,148	26,801	21,306	16,632	33,632	26,780	20,873	15,962
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**759**	**1,240**	**1,789**	**1,614**	**1,286**	**1,006**	**3,364**	**2,570**	**2,084**	**1,656**	**3,315**	**2,680**	**2,131**	**1,663**	**3,363**	**2,678**	**2,087**	**1,596**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	379	620	895	807	643	503	1,682	1,285	1,042	828	1,657	1,340	1,065	832	1,682	1,339	1,044	798
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	253	413	596	538	429	335	1,121	857	695	552	1,105	893	710	554	1,121	893	696	532
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	190	310	447	403	322	251	841	642	521	414	829	670	533	416	841	670	522	399
Assumed Distance to Transmission (mi)	10	10	10	25	25	50	50	50	50	50	50	50	50	50	50	50	50	50
Voltage of Nearby Transmission (kV)	345	345	345	345	345	230	230	230	230	230	230-500	230-500	230-500	230-500	230-500	230-500	230-500	230-500
Transmission Ownership	WAPA	WAPA	WAPA	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF

Table 2-3. Pumped Storage Alternative Preliminary Site Characteristics – Upper Colorado Region

Upper Colorado Alternative	Strawberry	McPhee	Taylor Park						Vallecito							
	1	1	1A	1B	1C	1D	1E	1F	1A	1B	2A	2B	2C	3A	3B	3C
Max Upper Reservoir Elev (msl)	8,590	7,410	11,170	11,150	11,130	11,110	11,090	11,070	8,620	8,610	8,480	8,590	8,630	8,640	8,680	8,720
Min Upper Reservoir Elev (msl)	8,400	7,360	10,950	10,950	10,950	10,950	10,950	10,950	8,450	8,450	8,300	8,450	8,450	8,530	8,530	8,530
Estimated Dam Fill Volume (CY)	11,674,572	703,134	19,440,767	17,014,128	14,818,194	12,798,100	10,946,535	9,258,328	10,439,219	9,707,042	7,316,247	7,605,134	10,404,960	5,883,684	8,741,403	12,430,721
Lower Reservoir Maximum Elev (msl)	7,600	6,920	9,330	9,330	9,330	9,330	9,330	9,330	7,665	7,665	7,665	7,665	7,665	7,665	7,665	7,665
Lower Reservoir Minimum Elev (msl)	7,580	6,860	9,290	9,290	9,290	9,290	9,290	9,290	7,620	7,620	7,620	7,620	7,620	7,620	7,620	7,620
Upper Reservoir Drawdown (ft)	190	50	220	200	180	160	140	120	170	160	180	140	180	110	150	190
Min Head / Max Head Ratio (>.70)	0.79	0.80	0.86	0.87	0.88	0.89	0.90	0.91	0.79	0.79	0.74	0.81	0.78	0.85	0.82	0.79
Approx. Static Head (ft) (<2650 ft)	905	495	1,750	1,740	1,730	1,720	1,710	1,700	893	888	748	878	898	943	963	983
Maximum Dam Height (ft) (<400ft)	399	123	370	350	330	310	290	270	363	353	400	365	405	214	254	294
Horiz. Dist. Intake-Discharge (ft)	4,436	4,867	12,897	12,897	12,897	12,897	12,897	12,897	4,143	4,143	3,562	4,753	4,753	4,546	4,546	4,546
Estimated Submergence Below TW (ft)	101	55	188	186	184	182	180	178	100	99	86	97	101	102	106	110
Est. Conveyance Length (L)	5,442	5,417	14,835	14,823	14,811	14,799	14,787	14,775	5,136	5,130	4,396	5,728	5,752	5,591	5,615	5,639
Conveyance Length (L) / Static Head (H)	6.01	10.94	8.48	8.52	8.56	8.60	8.65	8.69	5.75	5.78	5.88	6.53	6.41	5.93	5.83	5.74
L/H General Acceptance Criteria	< 12	< 10	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	19,100	2,500	36,400	31,300	26,600	22,300	18,300	14,700	17,000	15,500	9,300	8,527	12,600	12,100	18,900	27,340
Lower Reservoir Usable Vol (AF)	951,000	229,200	106,210	106,210	106,210	106,210	106,210	106,210	125,400	125,400	125,400	125,400	125,400	125,400	125,400	125,400
Upper Reservoir/Lower Reservoir (%)	2	1	34	29	25	21	17	14	14	12	7	7	10	10	15	22
Energy Storage (MWh)	15,211	1,089	56,056	47,927	40,496	33,753	27,538	21,991	13,352	12,106	6,118	6,585	9,951	10,036	16,008	23,638
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,521**	**109**	**5,606**	**4,793**	**4,050**	**3,375**	**2,754**	**2,199**	**1,335**	**1,211**	**612**	**658**	**995**	**1,004**	**1,601**	**2,364**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	761	54	2,803	2,396	2,025	1,688	1,377	1,100	668	605	306	329	498	502	800	1,182
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	507	36	1,869	1,598	1,350	1,125	918	733	445	404	204	219	332	335	534	788
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	380	27	1,401	1,198	1,012	844	688	550	334	303	153	165	249	251	400	591
Assumed Distance to Transmission (mi)	40	10	40	40	40	40	40	40	50	50	50	50	50	50	50	50
Voltage of Nearby Transmission (kV)	345	230-345	230	230	230	230	230	230	345	345	345	345	345	345	345	345
Transmission Ownership	PACIF	WAPA/TSGT	PSCO	PSCO	PSCO	PSCO	PSCO	PSCO	TSGT	TSGT	TSGT	TSGT	TSGT	TSGT	TSGT	TSGT

Table 2-4. Pumped Storage Alternative Preliminary Site Characteristics – Lower Colorado Region

Lower Colorado Alternative	Havasu	Mead												
	1	1	2A	2B	2C	2D	3	4	5	6	7A	7B	7C	7D
Max Upper Reservoir Elev (msl)	1,200	1,950	2,900	2,875	2,850	2,825	2,440	1,830	2,130	1,960	2,520	2,500	2,475	2,450
Min Upper Reservoir Elev (msl)	1,070	1,900	2,750	2,750	2,750	2,750	2,250	1,770	2,050	1,860	2,320	2,320	2,320	2,320
Estimated Dam Fill Volume (CY)	8,792,641	9,938,044	4,376,784	3,550,997	2,877,688	2,307,992	4,468,372	6,152,513	5,784,260	3,888,990	10,993,864	9,590,969	8,019,099	6,639,662
Lower Reservoir Maximum Elev (msl)	450	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220
Lower Reservoir Minimum Elev (msl)	400	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Upper Reservoir Drawdown (ft)	130	50	150	125	100	75	190	60	80	100	200	180	155	130
Min Head / Max Head Ratio (>.70)	0.78	0.76	0.83	0.84	0.85	0.86	0.74	0.71	0.77	0.70	0.75	0.76	0.77	0.79
Approx. Static Head (ft) (<2650 ft)	710	790	1,690	1,678	1,665	1,653	1,210	665	955	775	1,285	1,275	1,263	1,250
Maximum Dam Height (ft) (<400ft)	289	104	369	344	319	294	400	400	343	268	400	380	355	330
Horiz. Dist. Intake-Discharge (ft)	6,693	4,472	7,776	7,776	7,776	7,776	4,930	4,650	2,660	4,918	5,950	5,950	5,950	5,950
Estimated Submergence Below TW (ft)	80	90	185	183	180	178	139	78	108	91	147	145	143	140
Est. Conveyance Length (L)	7,483	5,352	9,651	9,636	9,621	9,606	6,279	5,393	3,723	5,784	7,382	7,370	7,355	7,340
Conveyance Length (L) / Static Head (H)	10.54	6.77	5.71	5.74	5.78	5.81	5.19	8.11	3.90	7.46	5.74	5.78	5.82	5.87
L/H General Acceptance Criteria	< 10	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	14,205	12,815	31,500	24,000	17,500	12,000	12,800	7,670	8,280	12,800	30,000	24,900	19,300	14,500
Lower Reservoir Usable Vol (AF)	180,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000
Upper Reservoir/Lower Reservoir (%)	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Energy Storage (MWh)	8,875	8,911	46,852	35,433	25,644	17,453	13,632	4,490	6,960	8,732	33,929	27,942	21,446	15,953
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**888**	**891**	**4,685**	**3,543**	**2,564**	**1,745**	**1,363**	**449**	**696**	**873**	**3,393**	**2,794**	**2,145**	**1,595**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	444	446	2,343	1,772	1,282	873	682	224	348	437	1,696	1,397	1,072	798
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	296	297	1,562	1,181	855	582	454	150	232	291	1,131	931	715	532
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	222	223	1,171	886	641	436	341	112	174	218	848	699	536	399
Assumed Distance to Transmission (mi)	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Voltage of Nearby Transmission (kV)	230	500	500	500	500	500	500	500	500	500	500	500	500	500
Transmission Ownership	MWD	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE

Table 2-4. Pumped Storage Alternative Preliminary Site Characteristics – Lower Colorado Region

Lower Colorado Alternative	Mead (Cont.)								Apache		
	7E	7F	8A	8B	8C	9A	9B	9C	1A	1B	1C
Max Upper Reservoir Elev (msl)	2,425	2,400	2,056	2,040	2,020	3,600	3,575	3,550	3,680	3,660	3,640
Min Upper Reservoir Elev (msl)	2,320	2,320	1,920	1,920	1,920	3,450	3,450	3,450	3,500	3,500	3,500
Estimated Dam Fill Volume (CY)	5,437,567	4,398,090	10,204,323	9,115,383	7,870,063	10,599,273	8,102,745	6,143,288	7,185,592	6,176,494	5,284,243
Lower Reservoir Maximum Elev (msl)	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,914	1,914	1,914
Lower Reservoir Minimum Elev (msl)	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,800	1,800	1,800
Upper Reservoir Drawdown (ft)	105	80	136	120	100	150	125	100	180	160	140
Min Head / Max Head Ratio (>.70)	0.80	0.82	0.70	0.71	0.72	0.87	0.88	0.89	0.84	0.85	0.86
Approx. Static Head (ft) (<2650 ft)	1,238	1,225	853	845	835	2,390	2,378	2,365	1,733	1,723	1,713
Maximum Dam Height (ft) (<400ft)	305	280	400	384	364	380	355	330	366	347	326
Horiz. Dist. Intake-Discharge (ft)	5,950	5,950	4,918	4,918	4,918	9,032	9,032	9,032	5,950	5,950	5,950
Estimated Submergence Below TW (ft)	138	135	101	99	97	255	253	250	188	186	184
Est. Conveyance Length (L)	7,325	7,310	5,872	5,862	5,850	11,677	11,662	11,647	7,871	7,859	7,847
Conveyance Length (L) / Static Head (H)	5.92	5.97	6.88	6.94	7.00	4.89	4.90	4.92	4.54	4.56	4.58
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	10,400	7,000	35,600	30,100	23,700	13,600	10,300	7,400	14,900	11,600	9,300
Lower Reservoir Usable Vol (AF)	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	17,350,000	245,138	245,138	245,138
Upper Reservoir/Lower Reservoir (%)	0	0	0	0	0	0	0	0	6	5	4
Energy Storage (MWh)	11,327	7,547	26,729	22,388	17,419	28,606	21,551	15,402	22,723	17,588	14,019
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,133**	**755**	**2,673**	**2,239**	**1,742**	**2,861**	**2,155**	**1,540**	**2,272**	**1,759**	**1,402**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	566	377	1,336	1,119	871	1,430	1,078	770	1,136	879	701
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	378	252	891	746	581	954	718	513	757	586	467
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	283	189	668	560	435	715	539	385	568	440	350
Assumed Distance to Transmission (mi)	5	5	5	5	5	5	5	5	30	30	30
Voltage of Nearby Transmission (kV)	500	500	500	500	500	500	500	500	500	500	500
Transmission Ownership	SCE	SCE	SCE	SCE	SCE	SCE	SCE	SCE	AZPS	AZPS	AZPS

Table 2-5. Pumped Storage Alternative Preliminary Site Characteristics – Mid-Pacific Region

Mid Pacific Alternative	New Melones			Upper Klamath		Tahoe		Shasta						
	1A	1B	2	1	2	1	2	1	2A	2B	2C	3A	3B	4
Max Upper Reservoir Elev (msl)	2,190	2,220	2,190	4,730	5,440	7,850	7,000	1,740	3,154	3,100	3,050	2,000	2,040	1,600
Min Upper Reservoir Elev (msl)	2,140	2,140	2,160	4,560	5,420	7,830	6,940	1,655	2,950	2,950	2,950	1,850	1,860	1,560
Estimated Dam Fill Volume (CY)	4,679,869	8,103,468	2,496,589	13,949,798	2,680,962	N/A	3,587,149	8,979,497	7,068,488	4,781,514	3,160,871	3,441,684	4,994,788	3,482,175
Lower Reservoir Maximum Elev (msl)	1,049	1,049	1,049	4,144	4,144	6,229	6,229	1,067	1,067	1,067	1,067	1,067	1,067	1,067
Lower Reservoir Minimum Elev (msl)	808	808	808	4,137	4,137	6,220	6,220	900	900	900	900	900	900	900
Upper Reservoir Drawdown (ft)	50	80	30	170	20	20	60	85	204	150	100	150	180	40
Min Head / Max Head Ratio (>.70)	0.79	0.77	0.80	0.70	0.98	0.98	0.91	0.70	0.84	0.86	0.88	0.71	0.70	0.70
Approx. Static Head (ft) (<2650 ft)	**1,237**	**1,252**	**1,247**	**505**	1,290	**1,615**	**745**	**714**	**2,069**	**2,042**	**2,017**	**942**	**967**	**597**
Maximum Dam Height (ft) (<400ft)	119	106	108	391	110	80	154	400	400	346	296	292	332	296
Horiz. Dist. Intake-Discharge (ft)	7,563	7,563	5,075	2,728	2,718	5,404	3,967	4,249	17,321	17,321	17,321	5,273	5,273	5,424
Estimated Submergence Below TW (ft)	138	141	138	59	130	163	78	84	225	220	215	110	114	70
Est. Conveyance Length (L)	8,938	8,956	6,460	3,292	4,138	7,182	4,790	5,047	19,615	19,583	19,553	6,325	6,354	6,091
Conveyance Length (L) / Static Head (H)	7.23	7.16	5.18	6.52	3.21	4.45	6.43	7.07	9.48	9.59	9.70	6.72	6.57	10.21
L/H General Acceptance Criteria	< 12	< 12	< 12	< 7	< 12	< 12	< 10	< 10	< 12	< 12	< 12	< 12	< 12	< 10
Upper Reservoir Usable Vol (AF)	7,500	12,700	2,680	58,000	2,800	N/A	10,000	8,800	38,700	23,900	13,300	10,400	15,200	4,200
Lower Reservoir Usable Vol (AF)	2,420,000	2,420,000	2,420,000	465,000	465,000	732,000	732,000	3,970,000	3,970,000	3,970,000	3,970,000	3,970,000	3,970,000	3,970,000
Upper Reservoir/Lower Reservoir (%)	0	1	0	12	1	N/A	1	0	1	1	0	0	0	0
Energy Storage (MWh)	8,161	13,987	2,940	25,750	3,177	N/A	6,560	5,529	70,445	42,937	23,601	8,617	12,928	2,205
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**816**	**1,399**	**294**	**2,575**	**318**	**N/A**	**656**	**553**	**7,044**	**4,294**	**2,360**	**862**	**1,293**	**220**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	408	699	147	1,287	159	N/A	328	276	3,522	2,147	1,180	431	646	110
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	272	466	98	858	106	N/A	219	184	2,348	1,431	787	287	431	73
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	204	350	73	644	79	N/A	164	138	1,761	1,073	590	215	323	55
Distance to Transmission (mi)	40	40	40	20	20	50	50	10	10	10	10	10	10	10
Voltage of Nearby Transmission (kV)	230	230	230	230	230	230	230	230-500	230-500	230-500	230-500	230-500	230-500	230-500
Transmission Ownership	PG	PG	PG	BPA	BPA	PG	PG	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA

Table 2-5. Pumped Storage Alternative Preliminary Site Characteristics – Mid-Pacific Region

Mid Pacific Alternative	Shasta (Cont.)					Whiskeytown		Millerton				San Luis	
	5A	5B	5C	6	7	1	2	1A	1B	1C	1D	1	2
Max Upper Reservoir Elev (msl)	2,400	2,280	2,170	2,000	2,000	2,580	1,980	1,440	1,400	1,350	1,330	870	1,390
Min Upper Reservoir Elev (msl)	2,270	2,150	2,000	1,840	1,840	2,400	1,770	1,260	1,230	1,190	1,180	870	1,300
Estimated Dam Fill Volume (CY)	14,391,874	6,830,515	8,279,997	6,475,671	8,993,289	7,743,801	14,434,068	12,851,587	9,671,392	6,673,574	5,673,189	2,357,955	3,289,676
Lower Reservoir Maximum Elev (msl)	1,067	1,067	1,067	1,067	1,067	1,210	1,210	578	578	578	578	544	544
Lower Reservoir Minimum Elev (msl)	900	900	900	900	900	1,180	1,180	470	470	470	470	340	340
Upper Reservoir Drawdown (ft)	130	130	170	160	160	180	210	180	170	160	150	0	90
Min Head / Max Head Ratio (>.70)	0.80	0.78	0.73	0.70	0.70	0.85	0.70	0.70	0.70	0.70	0.70	0.62	0.72
Approx. Static Head (ft) (<2650 ft)	**1,352**	**1,232**	**1,102**	**937**	**937**	**1,295**	**680**	**826**	**791**	**746**	**731**	**428**	**903**
Maximum Dam Height (ft) (<400ft)	297	345	398	373	399	400	399	400	360	310	290	164	172
Horiz. Dist. Intake-Discharge (ft)	5,172	5,745	6,819	8,556	6,890	10,112	8,130	4,686	4,686	4,686	4,686	2,290	6,291
Estimated Submergence Below TW (ft)	150	138	127	110	110	140	80	97	93	88	86	53	105
Est. Conveyance Length (L)	6,674	7,115	8,048	9,603	7,937	11,547	8,890	5,609	5,570	5,520	5,503	2,771	7,299
Conveyance Length (L) / Static Head (H)	4.94	5.78	7.31	10.25	8.47	8.92	13.07	6.79	7.04	7.40	7.53	6.47	8.08
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 12	< 10	< 10	< 7	< 12
Upper Reservoir Usable Vol (AF)	18,900	7,300	9,800	26,500	31,800	13,000	34,800	65,400	54,100	40,500	34,300	0	17,500
Lower Reservoir Usable Vol (AF)	3,970,000	3,970,000	3,970,000	3,970,000	3,970,000	214,000	214,000	433,800	433,800	433,800	433,800	1,960,000	1,960,000
Upper Reservoir/Lower Reservoir (%)	0	0	0	1	1	6	16	15	12	9	8	0	1
Energy Storage (MWh)	22,478	7,911	9,499	21,839	26,207	14,815	20,824	47,538	37,658	26,587	22,065	0	13,906
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**2,248**	**791**	**950**	**2,184**	**2,621**	**1,481**	**2,082**	**4,754**	**3,766**	**2,659**	**2,206**	**0**	**1,391**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	1,124	396	475	1,092	1,310	741	1,041	2,377	1,883	1,329	1,103	0	695
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	749	264	317	728	874	494	694	1,585	1,255	886	735	0	464
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	562	198	237	546	655	370	521	1,188	941	665	552	0	348
Distance to Transmission (mi)	10	10	10	10	10	20	20	10	10	10	10	20	20
Voltage of Nearby Transmission (kV)	230-500	230-500	230-500	230-500	230-500	230-500	230-500	230	230	230	230	500	500
Transmission Ownership	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG-WAPA	PG	PG	PG	PG	PG	PG

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Cle Elum				Keechelus					Little Kachess					Prineville		
	1A	1B	2A	2B	1A	1B	2A	2B	3	1	2A	2B	3A	3B	1	2	3
Max Upper Reservoir Elev (msl)	3,400	3,350	3,860	3,800	3,400	3,300	4,390	4,250	2,517	3,370	3,850	3,790	5,190	5,025	3,680	4,250	3,900
Min Upper Reservoir Elev (msl)	3,275	3,275	3,625	3,625	3,200	3,200	4,150	4,150	2,425	3,150	3,600	3,600	4,950	4,900	3,630	4,170	3,820
Estimated Dam Fill Volume (CY)	4,621,018	2,651,063	12,319,768	8,309,774	7,322,085	2,926,159	15,401,375	5,393,990	0	7,424,323	11,583,784	7,734,138	23,987,289	6,277,805	4,959,447	6,414,506	1,799,165
Lower Reservoir Maximum Elev (msl)	2,240	2,240	2,240	2,240	2,517	2,517	2,517	2,517	2,262	2,262	2,262	2,262	2,262	2,262	3,234	3,234	3,234
Lower Reservoir Minimum Elev (msl)	2,210	2,210	2,210	2,210	2,425	2,425	2,425	2,425	2,193	2,193	2,193	2,193	2,193	2,193	3,114	3,114	3,114
Upper Reservoir Drawdown (ft)	125	75	235	175	200	100	240	100	92	220	250	190	240	125	50	80	80
Min Head / Max Head Ratio (>.70)	0.87	0.91	0.84	0.87	0.70	0.78	0.83	0.89	0.50	0.75	0.81	0.84	0.90	0.93	0.70	0.82	0.75
Approx. Static Head (ft) (<2650 ft)	1,113	1,088	1,518	1,488	829	779	1,799	1,729	244	1,033	1,498	1,468	2,843	2,735	481	1,036	686
Maximum Dam Height (ft) (<400ft)	236	187	400	340	310	210	395	255		399	390	330	400	236	208	131	65
Horiz. Dist. Intake-Discharge (ft)	8,101	8,101	14,775	14,775	5,750	5,750	10,807	10,807	21,648	11,836	13,914	13,914	7,145	7,145	4,745	8,122	2,527
Estimated Submergence Below TW (ft)	119	114	165	159	98	88	197	183	32	118	166	160	300	283	57	114	79
Est. Conveyance Length (L)	9,333	9,303	16,458	16,422	6,677	6,617	12,803	12,719	21,924	12,986	15,577	15,541	10,287	10,163	5,283	9,272	3,292
Conveyance Length (L) / Static Head (H)	8.39	8.55	10.85	11.04	8.05	8.49	7.12	7.36	89.99	12.58	10.40	10.59	3.62	3.72	10.98	8.95	4.80
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 7	< 12	< 10
Upper Reservoir Usable Vol (AF)	30,800	15,500	25,100	16,400	75,900	32,100	41,500	13,500	15,000	21,300	24,800	16,300	28,300	10,550	15,400	18,600	17,900
Lower Reservoir Usable Vol (AF)	437,000	437,000	437,000	437,000	158,000	158,000	158,000	158,000	15,000	239,000	239,000	239,000	239,000	239,000	152,800	152,800	152,800
Upper Reservoir/Lower Reservoir (%)	7	4	6	4	48	20	26	9	10	9	10	7	12	4	10	12	12
Energy Storage (MWh)	30,153	14,834	33,519	21,468	55,371	22,005	65,699	20,541	3,216	19,356	32,684	21,052	70,793	25,393	6,519	16,957	10,806
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**3,015**	**1,483**	**3,352**	**2,147**	**5,537**	**2,201**	**6,570**	**2,054**	**322**	**1,936**	**3,268**	**2,105**	**7,079**	**2,539**	**652**	**1,696**	**1,081**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	1,508	742	1,676	1,073	2,769	1,100	3,285	1,027	161	968	1,634	1,053	3,540	1,270	326	848	540
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	1,005	494	1,117	716	1,846	734	2,190	685	107	645	1,089	702	2,360	846	217	565	360
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	754	371	838	537	1,384	550	1,642	514	80	484	817	526	1,770	635	163	424	270
Distance to Transmission (mi)	20	20	20	20	5	5	5	5	5	5	5	5	5	5	20	20	20
Voltage of Nearby Transmission (kV)	500	500	500	500	230/500	230/500	230/500	230/500	230/500	230/500	230/500	230/500	230/500	230/500	500	500	500
Transmission Ownership	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	PACIF	PACIF	PACIF

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Rimrock				Banks				Hungry Horse								
	1	2	3A	3B	1	2	3	4	1A	1B	2	3	4	5	6	7A	7B
Max Upper Reservoir Elev (msl)	3,760	3,820	5,200	5,170	2,450	2,310	2,300	2,410	6,320	6,230	4,680	4,500	4,460	4,400	4,120	4,960	4,910
Min Upper Reservoir Elev (msl)	3,650	3,725	5,025	5,025	2,420	2,260	2,200	2,340	6,075	6,075	4,500	4,370	4,350	4,300	4,110	4,800	4,800
Estimated Dam Fill Volume (CY)	2,348,917	5,247,852	9,066,408	6,858,280	3,431,860	2,109,320	2,786,661	3,374,647	10,958,790	6,002,459	7,036,719	10,109,579	7,352,875	5,699,347	6,612,110	26,320,206	15,975,533
Lower Reservoir Maximum Elev (msl)	2,926	2,926	2,926	2,926	1,570	1,570	1,570	1,570	3,560	3,560	3,560	3,560	3,560	3,560	3,560	3,560	3,560
Lower Reservoir Minimum Elev (msl)	2,766	2,766	2,766	2,766	1,539	1,539	1,539	1,539	3,336	3,336	3,336	3,336	3,336	3,336	3,336	3,336	3,336
Upper Reservoir Drawdown (ft)	110	95	175	145	30	50	100	70	245	155	180	130	110	100	10	160	110
Min Head / Max Head Ratio (>.70)	0.73	0.76	0.86	0.87	0.93	0.89	0.83	0.88	0.84	0.87	0.70	0.70	0.70	0.70	0.70	0.76	0.79
Approx. Static Head (ft) (<2650 ft)	859	927	2,267	2,252	881	731	696	821	2,750	2,705	1,142	987	957	902	667	1,432	1,407
Maximum Dam Height (ft) (<400ft)	202	226	400	360	87	132	177	83	391	301	317	**403**	240	220	303	399	349
Horiz. Dist. Intake-Discharge (ft)	5,420	3,145	11,782	11,782	4,612	4,416	2,667	2,865	11,451	11,451	7,519	7,249	3,964	6,127	3,245	5,028	5,028
Estimated Submergence Below TW (ft)	99	105	243	240	91	77	76	87	298	289	134	116	112	106	78	162	157
Est. Conveyance Length (L)	6,378	4,177	14,292	14,274	5,584	5,224	3,439	3,773	14,499	14,445	8,795	8,352	5,033	7,135	3,990	6,622	6,592
Conveyance Length (L) / Static Head (H)	7.43	4.51	6.31	6.34	6.34	7.15	4.94	4.60	5.27	5.34	7.70	8.46	5.26	7.91	5.98	4.62	4.69
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 10	< 10	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 12
Upper Reservoir Usable Vol (AF)	14,800	18,700	14,000	10,400	10,900	16,030	14,600	9,800	18,400	9,600	15,700	15,500	10,600	8,200	3,100	40,300	18,800
Lower Reservoir Usable Vol (AF)	198,000	198,000	198,000	198,000	715,000	715,000	715,000	715,000	2,982,026	2,982,026	2,982,026	2,982,026	2,982,026	2,982,026	2,982,026	2,982,026	2,982,026
Upper Reservoir/Lower Reservoir (%)	7	9	7	5	2	2	2	1	1	0	1	1	0	0	0	1	1
Energy Storage (MWh)	11,188	15,246	27,923	20,606	8,446	10,305	8,936	7,076	44,520	22,848	15,778	13,463	8,927	6,509	1,820	50,784	23,277
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,119**	**1,525**	**2,792**	**2,061**	**845**	**1,030**	**894**	**708**	**4,452**	**2,285**	**1,578**	**1,346**	**893**	**651**	**182**	**5,078**	**2,328**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	559	762	1,396	1,030	422	515	447	354	2,226	1,142	789	673	446	325	91	2,539	1,164
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	373	508	931	687	282	343	298	236	1,484	762	526	449	298	217	61	1,693	776
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	280	381	698	515	211	258	223	177	1,113	571	394	337	223	163	45	1,270	582
Distance to Transmission (mi)	50	50	50	50	10	10	10	10	5	5	5	5	5	5	5	5	5
Voltage of Nearby Transmission (kV)	500	500	500	500	500	500	500	500	230	230	230	230	230	230	230	230	230
Transmission Ownership	BPA	BPA	BPA	BPA	GC Power	GC Power	GC Power	GC Power	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Hungry Horse (Cont.)			Franklin D Roosevelt											
	8	**9A**	**9B**	**1**	**2A**	**2B**	**3**	**4**	**5**	**6**	**7**	**8**	**9A**	**9B**	**10**
Max Upper Reservoir Elev (msl)	5,800	6,350	6,180	2,400	2,000	2,590	2,400	2,400	2,330	2,600	2,000	2,080	2,150	2,100	2,040
Min Upper Reservoir Elev (msl)	5,720	6,100	6,100	2,275	1,880	2,425	2,175	2,175	2,120	2,425	1,850	1,900	1,945	1,945	1,930
Estimated Dam Fill Volume (CY)	1,111,263	12,405,364	3,057,423	4,413,021	2,181,621	6,232,851	9,017,961	7,921,140	9,014,091	6,801,450	14,511,094	11,944,215	12,808,982	9,181,434	23,422,564
Lower Reservoir Maximum Elev (msl)	3,560	3,560	3,560	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290
Lower Reservoir Minimum Elev (msl)	3,336	3,336	3,336	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208
Upper Reservoir Drawdown (ft)	80	250	80	125	120	165	225	225	210	175	150	180	205	155	110
Min Head / Max Head Ratio (>.70)	0.88	0.84	0.89	0.83	0.74	0.82	0.74	0.74	0.74	0.82	0.71	0.70	0.70	0.73	0.77
Approx. Static Head (ft) (<2650 ft)	2,312	2,777	2,692	1,089	691	1,259	1,039	1,039	976	1,264	676	741	799	774	736
Maximum Dam Height (ft) (<400ft)	126	394	224	226	172	340	371	399	399	334	290	370	394	343	178
Horiz. Dist. Intake-Discharge (ft)	11,654	15,270	15,270	8,230	4,384	5,097	3,247	7,454	6,431	6,142	4,451	5,006	5,450	5,450	4,004
Estimated Submergence Below TW (ft)	246	301	284	119	79	138	119	119	112	139	79	87	94	89	83
Est. Conveyance Length (L)	14,212	18,348	18,246	9,438	5,154	6,494	4,405	8,612	7,519	7,545	5,206	5,834	6,343	6,313	4,823
Conveyance Length (L) / Static Head (H)	6.15	6.61	6.78	8.67	7.46	5.16	4.24	8.29	7.70	5.97	7.70	7.87	7.94	8.16	6.55
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 10	< 12	< 12	< 12	< 12	< 12	< 10	< 10	< 12	< 12	< 10
Upper Reservoir Usable Vol (AF)	5,700	37,300	8,800	23,000	3,000	9,700	14,300	29,000	24,600	10,800	24,200	42,100	47,400	29,700	24,100
Lower Reservoir Usable Vol (AF)	2,982,026	2,982,026	2,982,026	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	0	1	0	0	0	0	0	1	0	0	0	1	1	1	0
Energy Storage (MWh)	11,597	91,152	20,847	22,031	1,824	10,743	13,068	26,503	21,128	12,008	14,396	27,453	33,307	20,216	15,609
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,160**	**9,115**	**2,085**	**2,203**	**182**	**1,074**	**1,307**	**2,650**	**2,113**	**1,201**	**1,440**	**2,745**	**3,331**	**2,022**	**1,561**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	580	4,558	1,042	1,102	91	537	653	1,325	1,056	600	720	1,373	1,665	1,011	780
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	387	3,038	695	734	61	358	436	883	704	400	480	915	1,110	674	520
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	290	2,279	521	551	46	269	327	663	528	300	360	686	833	505	390
Distance to Transmission (mi)	5	5	5	30	30	30	30	30	30	30	30	30	30	30	30
Voltage of Nearby Transmission (kV)	230	230	230	500	500	500	500	500	500	500	500	500	500	500	500
Transmission Ownership	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Franklin D Roosevelt (Cont.)														FDR to Banks
	11	**12**	**13**	**14A**	**14B**	**15A**	**15B**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	
Max Upper Reservoir Elev (msl)	2,040	2,040	2,600	2,600	2,530	2,400	2,350	2,400	2,600	2,000	2,220	2,050	2,000	2,400	1,570
Min Upper Reservoir Elev (msl)	1,925	1,980	2,530	2,425	2,425	2,275	2,275	2,150	2,540	1,930	2,000	1,960	1,920	2,225	1,539
Estimated Dam Fill Volume (CY)	22,110,008	1,532,897	1,598,128	10,511,691	5,345,442	3,468,913	2,321,408	20,405,001	2,477,356	1,057,649	8,397,906	12,292,906	2,328,176	4,805,792	0
Lower Reservoir Maximum Elev (msl)	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290
Lower Reservoir Minimum Elev (msl)	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208	1,208
Upper Reservoir Drawdown (ft)	115	60	70	175	105	125	75	250	60	70	220	90	80	175	31
Min Head / Max Head Ratio (>.70)	0.76	0.83	0.89	0.82	0.86	0.83	0.86	0.72	0.90	0.81	0.70	0.80	0.80	0.78	0.69
Approx. Static Head (ft) (<2650 ft)	734	761	1,316	1,264	1,229	1,089	1,064	1,026	1,321	716	861	756	711	1,064	306
Maximum Dam Height (ft) (<400ft)	238	130	135	284	214	190	140	396	95	114	335	158	138	337	0
Horiz. Dist. Intake-Discharge (ft)	3,544	6,555	7,278	11,852	11,852	9,618	9,618	5,978	11,301	6,109	5,455	2,093	3,376	5,538	8,000
Estimated Submergence Below TW (ft)	83	83	139	139	132	119	114	119	139	79	101	84	79	119	36
Est. Conveyance Length (L)	4,361	7,399	8,733	13,255	13,213	10,826	10,796	7,123	12,761	6,904	6,417	2,933	4,166	6,721	8,342
Conveyance Length (L) / Static Head (H)	5.95	9.72	6.64	10.49	10.76	9.95	10.15	6.94	9.66	9.64	7.45	3.88	5.86	6.32	27.31
L/H General Acceptance Criteria	< 10	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 12	< 12	< 10	< 12	< 7
Upper Reservoir Usable Vol (AF)	35,900	11,900	7,200	36,800	16,700	37,500	18,000	29,800	6,100	12,300	14,000	16,200	7,500	6,000	36,000
Lower Reservoir Usable Vol (AF)	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	1	0	0	1	0	1	0	1	0	0	0	0	0	0	1
Energy Storage (MWh)	23,173	7,969	8,338	40,917	18,054	35,921	16,846	26,906	7,091	7,750	10,608	10,778	4,693	5,615	9,678
Assumed Hours of Storage	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**2,317**	**797**	**834**	**4,092**	**1,805**	**3,592**	**1,685**	**2,691**	**709**	**775**	**1,061**	**1,078**	**469**	**562**	**968**
Assumed Hours of Storage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	1,159	398	417	2,046	903	1,796	842	1,345	355	387	530	539	235	281	484
Assumed Hours of Storage	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	772	266	278	1,364	602	1,197	562	897	236	258	354	359	156	187	323
Assumed Hours of Storage	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	579	199	208	1,023	451	898	421	673	177	194	265	269	117	140	242
Distance to Transmission (mi)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Voltage of Nearby Transmission (kV)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Transmission Ownership	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA	BPA

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Anderson Ranch				Cascade		Owyhee								
	1	2	3	4	1A	1B	1	1B	2A	2B	3	4A	4B	5	6
Max Upper Reservoir Elev (msl)	5,040	4,800	5,200		7,040	7,000	4,400	4,380	4,400	4,360	3,210	3,400	3,300	4,400	3,200
Min Upper Reservoir Elev (msl)	4,950	4,730	5,110	Reservoir	6,850	6,850	4,300	4,300	4,225	4,225	3,125	3,240	3,240	4,340	3,100
Estimated Dam Fill Volume (CY)	4,908,331	3,526,584	4,521,141	to Little	6,306,983	4,530,979	5,237,480	2,300,769	6,096,661	4,380,138	1,323,969	9,124,218	4,025,390	1,625,340	5,206,026
Lower Reservoir Maximum Elev (msl)	4,196	4,196	4,196	Camous	4,828	4,828	2,670	2,670	2,670	2,670	2,670	2,670	2,670	2,670	2,670
Lower Reservoir Minimum Elev (msl)	4,039	4,039	4,039		4,787	4,787	2,590	2,590	2,590	2,590	2,590	2,590	2,590	2,590	2,590
Upper Reservoir Drawdown (ft)	90	70	90	No Data	190	150	100	80	175	135	85	160	60	60	100
Min Head / Max Head Ratio (>.70)	0.75	0.70	0.79		0.90	0.91	0.90	0.91	0.86	0.88	0.73	0.70	0.80	0.92	0.71
Approx. Static Head (ft) (<2650 ft)	878	648	1,038		2,138	2,118	1,720	1,710	1,682	1,662	537	690	640	1,740	520
Maximum Dam Height (ft) (<400ft)	299	293	177		341	301	210	190	269	329	228	350	250	96	374
Horiz. Dist. Intake-Discharge (ft)	2,871	3,961	7,146		11,595	11,595	13,872	13,872	12,783	12,783	6,173	6,827	6,827	5,472	2,974
Estimated Submergence Below TW (ft)	100	76	116		225	221	181	179	181	177	62	81	71	181	61
Est. Conveyance Length (L)	3,849	4,685	8,300		13,958	13,934	15,773	15,761	14,646	14,622	6,772	7,598	7,538	7,393	3,555
Conveyance Length (L) / Static Head (H)	4.39	7.23	8.00		6.53	6.58	9.17	9.22	8.71	8.80	12.60	11.01	11.78	4.25	6.84
L/H General Acceptance Criteria	< 12	< 10	< 12		< 12	< 12	< 12	< 12	< 12	< 12	< 10	< 10	< 10	< 12	< 10
Upper Reservoir Usable Vol (AF)	6,300	16,200	14,000		19,540	11,700	18,500	12,700	28,800	11,500	21,100	79,400	16,900	7,300	16,800
Lower Reservoir Usable Vol (AF)	423,000	423,000	423,000		653,000	653,000	715,000	715,000	715,000	715,000	715,000	715,000	715,000	715,000	715,000
Upper Reservoir/Lower Reservoir (%)	1	4	3		3	2	3	2	4	2	3	11	2	1	2
Energy Storage (MWh)	4,865	9,231	12,782		36,755	21,802	28,000	19,110	42,639	16,823	9,978	48,205	9,517	11,177	7,686
Assumed Hours of Storage	**10**	**10**	**10**		**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**486**	**923**	**1,278**		**3,675**	**2,180**	**2,800**	**1,911**	**4,264**	**1,682**	**998**	**4,820**	**952**	**1,118**	**769**
Assumed Hours of Storage	20	20	20		20	20	20	20	20	20	20	20	20	20	20
Resulting Installed Capacity (MW)	243	462	639		1,838	1,090	1,400	955	2,132	841	499	2,410	476	559	384
Assumed Hours of Storage	30	30	30		30	30	30	30	30	30	30	30	30	30	30
Resulting Installed Capacity (MW)	162	308	426		1,225	727	933	637	1,421	561	333	1,607	317	373	256
Assumed Hours of Storage	40	40	40		40	40	40	40	40	40	40	40	40	40	40
Resulting Installed Capacity (MW)	122	231	320		919	545	700	478	1,066	421	249	1,205	238	279	192
Distance to Transmission (mi)	30	30	30		10	10	25	25	25	25	25	25	25	25	25
Voltage of Nearby Transmission (kV)	230	230	230		230	230	500	500	500	500	500	500	500	500	500
Transmission Ownership	IDPC	IDPC	IDPC		IDPC	IDPC	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF	PACIF

Table 2-6. Pumped Storage Alternative Preliminary Site Characteristics – Pacific Northwest Region

Pacific Northwest Alternative	Palisades			Warm Springs
	1	2	3	1
Max Upper Reservoir Elev (msl)	7,390	6,910	6,590	4,240
Min Upper Reservoir Elev (msl)	7,200	6,870	6,400	4,100
Estimated Dam Fill Volume (CY)	7,621,118	1,032,958	4,556,945	4,904,122
Lower Reservoir Maximum Elev (msl)	5,620	5,620	5,620	3,406
Lower Reservoir Minimum Elev (msl)	5,497	5,497	5,497	3,326
Upper Reservoir Drawdown (ft)	190	40	190	140
Min Head / Max Head Ratio (>.70)	0.83	0.88	0.71	0.76
Approx. Static Head (ft) (<2650 ft)	1,737	1,332	937	804
Maximum Dam Height (ft) (<400ft)	391	98	374	296
Horiz. Dist. Intake-Discharge (ft)	8,777	9,332	4,859	8,321
Estimated Submergence Below TW (ft)	189	141	109	91
Est. Conveyance Length (L)	10,703	10,805	5,905	9,216
Conveyance Length (L) / Static Head (H)	6.16	8.11	6.31	11.46
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	7,000	4,400	5,800	30,300
Lower Reservoir Usable Vol (AF)	1,200,000	1,200,000	1,200,000	191,000
Upper Reservoir/Lower Reservoir (%)	1	0	0	**16**
Energy Storage (MWh)	10,697	5,156	4,780	21,438
Assumed Hours of Storage	**10**	**10**	**10**	**10**
Resulting Installed Capacity (MW)	**1,070**	**516**	**478**	**2,144**
Assumed Hours of Storage	20	20	20	20
Resulting Installed Capacity (MW)	535	258	239	1,072
Assumed Hours of Storage	30	30	30	30
Resulting Installed Capacity (MW)	357	172	159	715
Assumed Hours of Storage	40	40	40	40
Resulting Installed Capacity (MW)	267	129	119	536
Distance to Transmission (mi)	60	60	60	20
Voltage of Nearby Transmission (kV)	345	345	345	500
Transmission Ownership	IDPC	IDPC	IDPC	PACIF

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Table 2-7 summarizes the results in the above tables and identifies the sites that were screened out at this level of analysis and those that move forward to the next screening step that includes Class 5 cost opinions and qualitative operations, environmental, regulatory, and economic evaluations.

This technical screening step also involved discussions with Reclamation representatives at each area office on each alternative. During these discussions, some fatal flaws were immediately recognized related to environmental or operational issues. Sites with fatal flaws were dropped from the analysis. Comments received from Reclamation area offices are documented in Appendix D. Table 2-7 also presents any fatal flaws identified during this screening step. The sites highlighted in red in Table 2-7 are those screened out for further analysis.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
Great Plains Region			
Wyoming	Buffalo Bill	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
		2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Wyoming	Bull	1A	Upper reservoir is 15% of lower reservoir volume and resulting installed capacity is over 3,000 MW, which is large compared to other sites in this evaluation. Alternative was optimized in Site 1B. Site 1A was screened out.
	Bull	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Bull	2A	Upper reservoir is 21% of lower reservoir volume and resulting installed capacity is over 5,000 MW, which is large for comparison purposes. Alternative was optimized in Site 2B. Site 2A was screened out.
	Bull	2B	Upper reservoir is 15% of lower reservoir volume and resulting installed capacity is over 3,000 MW, which is large for comparison purposes. Alternative was optimized in Alternative Site 2C. Alternative Site 2B was screened out.
	Bull	2C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Bull	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Bull	4	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Bull	5	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Montana	Canyon Ferry	1	L/H ratio greater than 10. Site was screened out.
	Canyon Ferry	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Canyon Ferry	3	L/H ratio greater than 10. Site was screened out.
E Colorado	Granby	1	Upper reservoir site in an area of protected fen wetlands and inundates significant recreation destination. Site was screened out.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
E Colorado	Green Mountain	1	Low minimum head/maximum head ratio; L/H ratio greater than 10; upper reservoir is 34% of lower reservoir. Site was screened out.
	Green Mountain	2	L/H ratio greater than 12; upper reservoir is 45% of lower reservoir; resulting installed capacity over 3,000 MW. Site was screened out.
	Green Mountain	3	Low minimum head/maximum head ratio; L/H ratio greater than 12; upper reservoir is 21% of lower reservoir, resulting installed capacity over 4,000 MW. Site was screened out.
E Colorado	Horsetooth	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
E Colorado	Ruedi	1	Upper reservoir is 17% of lower reservoir volume and there are system and water quality operational requirements.
E Colorado	Turquoise	1	Upper reservoir site is in an area of protected fen wetlands and in a Wilderness Boundary. Site was screened out.
Upper Colorado Region			
Power	Flaming Gorge	1A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Flaming Gorge	1B	Resulting installed capacity is over 2,000 MW. Alternative was optimized in Site 1C. Site 1B was screened out.
	Flaming Gorge	1C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Flaming Gorge	2A	Resulting installed capacity is over 6,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Flaming Gorge	2B	Resulting installed capacity is over 5,000 MW. Alternative was optimized in Site 2C. Site 2B was screened out.
	Flaming Gorge	2C	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 2D. Site 2C was screened out.
	Flaming Gorge	2D	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 2E. Site 2D was screened out.
	Flaming Gorge	2E	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 2F. Site 2E was screened out.
	Flaming Gorge	2F	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Power	Lake Powell	1A	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Lake Powell	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Lake Powell	2A	Resulting installed capacity was low (306 MW). Alternative was optimized in Site 2B and 2C. Site 2A was screened out.
	Lake Powell	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Lake Powell	2C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Provo	Deer Creek	1	L/H ratio greater than 10. Site was screened out.
	Deer Creek	2	L/H ratio greater than 10. Site was screened out.
Provo	Jordanelle	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Jordanelle	2A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Jordanelle	2B	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 2C and Site 2D. Site 2B was screened out.
	Jordanelle	2C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Jordanelle	2D	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Provo	Pineview	1A	L/H ratio greater than 10. Site was screened out.
	Pineview	1B	L/H ratio greater than 10. Site was screened out.
	Pineview	1C	L/H ratio greater than 10. Site was screened out.
	Pineview	1D	L/H ratio greater than 10. Site was screened out.
	Pineview	2A	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 2C and Site 2D. Site 2B was screened out.
	Pineview	2B	L/H ratio greater than 12. Site was screened out.
	Pineview	2C	L/H ratio greater than 12. Site was screened out.
	Pineview	2D	L/H ratio greater than 12. Site was screened out.
Provo	Strawberry	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Western Colorado	Blue Mesa	1A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Blue Mesa	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Blue Mesa	1C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Western Colorado	McPhee	1	L/H ratio greater than 10; resulting installed capacity was low (109 MW). Site 1 was screened out.
Western Colorado	Taylor Park	1A	Resulting installed capacity is over 5,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Taylor Park	1B	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 1C. Site 1B was screened out.
	Taylor Park	1C	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 1D. Site 1C was screened out.
	Taylor Park	1D	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 1E. Site 1D was screened out.
	Taylor Park	1E	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 2F. Site 1E was screened out.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Taylor Park	1F	The total volume of the upper reservoir Site 1F accounts for approximately 14% of the total volume of the lower reservoir, which may provide issues with existing downstream flow requirements and water usage during irrigation season. Site 1F was screened out.
Western Colorado	Vallecito	1A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Vallecito	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Vallecito	2A	Resulting installed capacity was low (612 MW). Alternative was optimized in Site 2B. Site 2A was screened out.
	Vallecito	2B	Resulting installed capacity was low (658 MW). Alternative was optimized in Site 2C. Site 2B was screened out.
	Vallecito	2C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Vallecito	3A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Vallecito	3B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Vallecito	3C	Upper reservoir is 22% of lower reservoir volume; large dam volume; and resulting installed capacity is near 2,500 MW. Site 3C was screened out.
Lower Colorado Region			
Lower Colorado	Havasu	1	L/H ratio greater than 10. Site 1 was screened out.
Lower Colorado	Mead	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	2A	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Mead	2B	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 2C. Site 2B was screened out.
	Mead	2C	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 2D. Site 2C was screened out.
	Mead	2D	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	4	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	5	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	6	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	7A	Resulting installed capacity over 3,000 MW; large dam volume. Alternative was optimized in Site 7B. Site 7A was screened out.
	Mead	7B	Resulting installed capacity over 2,500 MW; large dam volume. Alternative was optimized in Site 7C. Site 7B was screened out.
	Mead	7C	Resulting installed capacity over 3,000 MW; large dam volume. Alternative was optimized in Site 7B. Site 7A was screened out.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Mead	7D	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	7E	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	7F	Resulting installed capacity was low (658 MW). Alternative was optimized in Site 7D and Site 7E. Site 7F was screened out.
	Mead	8A	Resulting installed capacity over 2,500 MW; large dam volume. Alternative was optimized in Site 8B. Site 8A was screened out.
	Mead	8B	Resulting installed capacity over 2,000 MW; large dam volume. Alternative was optimized in Site 8C. Site 8B was screened out.
	Mead	8C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Mead	9A	Resulting installed capacity over 2,500 MW; large dam volume. Alternative was optimized in Site 9B. Site 9A was screened out.
	Mead	9B	Resulting installed capacity over 2,000 MW; large dam volume. Alternative was optimized in Site 9C. Site 9B was screened out.
	Mead	9C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Phoenix	Apache	1A	Resulting installed capacity over 2,000 MW. Alternative was optimized in Site 1B and 1C. Site 1A was screened out.
Phoenix	Apache	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Phoenix	Apache	1C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Mid-Pacific Region			
Central California	New Melones	1A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Central California	New Melones	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Central California	New Melones	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Klamath	Upper Klamath	1	Klamath Lake has endangered fish species that would make a pumped storage project impossible or very difficult to pass environmental clearance. This site inundates a highly used state highway. Site 1 was screened out.
Klamath	Upper Klamath	2	Klamath Lake has endangered fish species that would make a pumped storage project impossible or very difficult to pass environmental clearance. This site would draw/discharge in the vicinity of springs that fish use for spawning. Site 2 was screened out.
Lahontan	Tahoe	1	Site would affect existing water supply for Virginia City and Carson City, a fishery for threatened fish species, State Parks areas, and would not be consistent with TRPA Lake Tahoe Basin Management Plan. Site 1 was screened out.
Lahontan	Tahoe	2	Site would affect Incline Village sewer lines, State Parks areas, and would not be consistent with TRPA Lake Tahoe Basin Management Plan. Site 2 was screened out.
Northern California	Shasta	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Northern California	Shasta	2A	Resulting installed capacity is over 7,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
Northern California	Shasta	2B	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 2C. Site 2B was screened out.
Northern California	Shasta	2C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Shasta	3A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	3B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	4	L/H ratio greater than 10 and low resulting installed capacity (220 MW). Site 4 was screened out.
	Shasta	5A	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	5B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	5C	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	6	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Shasta	7	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Northern California	Whiskeytown	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Whiskeytown	2	L/H ratio greater than 10. Site 2 was screened out.
South-Central California	Millerton	1A	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Millerton	1B	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 1C. Site 1B was screened out.
	Millerton	1C	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 1D. Site 1C was screened out.
	Millerton	1D	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
South-Central California	San Luis	1	Low static head, minimum head/maximum head ratio is less than 0.7. Site 1 was screened out.
	San Luis	2	The upper reservoir site is in a state park where developments cannot occur.
Pacific Northwest Region			
Columbia-Cascades	Cle Elum	1A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Cle Elum	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Cle Elum	2A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Cle Elum	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Keechelus	1A	Upper reservoir is 48% of lower reservoir volume.
	Keechelus	1B	Upper reservoir is 20% of lower reservoir volume.
	Keechelus	2A	Resulting installed capacity is over 6,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Keechelus	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Keechelus	to Little Kachess	No technical or other fatal flaws. Retained for cost opinions and further evaluation.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Little Kachess	1	L/H ratio is greater than 12. Site 1 was screened out.
	Little Kachess	2A	Resulting installed capacity is over 3,000 MW, which is large for comparison purposes. Alternative was optimized in Site 2B. Site 2A was screened out.
	Little Kachess	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Little Kachess	3A	Static head is greater than 2,650 ft; resulting installed capacity is over 7,000 MW. Site 3A was screened out.
	Little Kachess	3B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Prineville	1	L/H ratio greater than 7, low static head. Site 1 was screened out.
	Prineville	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Prineville	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Rimrock	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Rimrock	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Rimrock	3A	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 3B. Site 3A was screened out.
	Rimrock	3B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Grand Coulee Power	Banks	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Banks	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Banks	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Banks	4	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Banks	to FDR	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	1A	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Hungry Horse	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	4	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	5	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	6	Low resulting installed capacity (182 MW). Site 6 was screened out.
	Hungry Horse	7A	Resulting installed capacity is over 5,000 MW. Alternative was optimized in Site 7B. Site 7A was screened out.
	Hungry Horse	7B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Hungry Horse	8	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Hungry Horse	9A	Resulting installed capacity is over 9,000 MW. Alternative was optimized in Site 9B. Site 9A was screened out.
	Hungry Horse	9B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	2A	Low resulting installed capacity (182 MW). Site 2A was screened out.
	Franklin D Roosevelt	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	4	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	5	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	6	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	7	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	8	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	9A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 9B. Site 9A was screened out.
	Franklin D Roosevelt	9B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	10	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	11	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	12	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	13	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	14A	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 14B. Site 14A was screened out.
	Franklin D Roosevelt	14B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	15A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 15B. Site 15A was screened out.
	Franklin D Roosevelt	15B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	16	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	17	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	18	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	19	No technical or other fatal flaws. Retained for cost opinions and further evaluation.

Table 2-7. Technical Screening Results Summary

Area Office	Reservoir	Alternative	Evaluation Result
	Franklin D Roosevelt	20	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	21	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Franklin D Roosevelt	22	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
Snake River	Anderson Ranch	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Anderson Ranch	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Anderson Ranch	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Anderson Ranch	4	
	Cascade	1A	Resulting installed capacity is over 3,000 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Cascade	1B	Upper reservoir would inundate portions of a popular ski resort. Site 1B was screened out.
	Owyhee	1	Resulting installed capacity is over 2,500 MW. Alternative was optimized in Site 1B. Site 1A was screened out.
	Owyhee	1B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Owyhee	2A	Resulting installed capacity is over 4,000 MW. Alternative was optimized in Site 2B. Site 2A was screened out.
	Owyhee	2B	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Owyhee	3	L/H ratio greater than 10. Site 3 was screened out.
	Owyhee	4A	L/H ratio greater than 10. Site 4A was screened out.
	Owyhee	4B	L/H ratio greater than 10. Site 4B was screened out.
	Owyhee	5	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Owyhee	6	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Palisades	1	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Palisades	2	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Palisades	3	No technical or other fatal flaws. Retained for cost opinions and further evaluation.
	Warm Springs	1	Reclamation does not hold title to this reservoir. It was screened out of the analysis.

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Chapter 3 Conceptual Layout and Cost Evaluation

3.1 General Procedures and Assumptions

This section describes the methods to develop conceptual layouts for each of the alternatives, including sizing, performing quantity take-offs, and generating Class 5 cost opinions for the following major project elements:

- Reservoirs and dams
- Water conveyance systems
- Power station and associated equipment
- Switchyard and transmission facilities
- Project access

The primary resource utilized for this task included the EPRI Document No. GS-6669 (1990). Because the cost estimating tools are based on 1988 pricings, all cost estimates were indexed to 2012 dollars using an escalation an average escalation factor of 3.0 for the reservoirs and dams, water conveyance systems, switchyard and transmission facilities and access. An escalation factor of 4.0 was used for power station and associated equipment to reflect the additional costs associated with variable speed technology. Refer to Appendix C for additional information regarding single versus variable speed technology.

3.2 Reservoirs and Dams

3.2.1 Reservoirs

Reservoirs for each alternative were sized using methods discussed in Chapter 2 of this report. The combined reservoir drawdown limits were limited to approximately 30 percent of the static head, which is common for variable speed pump-turbine operational restrictions (See Section 2.4 of the report for the assumed operating range of pump-turbine units).

3.2.1.1 Dams

All dams were assumed to be rockfill concrete face type. Material take-off estimates were performed for each dam structure assuming a crest elevation 10 ft. higher than the maximum reservoir elevation as well as upstream and downstream slopes of 1.75H:1.0V. Dam heights were increased by an additional 20 ft. to account for foundation and abutment stripping, and other factors.

Estimated earthwork volumes and construction costs details for each alternative are provided in Appendix B. For medium to large dams, Figure 6-10 in EPRI Document No. GS-6669 (1990) indicates a 1988 unit cost in the order of $8/CY. Assuming an escalation factor of 3.0, this calculates to a 2012 unit cost of approximately $24/CY.

3.2.1.2 Stream Diversion

A stream diversion system would be installed to divert flows during construction of the upper reservoir main dam for all alternatives with a new upper reservoir. For the purpose of this estimate, $5,000,000 was allocated for the installation of a stream diversion system (based on cost opinions of similar systems). The actual costs for a stream diversion system would be the product of more detailed engineering studies.

3.2.2 Spillway

There is very little drainage area associated with the new upper reservoir impoundments; therefore, no major spillway was assumed necessary for the purpose of passing a probable maximum flood. To protect the impoundments against the possibility of over-pumping, $5,000,000 was allocated for the construction of the spillway for all alternatives with a new upper reservoir (based on cost opinions of similar systems). The actual costs for a reservoir spillway system would be the product of more detailed engineering studies.

3.2.3 Power Station Structure

Power station construction costs for alternatives with a new upper reservoir assume an underground powerhouse. The power stations for the two alternatives, Keechelus Reservoir to Little Kachess and Banks Lake to Franklin D. Roosevelt Reservoir, assume shoreline structures at the lower reservoir. The unit costs were derived from Figures 6-8 through 6-9 of EPRI Document No. GS-6669 (1990) and escalated to 2012 dollars using an escalation factor of 4.0. Cost details of the power station structures are provided in Appendix B.

3.2.4 Water Conveyance, Equipment, Transmission, and Other Civil Works

3.2.4.1 Profile Assumptions

The water conveyance profile for all alternatives with a new upper reservoir was assumed to consist of a vertical intake/shaft, horizontal power tunnel, underground powerstation, draft tube tunnels, and tailrace tunnels. This profile is a common configuration for large off-stream pumped storage projects. The actual power complex profile would be the project of more detailed engineering studies.

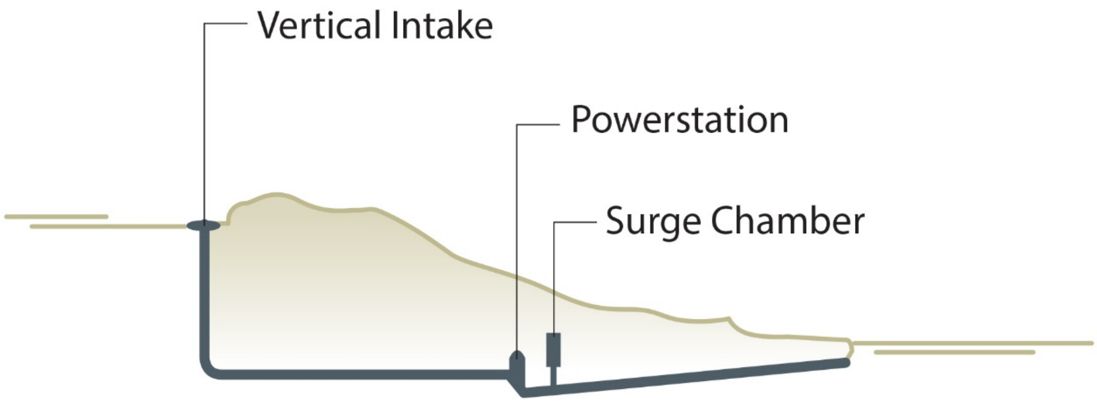

Figure 3-1. Water Conveyance Profile for Alternatives with New Upper Reservoir

The water conveyance profile for Keechelus Reservoir to Little Kachess and Banks Lake to Franklin D. Roosevelt Reservoir was assumed to consist of a horizontal intake, power tunnel, and shoreline power station.

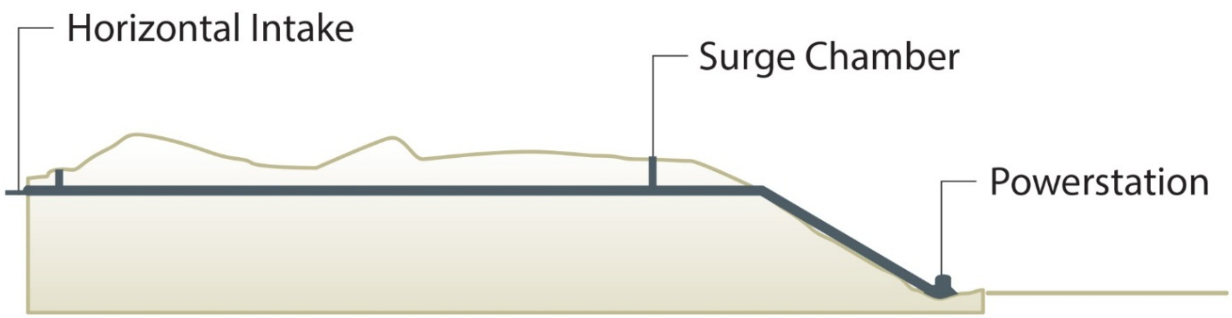

Figure 3-2. Water Conveyance Profile for Alternatives with Existing Upper and Lower Reservoirs

All tunnels were assumed to be fully lined with concrete. All penstocks and draft tubes are assumed to be steel lined.

3.2.4.2 Water Conduit Sizing Assumptions

3.2.4.2.1 Tunnel Diameter

The water conduit diameter is estimated using the following relationship:

$D = (1.273\ Q/V)^{0.5}$

Where: D = Water Conduit Diameter (ft)

Q = Generating Discharge (cfs)

V = Generating Velocity (ft/sec)

For tunnel diameters greater than 35 ft, an additional tunnel is recommended. The resulting water conveyance characteristics for each option are shown in Tables 3-2 to 3-6. Cost elements are provided in the following sections.

3.2.4.2.2 Generating Discharge

The generating discharge was estimated as follows:

Q = 11,800 C/He

Where: Q = Design Generating Discharge (cfs)

C = Rated Generating Capacity (MW)

H = Gross Head (ft)

e = Overall Generating Efficiency (assumed 0.86)

3.2.4.2.3 Flow Velocity

The EPRI 1990 criteria for estimating the maximum water velocity within the headrace tunnel was estimated as follows:

- If L/H < 6, then no surge chamber is assumed
- If L/H is > 6, then compute the maximum water velocity using the following relationship:

  V = 120 H/L

  Then, re-estimate water conduit dimensions using the conduit diameter equation in Section 3.4.2.1 and make provisions for surge protection.

The maximum velocity within the headrace tunnel should not be greater than 23 ft/sec. The minimum recommended velocity at this stage of development is 15 ft/sec.

The maximum velocity with the penstock and draft tubes can be estimated using the following criteria:

Table 3-1. Flow Velocity Criteria for Penstock and Draft Tubes

Maximum Head (ft)	Penstock Tunnel Velocity (ft/sec)	Draft Tube Tunnel Velocity (ft/sec)
200	17	6
300	18	8
500	20	10
1,000	25	13
1,500	28	15
2,200	32	17

Table 3-2. Water Conveyance Characteristics – Great Plains Region

Great Plains Region	Alt.	General Site Characteristics								Water Conveyance System - Preliminary Characteristics							
		Assumed Installed Capacity (MW) [1]	Number of Units (~300 MW Max)	Approx Static Head (H)	Est. Water Conveyance Length (L)	L/H	Maximum Flow Velocity Headrace Tunnel (ft/sec)	Assumed Surge Tank Required	Generating Discharge (cfs)	Headrace Tunnel Diameter (ft)	Number of Headrace Tunnels	Penstock Diameter (ft)	Number of Penstocks	Draft Tube Diameter (ft)	Number of Draft Tubes	Tailrace Tunnel Diameter (ft)	Number of Tailrace Tunnels
Buffalo Bill	1	1594	6	1,548	9,714	6.3	19.1	Yes	14,128	31	1	10	6	14	6	24	2
	2	1,885	8	1,428	12,183	8.5	15.0	Yes	18,111	28	2	10	8	14	8	28	2
Bull	1A	3,139	12	1,558	13,409	8.6	15.0	Yes	27,643	28	3	10	12	14	12	28	3
	1B	1,982	8	1,533	13,379	8.7	15.0	Yes	17,738	27	2	10	8	14	8	27	2
	2A	5,332	18	1,918	14,004	7.3	16.4	Yes	38,141	31	3	10	18	13	18	23	6
	2B	3,690	14	1,898	13,980	7.4	16.3	Yes	26,674	32	2	9	14	13	14	24	4
	2C	2,043	8	1,873	13,950	7.4	16.1	Yes	14,965	34	1	9	8	13	8	25	2
	3	527	4	1,498	9,135	6.1	19.7	Yes	4,827	18	1	7	4	10	4	20	1
	4	639	4	1,578	7,628	4.8	23.0	No	5,556	18	1	8	4	11	4	22	1
	5	977	4	1,683	7,743	4.6	23.0	No	7,965	21	1	10	4	13	4	26	1
Canyon Ferry	1	1,334	6	705	9,184	13.0	15.0	Yes	25,961	33	2	14	6	19	6	33	2
	2	1,919	8	1,330	14,776	11.1	15.0	Yes	19,796	29	2	11	8	14	8	29	2
	3	1,114	4	740	7,623	10.3	15.0	Yes	20,654	30	2	15	4	21	4	30	2
Granby	1	1,681	6	1,000	8,028	8.0	15.0	Yes	23,063	31	2	13	6	18	6	31	2
Green Mountain	1	2,111	8	620	7,347	11.9	15.0	Yes	46,714	31	4	16	8	22	8	31	4
	2	3,905	14	870	11,822	13.6	15.0	Yes	61,582	27	7	14	14	19	14	27	7
	3	4,262	16	2,035	26,503	13.0	15.0	Yes	28,734	25	4	9	16	12	16	25	4
Horsetooth	1	709	4	915	7,991	8.7	15.0	Yes	10,631	30	1	11	4	15	4	30	1
Ruedi	1	2,823	10	1,887	18,490	9.8	15.0	Yes	20,525	30	2	10	10	13	10	19	5
Turquoise	1	675	4	1,128	8,379	7.4	16.2	Yes	8,210	25	1	10	4	13	4	26	1

Notes:
[1] Based on a 10-hour run time.

Table 3-3. Water Conveyance Characteristics – Upper Colorado Region

Upper Colorado Region	Alt.	General Site Characteristics								Water Conveyance System - Preliminary Characteristics							
		Assumed Installed Capacity (MW) (1)	Number of Units (~300 MW Max)	Approx Static Head (H)	Est Water Conveyance Length (L)	L/H	Maximum Flow Velocity Headrace Tunnel (ft/sec)	Assumed Surge Tank Required	Generating Discharge (cfs)	Headrace Tunnel Diameter (ft)	Number of Headrace Tunnels	Penstock Diameter (ft)	Number of Penstocks	Draft Tube Diameter (ft)	Number of Draft Tubes	Tailrace Tunnel Diameter (ft)	Number of Tailrace Tunnels
Blue Mesa	1A	759	3	980	9,924	10.1	11.9	No	10,625	34	1	13	3	17	3	30	1
	1B	1,240	6	985	9,930	10.1	11.9	No	17,265	30	2	11	6	16	6	27	2
	1C	1,789	6	990	9,936	10.0	12.0	No	24,799	30	3	14	6	19	6	26	3
Flaming Gorge	1A	3,879	14	1,683	6,124	3.6	23.0	No	31,633	30	2	10	14	14	14	20	7
	1B	2,454	10	1,670	6,109	3.7	23.0	No	20,163	33	1	10	10	13	10	29	2
	1C	1,269	6	1,658	6,094	3.7	23.0	No	10,504	24	1	9	6	12	6	30	1
	2A	6,118	21	1,498	5,920	4.0	23.0	No	56,052	32	3	11	21	15	21	26	7
	2B	5,227	18	1,493	5,914	4.0	23.0	No	48,053	30	3	11	18	15	18	26	6
	2C	4,320	15	1,488	5,908	4.0	23.0	No	39,843	27	3	11	15	15	15	26	5
	2D	3,470	12	1,483	5,902	4.0	23.0	No	32,116	30	2	11	12	15	12	26	4
	2E	2,652	8	1,478	5,896	4.0	23.0	No	24,630	26	2	12	8	16	8	23	4
	2F	1,918	8	1,473	5,890	4.0	23.0	No	17,869	31	1	10	8	14	8	28	2
Lake Powell	1A	2,802	9	1,355	6,553	4.8	23.0	No	28,373	23	3	12	9	16	9	28	3
	1B	2,210	8	1,350	6,547	4.8	23.0	No	22,457	35	1	11	8	15	8	31	2
	2A	306	2	755	5,892	7.8	15.4	Yes	5,554	21	1	11	2	15	2	22	1
	2B	732	3	770	5,910	7.7	15.6	Yes	13,039	33	1	14	3	19	3	33	1
	2C	1,536	6	790	5,934	7.5	16.0	Yes	26,683	33	2	14	6	19	6	27	3
Deer Creek	1	1,614	8	579	6,729	11.6	10.3	Yes	38,273	34	4	15	8	20	8	28	4
	2	1,286	6	641	6,798	10.6	11.3	Yes	27,528	32	3	14	6	20	6	28	3
Jordanelle	1	1,006	4	900	9,387	10.4	11.5	Yes	15,333	29	2	13	4	18	4	26	2
	2A	3,364	12	1,505	13,242	8.8	13.6	Yes	30,667	31	3	11	12	15	12	29	3
	2B	2,570	10	1,490	13,224	8.9	13.5	Yes	23,664	33	2	10	10	14	10	20	5
	2C	2,084	8	1,480	13,212	8.9	15.0	Yes	19,318	29	2	10	8	14	8	29	2
	2D	1,656	6	1,470	13,200	9.0	15.0	Yes	15,454	26	2	11	6	15	6	26	2
Pineview	1A	3,315	12	730	8,054	11.0	15.0	Yes	62,300	30	6	15	12	21	12	30	6
	1B	2,680	10	720	8,042	11.2	15.0	Yes	51,071	29	5	15	10	21	10	29	5
	1C	2,131	8	710	8,030	11.3	15.0	Yes	41,171	30	4	15	8	21	8	30	4
	1D	1,663	6	700	8,018	11.5	15.0	Yes	32,599	30	3	16	6	21	6	30	3
	2A	3,363	12	970	11,619	12.0	15.0	Yes	47,570	32	4	13	12	18	12	32	4
	2B	2,678	10	960	11,607	12.1	15.0	Yes	38,273	25	5	13	10	18	10	25	5
	2C	2,087	8	945	11,589	12.3	15.0	Yes	30,305	25	4	13	8	18	8	25	4
	2D	1,596	6	935	11,577	12.4	15.0	Yes	23,423	32	2	13	6	18	6	32	2
Strawberry	1	1,521	6	905	5,442	6.0	20.0	No	23,061	27	2	13	6	18	6	26	3
McPhee	1	109	1	495	5,417	10.9	15.0	Yes	3,018	16	1	12	1	16	1	16	1

Table 3-3. Water Conveyance Characteristics – Upper Colorado Region

Taylor Park	1A	5,606	20	1,750	14,835	8.5	15.0	Yes	43,948	31	4	10	20	14	20	27	5
	1B	4,793	16	1,740	14,823	8.5	15.0	Yes	37,790	28	4	10	16	14	16	28	4
	1C	4,050	15	1,730	14,811	8.6	15.0	Yes	32,116	30	3	10	15	13	15	30	3
	1D	3,375	12	1,720	14,799	8.6	15.0	Yes	26,924	34	2	10	12	14	12	34	2
	1E	2,754	10	1,710	14,787	8.6	15.0	Yes	22,095	31	2	10	10	14	10	19	5
	1F	2,199	8	1,700	14,775	8.7	15.0	Yes	17,748	27	2	10	8	14	8	19	4
Vallecito	1A	1,335	6	893	5,136	5.8	20.9	No	20,525	25	2	12	6	17	6	24	3
	1B	1,211	6	888	5,130	5.8	20.8	No	18,714	24	2	12	6	16	6	28	2
	2A	612	2	748	4,396	5.9	20.4	No	11,228	26	1	16	2	22	2	22	2
	2B	658	3	878	5,728	6.5	18.4	Yes	10,295	27	1	12	3	17	3	30	1
	2C	995	4	898	5,752	6.4	18.7	Yes	15,213	32	1	13	4	18	4	25	2
	3A	1,004	4	943	5,591	5.9	20.2	No	14,609	30	1	13	4	18	4	25	2
	3B	1,601	6	963	5,615	5.8	20.6	No	22,819	27	2	13	6	18	6	25	3
	3C	2,364	8	983	5,639	5.7	20.9	No	33,009	32	2	14	8	19	8	26	4

Notes:
[1] Based on a 10-hour run time.

Table 3-4. Water Conveyance Characteristics – Lower Colorado Region

Lower Colorado Region	Alt.	General Site Characteristics								Water Conveyance System - Preliminary Characteristics							
		Assumed Installed Capacity (MW) [1]	Number of Units (~300 MW Max)	Approx Static Head (H)	Est Water Conveyance Length (L)	L/H	Maximum Flow Velocity Headrace Tunnel (ft/sec)	Assumed Surge Tank Required	Generating Discharge (cfs)	Headrace Tunnel Diameter (ft)	Number of Headrace Tunnels	Penstock Diameter (ft)	Number of Penstocks	Draft Tube Diameter (ft)	Number of Draft Tubes	Tailrace Tunnel Diameter (ft)	Number of Tailrace Tunnels
Havasu	1	888	4.0	710	7,483	10.5	15.0	Yes	17,151	27	2	14	4	19	4	27	2
Mead	1	891	4.0	790	5,352	6.8	17.7	Yes	15,472	33	1	13	4	18	4	26	2
	2A	4,685	16.0	1,690	9,651	5.7	21.0	No	38,032	34	2	10	16	14	16	28	4
	2B	3,543	12.0	1,678	9,636	5.7	20.9	No	28,977	30	2	10	12	14	12	25	4
	2C	2,564	10.0	1,665	9,621	5.8	20.8	No	21,129	25	2	10	10	13	10	19	5
	2D	1,745	6.0	1,653	9,606	5.8	20.6	No	14,488	30	1	10	6	14	6	25	2
	3	1,363	6.0	1,210	6,279	5.2	23.0	No	15,454	29	1	11	6	15	6	26	2
	4	449	2.0	665	5,393	8.1	15.0	Yes	9,260	28	1	15	2	20	2	28	1
	5	696	3.0	955	3,723	3.9	23.0	No	9,997	24	1	12	3	17	3	29	1
	6	873	3.0	775	5,784	7.5	16.1	Yes	15,454	35	1	15	3	21	3	21	3
	7A	3,393	12.0	1,285	7,382	5.7	20.9	No	36,221	27	3	12	12	16	12	32	3
	7B	2,794	10.0	1,275	7,370	5.8	20.8	No	30,063	30	2	12	10	16	10	23	5
	7C	2,145	8.0	1,263	7,355	5.8	20.6	No	23,302	27	2	12	8	16	8	31	2
	7D	1,595	6.0	1,250	7,340	5.9	20.4	No	17,507	33	1	12	6	16	6	27	2
	7E	1,133	4.0	1,238	7,325	5.9	20.3	No	12,557	28	1	12	4	16	4	23	2
	7F	755	3.0	1,225	7,310	6.0	20.1	No	8,452	23	1	11	3	15	3	27	1
	8A	2,673	9.0	853	5,872	6.9	17.4	Yes	42,982	32	3	15	9	20	9	35	3
	8B	2,239	9.0	845	5,862	6.9	17.3	Yes	36,342	30	3	14	9	19	9	32	3
	8C	1,742	6.0	835	5,850	7.0	17.1	Yes	28,614	33	2	15	6	20	6	28	3
	9A	2,861	10.0	2,390	11,677	4.9	23.0	No	16,420	30	1	9	10	12	10	26	2
	9B	2,155	8.0	2,378	11,662	4.9	23.0	No	12,436	26	1	8	8	11	8	23	2
	9C	1,540	6.0	2,365	11,647	4.9	23.0	No	8,934	22	1	8	6	11	6	28	1
Apache	1A	2,272	8.0	1,733	7,871	4.5	23.0	No	17,990	32	1	10	8	14	8	28	2
	1B	1,759	6.0	1,723	7,859	4.6	23.0	No	14,005	28	1	10	6	14	6	24	2
	1C	1,402	6.0	1,713	7,847	4.6	23.0	No	11,228	25	1	9	6	13	6	22	2

Notes:
[1] Based on a 10-hour run time.

Table 3-5. Water Conveyance Characteristics – Mid-Pacific Region

Mid Pacific Region	Alt.	General Site Characteristics								Water Conveyance System - Preliminary Characteristics							
		Assumed Installed Capacity (MW) [1]	Number of Units (~300 MW Max)	Approx Static Head (H)	Est Water Conveyance Length (L)	L/H	Maximum Flow Velocity Headrace Tunnel (ft/sec)	Assumed Surge Chamber Required	Generating Discharge (cfs)	Headrace Tunnel Diameter (ft)	Number of Headrace Tunnels	Penstock Diameter (ft)	Number of Penstocks	Draft Tube Diameter (ft)	Number of Draft Tubes	Tailrace Tunnel Diameter (ft)	Number of Tailrace Tunnels
New Melones	1A	816	3	1,237	8,938	7.2	16.6	Yes	9,051	26	1	12	3	16	3	28	1
	1B	1399	6	1,252	8,956	7.2	16.8	Yes	15,331	34	1	11	6	15	6	26	2
	2	294	2	1,247	6,460	5.2	23.0	Yes	3,235	13	1	9	2	12	2	17	1
Upper Klamath	1	2575	10	505	3,292	6.5	18.4	Yes	69,958	31	5	18	10	24	10	34	5
	2	**318**	2	1,290	4,138	3.2	23.0	No	3,382	14	1	9	2	12	2	17	1
Tahoe	1	1422	6	1,615	7,182	4.4	23.0	No	12,080	26	1	10	6	13	6	23	2
	2	656	3	745	4,790	6.4	18.7	Yes	12,074	29	1	14	3	18	3	32	1
Shasta	1	553	2	714	5,047	7.1	17.0	Yes	10,626	28	1	16	2	21	2	30	1
	2A	7044	24	2,069	19,615	9.5	15.0	Yes	46,710	31	4	9	24	13	24	22	8
	2B	4294	16	2,042	19,583	9.6	15.0	Yes	28,851	35	2	9	16	12	16	35	2
	2C	2360	8	2,017	19,553	9.7	15.0	Yes	16,053	26	2	10	8	13	8	26	2
	3A	862	3	942	6,325	6.7	17.9	Yes	12,555	30	1	14	3	19	3	33	1
	3B	1293	6	967	6,354	6.6	18.3	Yes	18,345	25	2	12	6	16	6	28	2
	4	220	1	597	6,091	10.2	15.0	Yes	5,056	21	1	15	1	21	1	21	1
	5A	2248	8	1,352	6,674	4.9	23.0	No	22,813	25	2	11	8	16	8	31	2
	5B	791	3	1,232	7,115	5.8	20.8	No	8,809	23	1	12	3	16	3	27	1
	5C	950	4	1,102	8,048	7.3	16.4	Yes	11,828	30	1	12	4	16	4	22	2
	6	2184	9	937	9,603	10.2	15.0	Yes	31,979	30	3	13	9	17	9	30	3
	7	2621	9	937	7,937	8.5	15.0	Yes	38,378	33	3	14	9	19	9	33	3
Whiskeytown	1	1481	6	1,295	11,547	8.9	15.0	Yes	15,691	26	2	11	6	15	6	26	2
	2	2082	10	680	8,890	13.1	15.0	Yes	42,007	27	5	14	10	19	10	30	4
Millerton	1A	4754	18	826	5,609	6.8	17.7	Yes	78,965	31	6	14	18	19	18	27	9
	1B	3766	15	791	5,570	7.0	17.0	Yes	65,322	31	5	14	15	19	15	33	5
	1C	2659	10	746	5,520	7.4	16.2	Yes	48,903	28	5	15	10	20	10	29	5
	1D	2206	9	731	5,503	7.5	15.9	Yes	41,404	33	3	14	9	20	9	34	3
San Luis	1	0	0	428	2,771	6.5	18.5	Yes									
	2	1391	6	903	7,299	8.1	15.0	Yes	21,135	30	2	13	6	17	6	30	2

Notes:
[1] Based on a 10-hour run time.

Table 3-6. Water Conveyance Characteristics – Pacific Northwest Region

Pacific Northwest Region	Alt.	General Site Characteristics								Water Conveyance System - Preliminary Characteristics							
		Assumed Installed Capacity (MW) (1)	Number of Units (~300 MW Max)	Approx Static Head (H)	Est Water Conveyance Length (L)	L/H	Maximum Flow Velocity Headrace Tunnel (ft/sec)	Assumed Surge Chamber Required	Generating Discharge (cfs)	Headrace Tunnel Diameter (ft)	Number of Headrace Tunnels	Penstock Diameter (ft)	Number of Penstocks	Draft Tube Diameter (ft)	Number of Draft Tubes	Tailrace Tunnel Diameter (ft)	Number of Tailrace Tunnels
Cle Elum	1A	3,015	12	1,113	9,333	8.4	15.0	Yes	37,187	32	3	12	12	16	12	32	3
	1B	1,483	6	1,088	9,303	8.6	15.0	Yes	18,714	28	2	12	6	16	6	28	2
	2A	3,352	12	1,518	16,458	10.8	15.0	Yes	30,305	29	3	11	12	15	12	29	3
	2B	2,147	8	1,488	16,422	11.0	15.0	Yes	19,801	29	2	11	8	14	8	29	2
Keechelus	1A	5,537	21	829	6,677	8.1	15.0	Yes	91,639	33	7	14	21	19	21	33	7
	1B	2,201	8	779	6,617	8.5	15.0	Yes	38,756	29	4	15	8	20	8	29	4
	2A	6,570	24	1,799	12,803	7.1	16.9	Yes	50,105	25	6	10	24	13	24	27	6
	2B	2,054	8	1,729	12,719	7.4	16.3	Yes	16,299	25	2	10	8	13	8	26	2
	3	322	2	244	21,648	88.7	15.0	Yes	18,106	28	2	20	2	28	2	28	2
Little Kachess	1	1,936	8	1,033	12,986	12.6	15.0	Yes	25,717	33	2	12	8	17	8	33	2
	2A	3,268	12	1,498	15,577	10.4	15.0	Yes	29,943	29	3	11	12	15	12	29	3
	2B	2,105	8	1,468	15,541	10.6	15.0	Yes	19,680	29	2	11	8	14	8	29	2
	3A	7,079	24	2,843	10,287	3.6	23.0	No	34,168	22	4	8	24	11	24	27	4
	3B	2,539	10	2,748	10,163	3.7	23.0	No	12,680	26	1	8	10	10	10	33	1
Prineville	1	652	4	481	5,283	11.0	15.0	Yes	18,593	28	2	15	4	20	4	28	2
	2	1,696	6	1,036	9,272	8.9	15.0	Yes	22,457	31	2	13	6	18	6	31	2
	3	1,081	4	686	3,292	4.8	23.0	No	21,620	24	2	16	4	21	4	30	2
Rimrock	1	1,119	4	859	6,378	7.4	15.0	Yes	17,869	28	2	14	4	19	4	28	2
	2	1,525	6	927	4,177	4.5	23.0	No	22,578	25	2	13	6	18	6	31	2
	3A	2,792	10	2,267	14,292	6.3	19.0	Yes	16,903	24	2	9	10	12	10	27	2
	3B	2,061	8	2,252	14,274	6.3	18.9	Yes	12,557	29	1	8	8	12	8	33	1
Banks	1	845	3	881	5,584	6.3	18.9	Yes	13,160	30	1	14	3	19	3	33	1
	2	1,030	4	731	5,224	7.2	16.8	Yes	19,354	27	2	15	4	20	4	29	2
	3	894	3	696	3,439	4.9	23.0	No	17,627	31	1	16	3	22	3	22	3
	4	708	3	821	3,773	4.6	23.0	No	11,832	26	1	13	3	18	3	32	1
	5	968	4	306	8,000	26.1	20.0	Yes	43,402	26	4	22	4	30	4	30	4
Hungry Horse	1A	4,452	15	2,750	14,499	5.3	23.0	No	22,215	20	3	8	15	11	15	25	3
	1B	2,285	8	2,705	14,445	5.3	22.5	No	11,591	26	1	8	8	11	8	31	1
	2	1,578	6	1,142	8,795	7.7	15.6	Yes	18,956	28	2	12	6	16	6	28	2
	3	1,346	6	987	8,352	8.5	15.0	Yes	18,714	28	2	12	6	16	6	28	2
	4	893	3	957	5,033	5.3	22.8	No	12,798	27	1	14	3	19	3	33	1
	5	651	3	902	7,135	7.9	15.2	Yes	9,900	29	1	12	3	17	3	29	1
	6	182	1	667	3,990	6.0	20.1	No	3,743	15	1	13	1	18	1	18	1
	7A	5,078	18	1,432	6,622	4.6	23.0	No	48,657	30	3	11	18	15	18	26	6
	7B	2,328	8	1,407	6,592	4.7	23.0	No	22,698	25	2	11	8	16	8	31	2
	8	1,160	4	2,312	14,212	6.1	19.5	Yes	6,882	21	1	9	4	12	4	24	1
	9A	9,115	32	2,777	18,348	6.6	18.2	Yes	45,035	28	4	8	32	11	32	31	4
	9B	2,085	7	2,692	18,246	6.8	17.7	Yes	10,625	28	1	8	7	11	7	30	1

Table 3-6. Water Conveyance Characteristics – Pacific Northwest Region

Franklin D. Roosevelt	1	2,203	8	1,089	9,438	8.7	15.0	Yes	27,769	34	2	13	8	17	8	34	2
	2A	182	1	691	5,154	7.5	16.1	Yes	3,622	17	1	13	1	18	1	18	1
	2B	1,074	4	1,259	6,494	5.2	23.0	No	11,711	25	1	12	4	16	4	32	1
	3	1,307	6	1,039	4,405	4.2	23.0	No	17,265	31	1	11	6	16	6	27	2
	4	2,650	9	1,039	8,612	8.3	15.0	Yes	35,013	31	3	13	9	18	9	31	3
	5	2,113	9	976	7,519	7.7	15.6	Yes	29,701	28	3	12	9	17	9	29	3
	6	1,201	5	1,264	7,545	6.0	20.1	No	13,039	29	1	11	5	15	5	33	1
	7	1,440	6	676	5,206	7.7	15.6	Yes	29,218	28	3	15	6	20	6	29	3
	8	2,745	10	741	5,834	7.9	15.2	Yes	50,830	29	5	15	10	21	10	29	5
	9A	3,331	12	799	6,343	7.9	15.1	Yes	57,229	35	4	15	12	20	12	28	6
	9B	2,022	9	774	6,313	8.2	15.0	Yes	35,859	32	3	13	9	18	9	32	3
	10	1,561	6	736	4,823	6.6	18.3	Yes	29,097	32	2	15	6	20	6	29	3
	11	2,317	10	734	4,361	5.9	20.2	No	43,344	23	5	14	10	19	10	27	5
	12	797	3	761	7,399	9.7	15.0	Yes	14,368	35	1	15	3	20	3	35	1
	13	834	3	1,316	8,733	6.6	18.1	Yes	8,693	25	1	11	3	16	3	27	1
	14A	4,092	15	1,264	13,255	10.5	15.0	Yes	44,431	35	3	12	15	16	15	35	3
	14B	1,805	8	1,229	13,213	10.8	15.0	Yes	20,163	29	2	11	8	15	8	29	2
	15A	3,592	12	1,089	10,826	9.9	15.0	Yes	45,276	31	4	13	12	18	12	31	4
	15B	1,685	6	1,064	10,796	10.2	15.0	Yes	21,732	30	2	13	6	18	6	30	2
	16	2,691	9	1,026	7,123	6.9	17.3	Yes	35,979	30	3	13	9	18	9	32	3
	17	709	3	1,321	12,761	9.7	15.0	Yes	7,365	25	1	11	3	14	3	25	1
	18	775	3	716	6,904	9.6	15.0	Yes	14,851	36	1	15	3	20	3	36	1
	19	1,061	4	861	6,417	7.5	16.1	Yes	16,903	26	2	14	4	19	4	27	2
	20	1,078	4	756	2,933	3.9	23.0	No	19,559	33	1	15	4	20	4	29	2
	21	469	2	711	4,166	5.9	20.5	No	9,055	24	1	14	2	20	2	28	1
	22	562	2	1,064	6,721	6.3	19.0	Yes	7,244	22	1	13	2	18	2	25	1
Anderson Ranch	1	486	2	878	3,849	4.4	23.0	No	7,606	21	1	13	2	18	2	25	1
	2	923	4	648	4,685	7.2	16.6	Yes	19,543	27	2	15	4	20	4	29	2
	3	1,278	6	1,038	8,300	8.0	15.0	Yes	16,903	27	2	11	6	15	6	27	2
	4	Reservoir to Little Camous															
Cascade	1A	3,675	14	2,138	13,958	6.5	18.4	Yes	23,592	29	2	9	14	12	14	32	2
	1B	2,180	8	2,118	13,934	6.6	23.0	Yes	14,122	28	1	9	8	12	8	24	2
Owyhee	1	2,800	10	1,720	15,773	9.2	15.0	Yes	22,336	31	2	10	10	14	10	31	2
	1B	1,911	8	1,710	15,761	9.2	15.0	Yes	15,333	36	1	9	8	13	8	36	1
	2A	4,264	15	1,682	14,646	8.7	15.0	Yes	34,772	31	3	10	15	14	15	31	3
	2B	1,682	6	1,662	14,622	8.8	15.0	Yes	13,885	34	1	10	6	14	6	34	1
	3	998	6	537	6,772	12.6	15.0	Yes	25,475	33	2	14	6	19	6	33	2
	4A	4,820	20	690	7,598	11.0	15.0	Yes	95,864	29	10	15	20	20	20	29	10
	4B	952	4	640	7,538	11.8	15.0	Yes	20,404	29	2	15	4	21	4	29	2
	5	1,118	4	1,740	7,393	4.2	23.0	No	8,814	22	1	10	4	14	4	27	1
	6	769	4	520	3,555	6.8	17.5	Yes	20,284	27	2	15	4	21	4	29	2
Palisades	1	1,070	4	1,737	10,703	6.2	19.5	Yes	8,452	24	1	10	4	13	4	27	1
	2	516	2	1,332	10,805	8.1	15.0	Yes	5,312	21	1	11	2	15	2	21	1
	3	478	2	937	5,905	6.3	19.0	Yes	7,003	22	1	13	2	17	2	24	1
Warm Springs	1	2,144	8	804	9,216	11.5	15.0	Yes	36,583	28	4	14	8	20	8	28	4

Notes:
[1] Based on a 10-hour run time

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3.2.4.3 Upper Reservoir Intake

Consistent with assumed water conveyance profile for new off-stream upper reservoirs, the upper reservoir intake for all alternatives with new upper reservoirs was assumed to be a submerged reinforced concrete vertical type bellmouth hooded structure, ungated with no trashracks, and located within a depression to provide sufficient submergence for generation with the reservoir nearly empty. This vertical type of intake is a common solution for off-stream new upper reservoirs at pumped storage facilities. The intakes for Keechelus Reservoir to Little Kachess and Banks Lake to Franklin D. Roosevelt Reservoir were assumed to be submerged horizontal structures, gated with trashracks. This type of intake is also common for new intakes at existing reservoirs. The actual type of intake structure would be the product of more detailed studies. Intake costs were derived from Figure 6-12 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.4 Vertical Shaft

Consistent with the assumed water conveyance profile (Figure 3-1), the concrete-lined vertical shaft extends from the intake structure to the horizontal power tunnel for all alternatives with a new upper reservoir site. The shaft height for each alternative was assumed to be equal to the static head. The costs were derived from Figure 6-14 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.5 Horizontal Power Tunnel

Consistent with the assumed water conveyance profile (Figure 3-1), the concrete-lined power tunnel extends from the vertical shaft to the penstock manifold. The power tunnel length for each concept was assumed to be equal to approximately 50 percent of the horizontal distance from intake to discharge for all alternatives with a new upper reservoir. For Keechelus Reservoir to Little Kachess and Banks Lake to Franklin D. Roosevelt Reservoir (Figure 3-2), the power tunnel length was assumed to be equal to 100 percent of the horizontal distance from intake to discharge because the surface powerstation on the lower reservoir would not have tailrace tunnels. The unit costs were derived from Figure 6-13 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.6 Penstock

Consistent with the assumed water conveyance profile, the power tunnel transitions via a distribution manifold into individual unit penstocks upstream of the underground powerhouse. The penstocks are assumed be equal to 25 percent of the average gross head. The unit costs were derived from Figure 6-15 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.7 Draft Tube Tunnels and Gates

Consistent with the assumed water conveyance profile, the draft tubes transition to the tailrace via a manifold downstream of the powerhouse. Each draft tube length is assumed to be 10 percent of the average gross head. The unit costs were derived from Figure 6-15 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.8 Draft Tube Gate / Transformer Gallery

The substation for the underground power complex is assumed to be located in an adjacent underground cavern located just downstream of the powerhouse within a common draft tube gate/transformer gallery. For the shoreline options, the substation would be on the surface adjacent to the powerhouse. According to HDR's in-house data base for similar projects, the estimated cost of the gallery would be on the order of $6,500,000 per generating unit.

3.2.4.9 Tailrace Tunnels

The concrete-lined tailrace tunnel(s) extend from the draft tubes to the lower reservoir discharge structure. The tailrace tunnel lengths were assumed to be equal to 50 percent of the horizontal distance from intake to discharge. The unit costs were derived from Figure 6-13 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.10 Lower Reservoir Discharge/Intake Structure and Channel

For all underground power complex options, a discharge/intake structure and channel will need to be constructed in the waters of the lower reservoir. The lower reservoir discharge/intake structure consists of a horizontal intake. The unit costs were derived from Figure 6-12 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.11 Surge Chambers

In general, water conduits and associated appurtenances are economically designed to accommodate permissible head losses and tunnel velocities, possess sufficient ability to follow load changes, and offer protections to structural members from excess pressure in the event of sudden gate changes and/or load rejections. When the control, directed by the governor, causes undesirable pressure variations (generally 40 percent rise and 25 percent drop), a surge chamber is often used to dissipate transient pressures. A surge chamber is generally a tank, cavern, or shaft consisting of an atmospheric standpipe, attached to the headrace tunnel and/or penstock. This facility provides a reservoir and expansion chamber to accommodate water demand or water rejection following sudden gate movements to mitigate internal pressures and rapid accelerations or decelerations of the flow within the water conveyance system.

This analysis assumes that surge protection would be required in accordance with Section 3.4.2.2 of this report. Firm determination, sizing, and location(s) of the water conveyances are beyond the scope of this study and therefore are not shown on the conceptual project sketches. According to page 6-22 in EPRI Document No. GS-6669 (1990), a Class 5 cost opinion for a surge chamber is approximately 30 percent of the cost to construct the water conveyance system.

3.2.4.12 Powerstation Equipment

Powerhouse equipment was evaluated for each alternative and cost estimates were developed. The 1988 cost estimates provided were obtained from Figures 6-17 through 6-18 of EPRI Document No. GS-6669 and include the items listed below. These costs were then indexed to 2012 dollars using an escalation factor of 4.0. Appendix B provided detailed cost estimates for all powerstation equipment for each alternative. Additional assumptions are provided below.

3.2.4.12.1 Major Equipment

Major equipment includes pump/turbines, governors, inlet valves, and generator/motors.

3.2.4.12.2 Accessory Electrical Equipment

Accessory electrical equipment includes main transformers, control and communications equipment, starting equipment, main leads, breakers, switches, and current limiting reactors.

3.2.4.12.3 Miscellaneous Mechanical Equipment

Miscellaneous mechanical equipment includes bridge crane, heating, ventilation, and air conditions (HVAC), cooling water, drainage, compressed air system, emergency diesel generator, and other smaller items.

3.2.4.13 Power Complex Access Tunnels

Access to each underground power complex was assumed to be via a main access tunnel and a high voltage/HVAC tunnel. Each tunnel was assumed to be a 25 ft.-tall horseshoe-type installed on a slope of 10 percent. To account for unit submergence and upper machine hall elevation, each tunnel was assumed to measure approximately half of the horizontal distance from intake to discharge. The unit costs were derived from Figure 6-19 in EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

3.2.4.14 Underground Excavation Haul Tunnels

Approximately 2,000 ft. of mucking tunnels is assumed needed for the purpose of removing muck during construction of the underground power complex and water conveyance tunnels. The costs of these tunnels have been estimated to cost in the order of $5,000 per linear foot, for a total cost opinion of $12,000,000.

3.2.4.15 Transmission Line

A new transmission line is assumed to be constructed from the new pumped generating station to an existing transmission line. Detailed costs were derived from Figure 6-21 of EPRI Document No. GS-6669 (1990) assuming average construction conditions. No attempt was made to establish a firm transmission alignment. An escalation factor of 3.0 was assumed for this exercise.

It should be noted that the cost to upgrade other existing substations and/or transmission facilities are not included in this report and could be substantial.

3.2.4.16 Switchyard

To estimate the switchyard cost, the project team assumed a conventional outdoor air-insulated substation with voltages consistent with that listed above for the new transmission lines. The 1988 cost estimates were obtained from Figure 6-20 of EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars assuming an escalation factor of 3.0.

3.2.4.17 Roads

Project access roads were assumed to be constructed at each of the primary project areas. New roads were assumed to extend from existing roads to major project elements. Assumed roadway lengths and costs are derived from Section 6 of EPRI Document No. GS-6669 (1990) and indexed to 2012 dollars using an escalation factor of 3.0.

1988 Cost for New Access Roads

Terrain	$/mile
Steep	439,000
Mild	283,000
Flat	189,000

3.2.4.18 Lands

The cost opinion does not include any cost for the acquisition of lands.

Chapter 4
Cost Opinions

4.1 Direct Cost Estimate

A summary of the estimated direct cost (i.e., cost of materials, equipment, and labor for construction of structures, and supply and installation of permanent equipment) for each alternative is provided in Table 4-1. It should be noted that these costs only represent an America Association of Cost Estimators (AACE) Class 5 cost opinion based on very conceptual layout information and derived from cost curves provided by EPRI's Pumped Storage Planning and Evaluation Guide, escalated to 2012 dollars.

Listed below are the basic definitions of an AACE Class 5 cost opinion:

- **Level of Project Definition:** Between 0 and 2 percent complete
- **End Usage:** Concept Screening
- **Methodology:** Capacity Factored, Parametric Models, Judgment, or Analogy
- **Expected Accuracy Range:** Low = -20 to -50 percent; High = +30 to +100 percent
- **Definition of Estimate:** Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.
- **Estimating Methods:** Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of various factors and other parametric and modeling techniques.

4.2 Indirect Costs

According to EPRI, historic indirect costs for pumped storage projects constructed in the U.S. have generally run between 15 and 30 percent of direct costs, and are largely dependent on configuration, environmental/regulatory, and ownership complexities. An allowance of 25 percent has been allocated for indirect costs, including:

- Preliminary engineering and studies (planning studies, environmental impact studies, investigations);
- License and permit applications and processing;
- Detailed engineering and studies;
- Construction management, quality assurance, and administration; and
- Bonds, insurances, taxes, and corporate overheads

Table 4-1. Opinion of Probable Cost Summary – Great Plains Region

Great Plains Region - Alternative	Buffalo Bill	Buffalo Bill	Bull	Bull	Bull	Bull	Bull	Canyon Ferry	Horsetooth
	1	2	1B	2C	3	4	5	2	1
Approximate Installed Capacity (MW)	1,594	1,885	1,982	2,043	527	639	977	1,919	709
Assumed Number of Units	6	8	8	8	4	4	4	8	4
Assumed Static Head (ft)	1,548	1,428	1,533	1,873	1,498	1,578	1,683	1,330	915
Assumed Usable Storage Volume (AF)	11,700	15,000	14,700	12,400	4,000	4,600	6,600	16,400	8,800
Energy Storage (MWH)	15,938	18,850	19,824	20,433	5,271	6,386	9,772	19,195	7,086
Hours of Storage	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 31 ft	2 @ 28 ft	2 @ 27 ft	1 @ 34 ft	1 @ 18 ft	1 @ 18 ft	1 @ 21 ft	2 @ 29 ft	1 @ 30 ft
Penstock Diameter (ft)	6 @ 10 ft	8 @ 10 ft	8 @ 10 ft	8 @ 9 ft	4 @ 7 ft	4 @ 8 ft	4 @ 10 ft	8 @ 11 ft	4 @ 11 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams									
Dam	$115,500,000	$91,260,000	$105,594,432	$152,300,375	$63,585,000	$54,710,810	$95,164,571	$299,490,000	$238,500,000
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works									
Power Station - Civil	$191,280,000	$226,200,000	$221,984,000	$220,644,000	$96,968,000	$115,020,000	$132,872,000	$230,280,000	$144,636,000
Upper Reservoir Intake	$6,900,000	$11,400,000	$10,800,000	$9,000,000	$2,100,000	$2,100,000	$3,000,000	$12,600,000	$6,900,000
Vertical Shaft	$27,399,600	$44,553,600	$45,990,000	$36,523,500	$15,729,000	$16,569,000	$20,196,000	$43,890,000	$15,921,000
Horizontal Power Tunnel	$69,940,800	$153,505,800	$160,548,000	$119,272,500	$24,664,500	$20,595,600	$27,874,800	$195,043,200	$55,137,900
Penstocks	$20,898,000	$24,847,200	$27,594,000	$33,714,000	$8,988,000	$12,781,800	$16,156,800	$23,142,000	$7,411,500
Draft Tube Tunnels & DT Gates	$14,489,280	$17,136,000	$19,131,840	$23,824,560	$5,392,800	$6,816,960	$10,098,000	$14,364,000	$4,941,000
Tailrace Tunnels	$96,168,600	$157,160,700	$172,589,100	$142,290,000	$32,886,000	$29,749,200	$39,489,300	$199,476,000	$55,137,900
Discharge Structure & Channel	$36,000,000	$50,400,000	$46,800,000	$39,000,000	$12,300,000	$15,000,000	$21,000,000	$54,600,000	$28,800,000
Surge Chamber	$68,668,884	$119,160,990	$127,755,882	$106,687,368	$26,298,090			$142,774,560	$41,564,790
Draft Tube / Transformer Gallery	$39,000,000	$52,000,000	$52,000,000	$52,000,000	$26,000,000	$26,000,000	$26,000,000	$52,000,000	$26,000,000
Access Tunnels	$36,136,080	$46,234,485	$51,375,360	$53,777,250	$33,708,150	$27,460,800	$27,874,800	$57,404,760	$29,007,330
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,122,500	$2,122,500	$2,971,500	$2,971,500	$2,971,500	$2,971,500	$2,971,500	$5,943,000	$3,396,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$752,368,000	$904,800,000	$935,504,000	$964,296,000	$354,144,000	$426,852,000	$504,132,000	$905,768,000	$380,024,000
Switchyard	$63,000,000	$75,000,000	$75,000,000	$75,000,000	$10,500,000	$18,300,000	$24,000,000	$75,000,000	$18,300,000
Transmission	$54,000,000	$54,000,000	$72,000,000	$72,000,000	$48,000,000	$48,000,000	$48,000,000	$40,200,000	$11,400,000
Subtotal	$1,640,871,744	$2,076,781,275	$2,174,638,114	$2,150,301,053	$811,235,040	$869,927,670	$1,045,829,771	$2,398,975,520	$1,114,077,420
Temporary Facilities & Site Prep	$82,043,587	$103,839,064	$108,731,906	$107,515,053	$40,561,752	$43,496,384	$52,291,489	$119,948,776	$55,703,871
Subtotal Direct Costs	$1,722,915,331	$2,180,620,339	$2,283,370,020	$2,257,816,105	$851,796,792	$913,424,054	$1,098,121,259	$2,518,924,296	$1,169,781,291
Contingency (25%)	$430,728,833	$545,155,085	$570,842,505	$564,454,026	$212,949,198	$228,356,013	$274,530,315	$629,731,074	$292,445,323
Indirect Costs (25%)	$430,728,833	$545,155,085	$570,842,505	$564,454,026	$212,949,198	$228,356,013	$274,530,315	$629,731,074	$292,445,323
Total Construction Costs (2) (3)	$2,584,372,997	$3,270,930,508	$3,425,055,030	$3,386,724,158	$1,277,695,188	$1,370,136,080	$1,647,181,889	$3,778,386,444	$1,754,671,937
Estimated Cost ($/MW)	$1,621,495	$1,735,278	$1,727,695	$1,657,500	$2,423,917	$2,145,625	$1,685,621	$1,968,467	$2,476,336
Regional Cost Ranking $/MW	1	5	4	2	8	7	3	6	9

1. Costs to be estimated by Bureau of Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

Table 4-2. Opinion of Probably Cost Summary – Upper Colorado Region

Upper Colorado Region - Alternative	Blue Mesa	Blue Mesa	Blue Mesa	Flaming Gorge	Flaming Gorge	Lake Powell	Lake Powell	Lake Powell	Jordanelle	Jordanelle	Jordanelle
	1A	1B	1C	1C	2F	1B	2B	2C	1	2C	2D
Approximate Installed Capacity (MW)	759	1,240	1,789	1,269	1,918	2,210	732	1,536	1,006	2,084	1,656
Assumed Number of Units	3	6	6	6	8	8	3	6	4	8	6
Assumed Static Head (ft)	980	985	990	1,658	1,473	1,350	770	790	900	1,480	1,470
Assumed Usable Storage Volume (AF)	8,800	14,300	20,540	8,700	14,800	18,600	10,800	22,100	12,700	16,000	12,800
Energy Storage (MWH)	7,589	12,395	17,894	12,690	19,178	22,097	7,318	15,364	10,058	20,838	16,558
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 34 ft	2 @ 30 ft	3 @ 30 ft	1 @ 24 ft	1 @ 31 ft	1 @ 35 ft	1 @ 33 ft	2 @ 33 ft	2 @ 29 ft	2 @ 29 ft	2 @ 26 ft
Penstock Diameter (ft)	3 @ 13 ft	6 @ 11 ft	6 @ 14 ft	6 @ 9 ft	8 @ 10 ft	8 @ 11 ft	3 @ 14 ft	6 @ 14 ft	4 @ 13 ft	8 @ 10 ft	6 @ 11 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams											
Dam	$64,071,755	$92,270,552	$121,836,746	$167,084,882	$159,426,691	$235,773,270	$84,684,413	$184,404,431	$237,899,633	$310,958,768	$263,555,775
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works											
Power Station - Civil	$160,889,344	$213,198,128	$279,153,389	$167,505,624	$222,462,944	$247,484,160	$187,342,848	$319,569,536	$193,121,280	$241,725,440	$205,320,192
Upper Reservoir Intake	$9,000,000	$13,800,000	$20,700,000	$3,600,000	$7,500,000	$10,500,000	$8,400,000	$16,800,000	$12,000,000	$12,000,000	$9,000,000
Vertical Shaft	$19,110,000	$33,982,500	$51,232,500	$22,376,250	$26,505,000	$27,337,500	$14,553,000	$29,862,000	$29,700,000	$48,840,000	$42,336,000
Horizontal Power Tunnel	$81,873,000	$137,034,000	$205,675,200	$28,334,775	$41,520,975	$56,958,900	$46,984,500	$94,350,600	$123,908,400	$178,362,000	$150,480,000
Penstocks	$7,717,500	$11,967,750	$17,820,000	$20,884,500	$26,505,000	$24,300,000	$6,583,500	$13,509,000	$9,720,000	$26,640,000	$23,152,500
Draft Tube Tunnels & DT Gates	$4,851,000	$8,865,000	$12,474,000	$12,530,700	$18,730,200	$16,200,000	$4,504,500	$9,243,000	$6,912,000	$19,180,800	$15,876,000
Tailrace Tunnels	$68,475,600	$110,223,000	$156,492,000	$41,131,125	$72,440,850	$92,312,700	$47,871,000	$96,130,800	$95,747,400	$178,362,000	$146,520,000
Discharge Structure & Channel	$28,500,000	$44,400,000	$63,000,000	$28,500,000	$48,000,000	$62,400,000	$36,000,000	$66,600,000	$42,000,000	$52,200,000	$42,000,000
Surge Chamber							$36,148,950	$72,928,620	$79,796,340	$135,415,440	$113,509,350
Draft Tube / Transformer Gallery	$19,500,000	$39,000,000	$39,000,000	$39,000,000	$52,000,000	$52,000,000	$19,500,000	$39,000,000	$26,000,000	$52,000,000	$39,000,000
Access Tunnels	$36,619,560	$36,641,700	$36,663,840	$21,479,588	$20,672,145	$23,274,585	$20,744,100	$20,828,340	$34,356,420	$50,337,720	$50,292,000
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,122,500	$2,122,500	$2,122,500	$4,245,000	$5,094,000	$8,490,000	$3,396,000	$3,396,000	$2,122,500	$2,122,500	$2,122,500
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$391,598,592	$634,636,288	$801,671,270	$649,718,784	$912,865,184	$989,936,640	$392,249,088	$774,341,568	$506,943,360	$966,901,760	$768,294,912
Switchyard	$18,300,000	$66,000,000	$66,000,000	$57,000,000	$75,000,000	$75,000,000	$18,300,000	$66,000,000	$48,000,000	$75,000,000	$66,000,000
Transmission	$12,000,000	$21,000,000	$21,000,000	$39,000,000	$39,000,000	$79,200,000	$54,000,000	$79,200,000	$70,500,000	$70,500,000	$70,500,000
Subtotal	$971,628,851	$1,512,141,418	$1,941,841,445	$1,349,391,228	$1,774,722,989	$2,048,167,755	$1,028,261,899	$1,933,163,895	$1,565,727,333	$2,467,546,428	$2,054,959,229
Temporary Facilities & Site Prep	$48,581,443	$75,607,071	$97,092,072	$67,469,561	$88,736,149	$102,408,388	$51,413,095	$96,658,195	$78,286,367	$123,377,321	$102,747,961
Subtotal Direct Costs	$1,020,210,293	$1,587,748,489	$2,038,933,517	$1,416,860,789	$1,863,459,138	$2,150,576,143	$1,079,674,994	$2,029,822,090	$1,644,013,699	$2,590,923,750	$2,157,707,190
Contingency (25%)	$255,052,573	$396,937,122	$509,733,379	$354,215,197	$465,864,785	$537,644,036	$269,918,748	$507,455,523	$411,003,425	$647,730,937	$539,426,798
Indirect Costs (25%)	$255,052,573	$396,937,122	$509,733,379	$354,215,197	$465,864,785	$537,644,036	$269,918,748	$507,455,523	$411,003,425	$647,730,937	$539,426,798
Total Construction Costs (2) (3)	$1,530,315,440	$2,381,622,734	$3,058,400,276	$2,125,291,184	$2,795,188,708	$3,225,864,214	$1,619,512,491	$3,044,733,135	$2,466,020,549	$3,886,385,625	$3,236,560,786
Estimated Cost ($/MW)	$2,016,460	$1,921,401	$1,709,134	$1,674,800	$1,457,510	$1,459,878	$2,213,029	$1,981,742	$2,451,703	$1,865,012	$1,954,672
Regional Cost Ranking $/MW	14	9	5	3	1	2	16	13	17	7	11

1. Costs to be estimated by Bureau of Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

Table 4-2. Opinion of Probably Cost Summary – Upper Colorado Region

Upper Colorado Region - Alternative	Strawberry	Vallecito	Vallecito	Vallecito	Vallecito	Vallecito
	1	1A	1B	2C	3A	3B
Approximate Installed Capacity (MW)	1,521	1,335	1,211	995	1,004	1,601
Assumed Number of Units	6	6	6	4	4	6
Assumed Static Head (ft)	905	893	888	898	943	963
Assumed Usable Storage Volume (AF)	19,100	17,000	15,500	12,600	12,100	18,900
Energy Storage (MWH)	15,211	13,352	12,106	9,951	10,036	16,008
Hours of Storage	10	10	10	10	10	10
Tunnel Diameter (ft)	2 @ 27 ft	2 @ 25 ft	2 @ 24 ft	1 @ 32 ft	1 @ 30 ft	2 @ 27 ft
Penstock Diameter (ft)	6 @ 13 ft	6 @ 12 ft	6 @ 12 ft	4 @ 13 ft	4 @ 13 ft	6 @ 13 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams						
Dam	$262,677,870	$234,882,428	$218,408,445	$234,111,600	$135,030,548	$197,992,778
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works						
Power Station - Civil	$255,548,832	$256,354,560	$222,741,200	$206,990,784	$192,686,208	$262,536,120
Upper Reservoir Intake	$10,800,000	$8,400,000	$7,200,000	$8,100,000	$6,900,000	$10,800,000
Vertical Shaft	$27,693,000	$25,436,250	$23,962,500	$16,693,500	$16,258,125	$29,452,500
Horizontal Power Tunnel	$60,406,200	$50,841,450	$47,704,350	$41,410,800	$37,735,875	$60,636,600
Penstocks	$14,253,750	$12,450,375	$12,380,625	$9,423,750	$9,896,250	$15,159,375
Draft Tube Tunnels & DT Gates	$10,099,800	$9,157,050	$7,668,000	$7,000,500	$7,351,500	$11,261,250
Tailrace Tunnels	$83,262,600	$69,329,250	$63,092,850	$56,939,850	$55,345,950	$83,375,325
Discharge Structure & Channel	$63,000,000	$53,100,000	$51,000,000	$39,000,000	$39,000,000	$58,500,000
Surge Chamber				$39,440,520		
Draft Tube / Transformer Gallery	$39,000,000	$39,000,000	$39,000,000	$26,000,000	$26,000,000	$39,000,000
Access Tunnels	$19,019,790	$17,871,540	$17,850,660	$20,187,765	$19,622,655	$19,706,895
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,971,500	$1,698,000	$1,698,000	$1,698,000	$1,698,000	$1,698,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$736,224,016	$688,952,880	$619,801,600	$513,496,368	$505,801,296	$761,995,080
Switchyard	$66,000,000	$66,000,000	$66,000,000	$23,700,000	$48,000,000	$66,000,000
Transmission	$72,000,000	$70,500,000	$70,500,000	$48,000,000	$70,500,000	$70,500,000
Subtotal	$1,769,957,358	$1,650,973,783	$1,516,008,230	$1,339,193,437	$1,218,826,407	$1,735,613,923
Temporary Facilities & Site Prep	$88,497,868	$82,548,689	$75,800,412	$66,959,672	$60,941,320	$86,780,696
Subtotal Direct Costs	$1,858,455,226	$1,733,522,472	$1,591,808,642	$1,406,153,109	$1,279,767,727	$1,822,394,619
Contingency (25%)	$464,613,806	$433,380,618	$397,952,160	$351,538,277	$319,941,932	$455,598,655
Indirect Costs (25%)	$464,613,806	$433,380,618	$397,952,160	$351,538,277	$319,941,932	$455,598,655
Total Construction Costs (2) (3)	$2,787,682,839	$2,600,283,707	$2,387,712,962	$2,109,229,663	$1,919,651,591	$2,733,591,929
Estimated Cost ($/MW)	$1,832,647	$1,947,515	$1,972,420	$2,119,514	$1,912,815	$1,707,609
Regional Cost Ranking $/MW	6	10	12	15	8	4

1. Costs to be estimated by Bureau of Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

Table 4-3. Opinion of Probable Cost Summary – Lower Colorado Region

Lower Colorado Region - Alternatives	Mead	Mead	Mead	Mead	Mead	Mead	Mead	Mead	Mead	Mead	Apache	Apache
	1	2D	3	4	5	6	7D	7E	8C	9C	1B	1C
Approximate Installed Capacity (MW)	891	1,745	1,363	449	696	873	1,595	1,133	1,742	1,540	1,759	1,402
Assumed Number of Units	4	6	6	2	3	3	6	4	6	6	6	6
Assumed Static Head (ft)	790	1,653	1,210	665	955	775	1,250	1,238	835	2,365	1,723	1,713
Assumed Usable Storage Volume (acre-ft)	12,815	12,000	12,800	7,670	8,280	12,800	14,500	10,400	23,700	7,400	11,600	9,300
Energy Storage (MWH)	8,911	17,453	13,632	4,490	6,960	8,732	15,953	11,327	17,419	15,402	17,588	14,019
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 33 ft	1 @ 30 ft	1 @ 29 ft	1 @ 28 ft	1 @ 24 ft	1 @ 35 ft	1 @ 33 ft	1 @ 28 ft	2 @ 33 ft	1 @ 22 ft	1 @ 28 ft	1 @ 25 ft
Penstock Diameter (ft)	4 @ 13 ft	6 @ 10 ft	6 @ 11 ft	2 @ 15 ft	3 @ 12 ft	3 @ 15 ft	6 @ 12 ft	4 @ 12 ft	6 @ 15 ft	6 @ 8 ft	6 @ 10 ft	6 @ 9 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams												
Dam	$223,605,990	$54,699,410	$103,889,649	$140,277,296	$132,748,767	$91,002,366	$151,384,294	$124,792,163	$178,256,927	$140,066,966	$140,824,063	$121,273,377
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works												
Power Station - Civil	$213,869,843	$195,468,134	$190,843,699	$152,654,353	$150,335,336	$209,564,467	$210,573,686	$167,645,970	$306,573,189	$172,504,443	$196,989,901	$173,837,981
Upper Reservoir Intake	$8,400,000	$6,600,000	$6,000,000	$5,400,000	$3,300,000	$9,900,000	$8,400,000	$5,400,000	$16,800,000	$2,700,000	$5,400,000	$4,200,000
Vertical Shaft	$15,171,840	$28,261,170	$19,968,300	$10,576,680	$12,895,200	$15,581,520	$24,003,840	$19,679,430	$32,071,680	$29,801,520	$27,395,700	$24,153,300
Horizontal Power Tunnel	$43,352,820	$66,282,780	$40,500,840	$33,168,180	$16,195,920	$50,322,540	$59,455,620	$45,049,980	$94,773,240	$45,424,080	$48,332,850	$38,842,650
Penstocks	$8,297,100	$22,311,450	$15,793,110	$4,290,540	$6,447,600	$7,674,480	$19,690,650	$12,995,850	$16,536,960	$29,801,520	$25,586,550	$25,438,050
Draft Tube Tunnels & DT Gates	$5,689,440	$15,766,758	$11,327,472	$2,793,840	$4,556,304	$5,581,440	$12,827,052	$8,465,868	$10,824,192	$18,306,648	$18,608,400	$16,958,700
Tailrace Tunnels	$56,198,100	$103,746,960	$67,815,360	$33,168,180	$23,456,160	$67,675,140	$84,779,310	$65,926,800	$115,833,960	$73,377,360	$77,804,100	$65,914,800
Discharge Structure & Channel	$42,000,000	$38,400,000	$42,000,000	$24,900,000	$26,400,000	$39,600,000	$45,600,000	$32,400,000	$74,700,000	$24,900,000	$35,400,000	$29,400,000
Surge Chamber	$38,612,790			$25,199,226		$44,050,536			$81,012,010			
Draft Tube / Transformer Gallery	$26,000,000	$39,000,000	$39,000,000	$13,000,000	$19,500,000	$19,500,000	$39,000,000	$26,000,000	$39,000,000	$39,000,000	$39,000,000	$39,000,000
Access Tunnels	$18,545,373	$35,735,064	$22,134,180	$18,687,438	$12,286,560	$20,215,779	$26,424,720	$26,370,720	$20,446,449	$43,677,000	$28,528,170	$28,484,610
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$4,245,000	$4,245,000	$5,943,000	$14,433,000	$10,188,000	$12,735,000	$11,037,000	$11,037,000	$12,735,000	$4,245,000	$3,396,000	$3,396,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$484,771,643	$788,853,542	$681,584,640	$265,798,168	$370,270,366	$433,099,899	$746,579,434	$525,592,771	$808,238,408	$776,269,993	$802,030,310	$700,959,600
Switchyard	$48,000,000	$66,000,000	$66,000,000	$22,200,000	$39,000,000	$39,000,000	$66,000,000	$48,000,000	$66,000,000	$66,000,000	$66,000,000	$66,000,000
Transmission	$6,000,000	$10,500,000	$10,500,000	$6,000,000	$6,000,000	$6,000,000	$10,500,000	$10,500,000	$10,500,000	$10,500,000	$54,000,000	$54,000,000
Subtotal	$1,289,759,939	$1,522,870,269	$1,370,300,250	$819,546,902	$880,580,213	$1,118,503,167	$1,563,255,606	$1,176,856,551	$1,931,302,014	$1,523,574,530	$1,616,296,044	$1,438,859,068
Temporary Facilities & Site Prep	$64,487,997	$76,143,513	$68,515,013	$40,977,345	$44,029,011	$55,925,158	$78,162,780	$58,842,828	$96,565,101	$76,178,727	$80,814,802	$71,942,953
Subtotal Direct Costs	$1,354,247,936	$1,599,013,783	$1,438,815,263	$860,524,247	$924,609,224	$1,174,428,325	$1,641,418,386	$1,235,699,379	$2,027,867,115	$1,599,753,257	$1,697,110,847	$1,510,802,021
Contingency (25%)	$338,561,984	$399,753,446	$359,703,816	$215,131,062	$231,152,306	$293,607,081	$410,354,596	$308,924,845	$506,966,779	$399,938,314	$424,277,712	$377,700,505
Indirect Costs (25%)	$338,561,984	$399,753,446	$359,703,816	$215,131,062	$231,152,306	$293,607,081	$410,354,596	$308,924,845	$506,966,779	$399,938,314	$424,277,712	$377,700,505
Total Construction Costs (2) (3)	$2,031,371,903	$2,398,520,674	$2,158,222,894	$1,290,786,370	$1,386,913,836	$1,761,642,488	$2,462,127,579	$1,853,549,068	$3,041,800,673	$2,399,629,885	$2,545,666,270	$2,266,203,032
Estimated Cost ($/MW)	$2,279,561	$1,374,313	$1,583,239	$2,874,909	$1,992,701	$2,017,490	$1,543,407	$1,636,337	$1,746,261	$1,557,980	$1,447,357	$1,616,500
Regional Cost Ranking$/MW	11	1	5	12	9	10	4	7	8	3	2	6

1. Costs to be estimated by Bureau of Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

Table 4-4. Opinion of Probably Cost Summary – Mid-Pacific Region

Mid-Pacific Region - Alternative	New Melones	New Melones	New Melones	Shasta	Shasta	Shasta	Shasta	Shasta	Shasta	Shasta
	1A	1B	2	1	2C	3A	3B	5A	5B	5C
Approximate Installed Capacity (MW)	816	1,399	294	553	2,360	862	1,293	2,248	791	950
Assumed Number of Units	3	6	2	2	8	3	6	8	3	4
Assumed Static Head (ft)	1,237	1,252	1,247	714	2,017	942	967	1,352	1,232	1,102
Assumed Usable Storage Volume (AF)	7,500	12,700	2,680	8,800	13,300	10,400	15,200	18,900	7,300	9,800
Energy Storage (MWH)	8,161	13,987	2,940	5,529	23,601	8,617	12,928	22,478	7,911	9,499
Hours of Storage	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 26 ft	1 @ 34 ft	1 @ 13 ft	1 @ 28 ft	2 @ 26 ft	1 @ 30 ft	2 @ 25 ft	2 @ 25 ft	1 @ 23 ft	1 @ 30 ft
Penstock Diameter (ft)	3 @ 12 ft	6 @ 11 ft	2 @ 9 ft	2 @ 16 ft	8 @ 10 ft	3 @ 14 ft	6 @ 12 ft	8 @ 11 ft	3 @ 12 ft	4 @ 12 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams										
Dam	$63,663,655	$91,679,075	$121,836,746	$84,141,564	$185,625,653	$239,485,630	$313,045,740	$265,312,814	$264,429,056	$211,089,878
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works										
Power Station - Civil	$137,088,000	$195,860,000	$77,616,000	$157,052,000	$236,000,000	$172,400,000	$206,880,000	$251,776,000	$136,052,000	$155,800,000
Upper Reservoir Intake	$5,100,000	$9,300,000	$1,200,000	$5,700,000	$10,200,000	$6,900,000	$8,400,000	$8,400,000	$3,600,000	$6,900,000
Vertical Shaft	$18,183,900	$24,414,000	$9,352,500	$11,566,800	$59,299,800	$16,108,200	$26,689,200	$37,315,200	$16,262,400	$18,844,200
Horizontal Power Tunnel	$46,924,500	$75,230,400	$12,597,000	$30,282,000	$228,770,100	$42,693,750	$62,904,600	$66,072,600	$29,883,000	$54,324,000
Penstocks	$9,741,375	$16,902,000	$4,489,200	$5,247,900	$44,777,400	$8,689,950	$13,054,500	$24,336,000	$8,870,400	$9,918,000
Draft Tube Tunnels & DT Gates	$6,568,470	$11,718,720	$2,618,700	$3,298,680	$29,044,800	$5,765,040	$8,703,000	$18,819,840	$6,431,040	$7,669,920
Tailrace Tunnels	$54,968,700	$102,098,400	$15,504,000	$34,067,250	$222,904,200	$50,283,750	$81,966,600	$98,107,800	$39,488,250	$65,188,800
Discharge Structure & Channel	$24,600,000	$42,000,000	$9,600,000	$28,800,000	$42,000,000	$35,400,000	$49,200,000	$61,800,000	$23,700,000	$29,400,000
Surge Chamber	$40,916,084	$69,109,056	$13,368,420	$25,338,789	$175,438,890	$37,062,207	$57,995,370			$46,783,476
Draft Tube / Transformer Gallery	$19,500,000	$39,000,000	$13,000,000	$13,000,000	$52,000,000	$19,500,000	$39,000,000	$52,000,000	$19,500,000	$26,000,000
Access Tunnels	$32,713,080	$32,778,960	$23,062,200	$17,639,265	$78,603,060	$22,580,250	$22,683,780	$23,926,290	$25,614,000	$29,214,240
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$3,396,000	$3,396,000	$2,122,500	$2,547,000	$2,122,500	$3,396,000	$3,396,000	$2,547,000	$2,547,000	$2,547,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$401,472,000	$688,308,000	$209,328,000	$294,196,000	$1,066,720,000	$420,656,000	$662,016,000	$998,112,000	$392,336,000	$478,800,000
Switchyard	$18,000,000	$66,000,000	$5,100,000	$10,500,000	$75,000,000	$18,000,000	$66,000,000	$75,000,000	$18,000,000	$24,000,000
Transmission	$12,000,000	$21,000,000	$8,100,000	$54,000,000	$77,400,000	$48,000,000	$70,500,000	$70,500,000	$43,200,000	$43,200,000
Subtotal	$941,835,763	$1,535,794,611	$575,895,266	$824,377,248	$2,632,906,403	$1,193,920,777	$1,739,434,790	$2,101,025,544	$1,076,913,146	$1,256,679,514
Temporary Facilities & Site Prep	$47,091,788	$76,789,731	$28,794,763	$41,218,862	$131,645,320	$59,696,039	$86,971,740	$105,051,277	$53,845,657	$62,833,976
Subtotal Direct Costs	$988,927,551	$1,612,584,341	$604,690,029	$865,596,110	$2,764,551,723	$1,253,616,816	$1,826,406,530	$2,206,076,821	$1,130,758,803	$1,319,513,490
Contingency (25%)	$247,231,888	$403,146,085	$151,172,507	$216,399,028	$691,137,931	$313,404,204	$456,601,632	$551,519,205	$282,689,701	$329,878,373
Indirect Costs (25%)	$247,231,888	$403,146,085	$151,172,507	$216,399,028	$691,137,931	$313,404,204	$456,601,632	$551,519,205	$282,689,701	$329,878,373
Total Construction Costs (2) (3)	$1,483,391,327	$2,418,876,512	$907,035,044	$1,298,394,166	$4,146,827,584	$1,880,425,224	$2,739,609,794	$3,309,115,231	$1,696,138,205	$1,979,270,235
Estimated Cost ($/MW)	$1,817,681	$1,729,404	$3,085,420	$2,348,243	$1,757,047	$2,182,327	$2,119,145	$1,472,148	$2,143,983	$2,083,588
Regional Cost Ranking $/MW	6	3	14	13	4	12	10	1	11	9

1. Costs to be estimated by Bureau of Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

Table 4-4 Opinion of Probably Cost Summary – Mid-Pacific Region

Mid-Pacific Region - Alternative	Shasta	Shasta	Whiskeytown	Millerton
	6	7	1	1D
Approximate Installed Capacity (MW)	2,184	2,621	1,481	2,206
Assumed Number of Units	9	9	6	9
Assumed Static Head (ft)	937	937	1,295	731
Assumed Usable Storage Volume (AF)	26,500	31,800	13,000	34,300
Energy Storage (MWH)	21,839	26,207	14,815	22,065
Hours of Storage	10	10	10	10
Tunnel Diameter (ft)	3 @ 30 ft	3 @ 33 ft	2 @ 26 ft	3 @ 33 ft
Penstock Diameter (ft)	9 @ 13 ft	9 @ 14 ft	6 @ 11 ft	9 @ 14 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams				
Dam	$236,448,310	$221,320,558	$235,672,344	$135,913,100
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works				
Power Station - Civil	$297,024,000	$345,972,000	$201,416,000	$379,432,000
Upper Reservoir Intake	$20,700,000	$26,100,000	$10,200,000	$26,100,000
Vertical Shaft	$48,068,100	$53,127,900	$38,073,000	$41,447,700
Horizontal Power Tunnel	$198,782,100	$189,297,450	$128,171,700	$131,246,550
Penstocks	$22,769,100	$26,563,950	$16,899,750	$19,737,000
Draft Tube Tunnels & DT Gates	$14,167,440	$17,709,300	$11,888,100	$14,210,640
Tailrace Tunnels	$198,782,100	$192,869,100	$131,635,800	$143,628,300
Discharge Structure & Channel	$86,400,000	$106,200,000	$42,000,000	$117,000,000
Surge Chamber	$144,770,652	$143,870,310	$98,000,505	$105,081,057
Draft Tube / Transformer Gallery	$58,500,000	$58,500,000	$39,000,000	$58,500,000
Access Tunnels	$35,435,070	$28,811,310	$43,301,250	$19,398,075
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,122,500	$2,547,000	$2,547,000	$2,547,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$1,039,584,000	$1,153,240,000	$716,804,000	$1,085,352,000
Switchyard	$90,000,000	$90,000,000	$66,000,000	$90,000,000
Transmission	$70,500,000	$70,500,000	$70,500,000	$70,500,000
Subtotal	$2,611,053,372	$2,773,628,878	$1,899,109,449	$2,487,093,422
Temporary Facilities & Site Prep	$130,552,669	$138,681,444	$94,955,472	$124,354,671
Subtotal Direct Costs	$2,741,606,041	$2,912,310,321	$1,994,064,921	$2,611,448,094
Contingency (25%)	$685,401,510	$728,077,580	$498,516,230	$652,862,023
Indirect Costs (25%)	$685,401,510	$728,077,580	$498,516,230	$652,862,023
Total Construction Costs (2) (3)	$4,112,409,061	$4,368,465,482	$2,991,097,382	$3,917,172,140
Estimated Cost ($/MW)	$1,883,042	$1,666,907	$2,018,993	$1,775,328
Regional Cost Ranking $/MW	7	2	8	5

1. Costs to be estimated by Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material

Table 4-5. Opinion of Probably Cost Summary – Pacific Northwest Region (1 of 5)

Pacific Northwest Region - Alternative	Cle Elum	Cle Elum	Keechelus	Keechelus to Little Kachess	Little Kachess	Little Kachess	Prineville	Prineville	Rimrock	Rimrock	Rimrock
	1B	**2B**	**2B**	**3**	**2B**	**3B**	**2**	**3**	**1**	**2**	**3B**
Approximate Installed Capacity (MW)	1,483	2,147	2,054	322	2,105	2,539	1,696	1,081	1,119	1,525	2,061
Assumed Number of Units	6	8	8	2	8	10	6	4	4	6	8
Assumed Static Head (ft)	1,088	1,488	1,729	244	1,468	2,735	1,036	686	859	927	2,252
Assumed Usable Storage Volume (AF)	15,500	16,400	13,500	15,000	16,300	10,550	18,600	17,900	14,800	18,700	10,400
Energy Storage (MWH)	14,834	21,468	20,541	3,216	21,052	25,393	16,957	10,806	11,188	15,246	20,606
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	2 @ 28 ft	2 @ 29 ft	2 @ 25 ft	2 @ 28 ft	2 @ 29 ft	1 @ 27 ft	2 @ 31 ft	2 @ 24 ft	2 @ 27 ft	2 @ 25 ft	1 @ 29 ft
Penstock Diameter (ft)	6 @ 12 ft	8 @ 11 ft	8 @ 10 ft	2 @ 20 ft	8 @ 11 ft	10 @ 8 ft	6 @ 13 ft	4 @ 16 ft	4 @ 14 ft	6 @ 13 ft	8 @ 8 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams											
Dam	$62,830,193	$189,462,847	$124,601,169	$-	$176,338,346	$144,075,625	$147,212,913	$44,799,209	$56,021,670	$121,225,381	$157,397,526
Stream Diversion	$5,000,000	$5,000,000	$5,000,000		$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000		$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works											
Power Station - Civil	$231,402,600	$240,437,120	$230,053,824	$77,280,000	$235,778,066	$253,929,005	$250,967,270	$268,088,000	$223,752,320	$256,140,931	$214,299,571
Upper Reservoir Intake	$11,400,000	$12,000,000	$9,000,000	$-	$12,000,000	$5,100,000	$14,400,000	$7,200,000	$9,600,000	$9,000,000	$6,000,000
Vertical Shaft	$34,582,500	$49,087,500	$48,757,800	$-	$48,431,625	$41,847,413	$37,296,000	$18,522,000	$26,285,400	$26,127,300	$37,149,750
Horizontal Power Tunnel	$114,420,750	$221,690,250	$133,544,250	$-	$214,470,630	$57,929,100	$136,292,520	$28,640,400	$68,886,720	$40,098,240	$96,348,825
Penstocks	$14,681,250	$31,237,500	$34,234,200	$2,009,906	$30,820,125	$82,053,750	$17,249,400	$9,672,600	$10,308,000	$14,592,375	$49,983,300
Draft Tube Tunnels & DT Gates	$9,787,500	$18,921,000	$21,577,920	$-	$18,315,960	$36,924,188	$12,121,200	$6,256,320	$7,009,440	$11,006,820	$30,260,160
Tailrace Tunnels	$117,211,500	$226,616,700	$141,175,350	$-	$214,470,630	$85,369,200	$133,511,040	$42,466,800	$82,281,360	$60,147,360	$119,900,760
Discharge Structure & Channel	$49,800,000	$54,000,000	$40,800,000	$-	$54,000,000	$37,200,000	$62,400,000	$57,600,000	$49,800,000	$62,400,000	$37,200,000
Surge Chamber	$87,205,050	$164,265,885	$113,786,856	$100,000,000	$157,952,691		$100,941,048		$58,431,276		$100,092,839
Draft Tube / Transformer Gallery	$39,000,000	$52,000,000	$52,000,000		$52,000,000	$65,000,000	$39,000,000	$26,000,000	$26,000,000	$39,000,000	$52,000,000
Access Tunnels	$34,605,300	$64,290,173	$48,457,485	$-	$60,611,265	$38,111,250	$34,490,352	$10,863,600	$22,866,564	$14,410,305	$55,025,885
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000		$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,547,000	$3,396,000	$2,122,500	$-	$2,122,500	$2,122,500	$4,245,000	$3,820,500	$2,122,500	$2,122,500	$2,122,500
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$723,874,800	$978,922,560	$961,296,336	$251,160,000	$968,374,198	$1,249,330,705	$773,250,509	$557,796,000	$545,955,661	$737,929,826	$997,317,235
Switchyard	$66,000,000	$75,000,000	$75,000,000	$5,100,000	$75,000,000	$90,000,000	$66,000,000	$48,000,000	$48,000,000	$66,000,000	$75,000,000
Transmission	$39,000,000	$39,000,000	$12,000,000	$4,050,000	$12,000,000	$12,000,000	$39,000,000	$39,000,000	$69,000,000	$69,000,000	$69,000,000
Subtotal	$1,685,348,443	$2,467,327,535	$2,095,407,690	$464,599,906	$2,379,686,036	$2,247,992,734	$1,915,377,252	$1,215,725,429	$1,353,320,911	$1,576,201,038	$2,146,098,350
Temporary Facilities & Site Prep	$84,267,422	$123,366,377	$104,770,385	$23,229,995	$118,984,302	$112,399,637	$95,768,863	$60,786,271	$67,666,046	$78,810,052	$107,304,918
Subtotal Direct Costs	$1,769,615,865	$2,590,693,911	$2,200,178,075	$487,829,902	$2,498,670,338	$2,360,392,371	$2,011,146,114	$1,276,511,700	$1,420,986,957	$1,655,011,090	$2,253,403,268
Contingency (25%)	$442,403,966	$647,673,478	$550,044,519	$121,957,475	$624,667,584	$590,098,093	$502,786,529	$319,127,925	$355,246,739	$413,752,772	$563,350,817
Indirect Costs (25%)	$442,403,966	$647,673,478	$550,044,519	$121,957,475	$624,667,584	$590,098,093	$502,786,529	$319,127,925	$355,246,739	$413,752,772	$563,350,817
Total Construction Costs (2) (3)	$2,654,423,798	$3,886,040,867	$3,300,267,112	$731,744,852	$3,748,005,507	$3,540,588,557	$3,016,719,172	$1,914,767,550	$2,131,480,435	$2,482,516,635	$3,380,104,902
Estimated Cost ($/MW)	$1,789,479	$1,810,189	$1,606,711	$2,275,432	$1,780,389	$1,394,322	$1,779,015	$1,771,969	$1,905,214	$1,628,255	$1,640,372
Regional Cost Ranking $/MW	27	29	7	54	25	1	24	23	35	9	11

Table 4-5. Opinion of Probably Cost Summary – Pacific Northwest Region (2 of 5)

Pacific Northwest Region - Alternative	Banks	Banks	Banks	Banks	Banks to FDR	Hungry Horse	Hungry Horse	Hungry Horse	Hungry Horse	Hungry Horse	Hungry Horse
	1	**2**	**3**	**4**	**5**	**1B**	**2**	**3**	**4**	**5**	**7B**
Approximate Installed Capacity (MW)	845	1,030	894	708	968	2,285	1,578	1,346	893	651	2,328
Assumed Number of Units	3	4	3	3	4	8	6	6	3	3	8
Assumed Static Head (ft)	881	731	696	821	306	2,705	1,142	987	957	902	1,407
Assumed Usable Storage Volume (AF)	10,900	16,030	14,600	9,800	36,000	9,600	15,700	15,500	10,600	8,200	18,800
Energy Storage (MWH)	8,446	10,305	8,936	7,076	9,678	22,848	15,778	13,463	8,927	6,509	23,277
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 30 ft	2 @ 27 ft	1 @ 31 ft	1 @ 26 ft	4 @ 26 ft	1 @ 26 ft	2 @ 28 ft	2 @ 28 ft	1 @ 27 ft	1 @ 29 ft	2 @ 25 ft
Penstock Diameter (ft)	3 @ 14 ft	4 @ 15 ft	3 @ 16 ft	3 @ 13 ft	4 @ 22 ft	8 @ 8 ft	6 @ 12 ft	6 @ 12 ft	3 @ 14 ft	3 @ 12 ft	8 @ 11 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams											
Dam	$79,790,745	$50,623,680	$66,043,866	$78,460,543	$-	$137,756,434	$160,437,193	$228,981,964	$167,645,550	$131,654,916	$359,449,493
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000		$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works											
Power Station - Civil	$185,806,632	$234,947,735	$239,479,011	$166,993,411	$154,880,000	$228,476,160	$220,890,208	$231,558,096	$174,967,162	$104,141,312	$251,396,006
Upper Reservoir Intake	$6,600,000	$10,200,000	$7,200,000	$4,500,000	$18,000,000	$4,500,000	$11,400,000	$11,400,000	$4,800,000	$6,000,000	$9,000,000
Vertical Shaft	$15,056,550	$22,353,300	$12,519,000	$12,061,350	$17,992,800	$39,756,150	$36,315,600	$31,386,600	$14,642,100	$14,883,000	$39,677,400
Horizontal Power Tunnel	$37,689,300	$59,549,040	$23,726,340	$19,240,260	$172,800,000	$75,835,725	$113,460,660	$107,745,960	$27,935,370	$46,023,330	$65,264,760
Penstocks	$7,924,500	$9,204,300	$7,354,913	$6,461,438	$6,426,000	$64,908,000	$15,417,000	$12,880,350	$9,043,650	$6,088,500	$27,014,400
Draft Tube Tunnels & DT Gates	$5,150,925	$6,311,520	$5,070,195	$4,652,235	$-	$32,454,000	$10,483,560	$8,883,000	$6,029,100	$4,302,540	$22,624,560
Tailrace Tunnels	$45,227,160	$68,951,520	$41,778,990	$27,728,610	$-	$108,336,750	$108,183,420	$102,734,520	$40,015,530	$46,023,330	$94,930,560
Discharge Structure & Channel	$37,200,000	$54,000,000	$43,200,000	$34,200,000	$-	$31,200,000	$49,800,000	$49,800,000	$37,200,000	$27,000,000	$62,400,000
Surge Chamber	$33,314,531	$49,910,904			$100,000,000		$85,158,072	$79,089,129		$35,196,210	
Draft Tube / Transformer Gallery	$19,500,000	$26,000,000	$19,500,000	$19,500,000		$52,000,000	$39,000,000	$39,000,000	$19,500,000	$19,500,000	$52,000,000
Access Tunnels	$19,849,698	$18,413,190	$11,347,380	$12,845,703	$-	$55,685,090	$32,455,026	$30,695,070	$17,742,735	$25,901,502	$23,732,640
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000		$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$4,245,000	$5,943,000	$8,490,000	$2,547,000	$-	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$418,909,498	$531,723,820	$450,363,514	$379,273,171	$569,184,000	$1,078,407,475	$744,715,558	$683,904,144	$424,920,250	$351,476,928	$1,024,205,952
Switchyard	$18,300,000	$48,000,000	$18,300,000	$18,300,000	$48,000,000	$75,000,000	$66,000,000	$66,000,000	$18,300,000	$18,300,000	$75,000,000
Transmission	$12,000,000	$21,000,000	$12,000,000	$12,000,000	$58,500,000	$12,000,000	$12,000,000	$12,000,000	$6,750,000	$6,750,000	$12,000,000
Subtotal	$993,564,538	$1,264,132,009	$1,013,373,208	$845,763,721	$1,170,782,800	$2,045,438,284	$1,754,838,798	$1,745,181,333	$1,018,613,946	$892,364,068	$2,167,818,271
Temporary Facilities & Site Prep	$49,678,227	$63,206,600	$50,668,660	$42,288,186	$58,539,140	$102,271,914	$87,741,940	$87,259,067	$50,930,697	$44,618,203	$108,390,914
Subtotal Direct Costs	$1,043,242,765	$1,327,338,609	$1,064,041,868	$888,051,907	$1,229,321,940	$2,147,710,198	$1,842,580,737	$1,832,440,400	$1,069,544,644	$936,982,271	$2,276,209,184
Contingency (25%)	$260,810,691	$331,834,652	$266,010,467	$222,012,977	$307,330,485	$536,927,549	$460,645,184	$458,110,100	$267,386,161	$234,245,568	$569,052,296
Indirect Costs (25%)	$260,810,691	$331,834,652	$266,010,467	$222,012,977	$307,330,485	$536,927,549	$460,645,184	$458,110,100	$267,386,161	$234,245,568	$569,052,296
Total Construction Costs (2) (3)	$1,564,864,148	$1,991,007,914	$1,596,062,803	$1,332,077,860	$1,843,982,910	$3,221,565,297	$2,763,871,106	$2,748,660,600	$1,604,316,965	$1,405,473,407	$3,414,313,777
Estimated Cost ($/MW)	$1,852,841	$1,932,131	$1,786,147	$1,882,532	$1,905,287	$1,410,023	$1,751,739	$2,041,689	$1,797,172	$2,159,333	$1,466,793
Regional Cost Ranking $/MW	30	38	26	33	36	2	18	40	28	47	3

Table 4-5. Opinion of Probably Cost Summary – Pacific Northwest Region (3 of 5)

Pacific Northwest Region - Alternative	Hungry Horse	Hungry Horse	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt
	8	**9B**	**1**	**2B**	**3**	**4**	**5**	**6**	**7**	**8**	**9B**
Approximate Installed Capacity (MW)	1,160	2,085	2,203	1,074	1,307	2,650	2,113	1,201	1,440	2,745	2,022
Assumed Number of Units	4	7	8	4	6	9	9	5	6	10	9
Assumed Static Head (ft)	2,312	2,692	1,089	1,259	1,039	1,039	976	1,264	676	741	774
Assumed Usable Storage Volume (AF)	5,700	8,800	23,000	9,700	14,300	29,000	24,600	10,800	24,200	42,100	29,700
Energy Storage (MWH)	11,597	20,847	22,031	10,743	13,068	26,503	21,128	12,008	14,396	27,453	20,216
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 21 ft	1 @ 28 ft	2 @ 34 ft	1 @ 25 ft	1 @ 31 ft	3 @ 31 ft	3 @ 28 ft	1 @ 29 ft	3 @ 28 ft	5 @ 29 ft	3 @ 32 ft
Penstock Diameter (ft)	4 @ 9 ft	7 @ 8 ft	8 @ 13 ft	4 @ 12 ft	6 @ 11 ft	9 @ 13 ft	9 @ 12 ft	5 @ 11 ft	6 @ 15 ft	10 @ 15 ft	9 @ 13 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams											
Dam	$29,003,964	$71,543,698	$101,940,785	$143,043,930	$205,609,511	$180,601,992	$205,521,275	$156,093,278	$326,499,615	$270,536,470	$209,336,695
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works											
Power Station - Civil	$134,525,107	$208,468,480	$290,812,368	$163,286,851	$182,958,776	$318,030,240	$295,798,272	$177,722,899	$333,989,427	$428,260,061	$355,805,050
Upper Reservoir Intake	$2,700,000	$5,400,000	$19,200,000	$4,200,000	$7,200,000	$21,600,000	$17,100,000	$6,000,000	$17,100,000	$30,000,000	$23,400,000
Vertical Shaft	$27,050,400	$42,802,800	$42,451,500	$17,744,850	$18,693,000	$56,079,000	$46,555,200	$20,847,750	$32,245,200	$61,132,500	$42,465,150
Horizontal Power Tunnel	$55,428,360	$120,426,240	$161,384,670	$32,143,815	$31,053,135	$186,012,720	$138,729,240	$48,663,315	$100,739,970	$188,152,950	$139,195,035
Penstocks	$26,356,800	$53,705,400	$24,164,700	$12,836,700	$13,085,100	$24,534,563	$19,764,000	$13,740,563	$12,776,400	$23,897,250	$18,796,050
Draft Tube Tunnels & DT Gates	$15,259,200	$30,527,280	$14,368,200	$7,853,040	$9,533,430	$18,225,675	$14,493,600	$9,665,775	$8,517,600	$17,784,000	$13,366,080
Tailrace Tunnels	$70,351,380	$131,374,080	$158,553,360	$47,728,695	$50,213,580	$189,887,985	$145,496,520	$61,112,070	$98,397,180	$183,777,300	$144,876,465
Discharge Structure & Channel	$17,400,000	$28,800,000	$78,000,000	$34,200,000	$43,200,000	$93,600,000	$81,000,000	$37,200,000	$81,000,000	$135,000,000	$102,600,000
Surge Chamber	$58,333,842	$113,650,740	$120,276,729			$142,421,983	$109,511,568		$75,802,905	$142,423,200	$107,609,634
Draft Tube / Transformer Gallery	$26,000,000	$45,500,000	$52,000,000	$26,000,000	$39,000,000	$58,500,000	$58,500,000	$32,500,000	$39,000,000	$65,000,000	$58,500,000
Access Tunnels	$54,788,802	$72,255,744	$35,108,244	$23,279,915	$15,262,286	$31,777,173	$27,407,484	$27,500,432	$18,351,855	$20,828,094	$22,631,030
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,122,500	$2,122,500	$6,792,000	$11,886,000	$11,886,000	$8,490,000	$4,245,000	$3,396,000	$2,122,500	$2,547,000	$5,943,000
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$561,294,413	$975,632,486	$995,812,048	$511,345,666	$658,651,594	$1,144,908,864	$1,014,165,504	$595,611,878	$760,113,869	$1,273,799,155	$1,026,982,757
Switchyard	$48,000,000	$72,000,000	$75,000,000	$48,000,000	$66,000,000	$81,000,000	$81,000,000	$54,000,000	$66,000,000	$90,000,000	$81,000,000
Transmission	$12,000,000	$12,000,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000	$58,500,000
Subtotal	$1,187,614,768	$2,033,209,449	$2,281,364,604	$1,189,049,462	$1,457,846,411	$2,661,170,194	$2,364,787,663	$1,349,553,959	$2,078,156,521	$3,038,637,980	$2,458,006,945
Temporary Facilities & Site Prep	$59,380,738	$101,660,472	$114,068,230	$59,452,473	$72,892,321	$133,058,510	$118,239,383	$67,477,698	$103,907,826	$151,931,899	$122,900,347
Subtotal Direct Costs	$1,246,995,507	$2,134,869,921	$2,395,432,834	$1,248,501,935	$1,530,738,731	$2,794,228,704	$2,483,027,046	$1,417,031,657	$2,182,064,347	$3,190,569,879	$2,580,907,292
Contingency (25%)	$311,748,877	$533,717,480	$598,858,209	$312,125,484	$382,684,683	$698,557,176	$620,756,761	$354,257,914	$545,516,087	$797,642,470	$645,226,823
Indirect Costs (25%)	$311,748,877	$533,717,480	$598,858,209	$312,125,484	$382,684,683	$698,557,176	$620,756,761	$354,257,914	$545,516,087	$797,642,470	$645,226,823
Total Construction Costs (2) (3)	$1,870,493,260	$3,202,304,882	$3,593,149,251	$1,872,752,902	$2,296,108,097	$4,191,343,056	$3,724,540,569	$2,125,547,486	$3,273,096,521	$4,785,854,818	$3,871,360,939
Estimated Cost ($/MW)	$1,612,912	$1,536,110	$1,630,934	$1,743,303	$1,756,981	$1,581,488	$1,762,808	$1,770,065	$2,273,600	$1,743,318	$1,914,980
Regional Cost Ranking $/MW	8	5	10	16	19	6	21	22	53	17	37

Table 4-5. Opinion of Probably Cost Summary – Pacific Northwest Region (4 of 5)

Pacific Northwest Region - Alternative	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt	Franklin D Roosevelt
	10	**11**	**12**	**13**	**14B**	**15B**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Approximate Installed Capacity (MW)	1,561	2,317	797	834	1,805	1,685	2,691	709	775	1,061	1,078	469	562
Assumed Number of Units	6	10	3	3	8	6	9	3	3	4	4	2	2
Assumed Static Head (ft)	736	734	761	1,316	1,229	1,064	1,026	1,321	716	861	756	711	1,064
Assumed Usable Storage Volume (AF)	24,100	35,900	11,900	7,200	16,700	18,000	29,800	6,100	12,300	14,000	16,200	7,500	6,000
Energy Storage (MWH)	15,609	23,173	7,969	8,338	18,054	16,846	26,906	7,091	7,750	10,608	10,778	4,693	5,615
Hours of Storage	10	10	10	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	2 @ 32 ft	5 @ 23 ft	1 @ 35 ft	1 @ 25 ft	2 @ 29 ft	2 @ 30 ft	3 @ 30 ft	1 @ 25 ft	1 @ 36 ft	2 @ 26 ft	1 @ 33 ft	1 @ 24 ft	1 @ 22 ft
Penstock Diameter (ft)	6 @ 15 ft	10 @ 14 ft	3 @ 15 ft	3 @ 11 ft	8 @ 11 ft	6 @ 13 ft	9 @ 13 ft	3 @ 11 ft	3 @ 15 ft	4 @ 14 ft	4 @ 15 ft	2 @ 14 ft	2 @ 13 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams													
Dam	$523,494,305	$494,158,679	$39,088,874	$40,752,264	$123,479,710	$55,365,581	$456,051,772	$59,084,941	$27,604,639	$191,472,257	$278,434,321	$55,526,998	$111,013,795
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works													
Power Station - Civil	$318,425,395	$380,032,805	$197,635,962	$133,410,816	$223,870,046	$249,318,432	$322,869,888	$119,130,950	$195,299,597	$216,393,408	$241,416,806	$142,655,040	$121,290,048
Upper Reservoir Intake	$15,600,000	$16,500,000	$10,200,000	$4,200,000	$12,000,000	$13,200,000	$19,800,000	$4,500,000	$11,100,000	$9,000,000	$8,700,000	$3,600,000	$3,000,000
Vertical Shaft	$26,937,600	$47,310,750	$15,296,100	$18,555,600	$40,540,500	$36,371,700	$52,633,800	$18,626,100	$14,606,400	$25,313,400	$14,288,400	$9,598,500	$13,081,050
Horizontal Power Tunnel	$70,901,040	$91,574,700	$65,482,920	$43,229,340	$174,407,640	$145,741,950	$144,244,800	$65,082,120	$64,209,060	$69,305,760	$22,878,960	$17,498,040	$25,202,625
Penstocks	$13,910,400	$20,904,750	$7,362,675	$8,883,000	$22,113,000	$17,707,275	$25,624,350	$8,916,750	$6,927,300	$9,815,400	$9,979,200	$4,052,700	$6,061,950
Draft Tube Tunnels & DT Gates	$9,538,560	$14,523,300	$4,931,280	$6,869,520	$15,626,520	$12,442,950	$18,006,300	$5,706,720	$4,704,120	$7,025,760	$6,713,280	$3,156,840	$4,147,650
Tailrace Tunnels	$91,158,480	$117,738,900	$64,373,040	$49,779,240	$174,407,640	$155,458,080	$160,272,000	$66,996,300	$62,137,800	$71,230,920	$36,958,320	$24,997,200	$33,267,465
Discharge Structure & Channel	$81,000,000	$108,000,000	$42,000,000	$21,600,000	$54,000,000	$57,600,000	$102,600,000	$18,900,000	$45,000,000	$43,200,000	$54,000,000	$24,900,000	$18,900,000
Surge Chamber	$63,733,824		$47,233,805	$38,195,010	$128,128,590	$110,316,587	$120,234,375	$49,598,397	$45,775,404	$54,807,372			$24,528,222
Draft Tube / Transformer Gallery	$39,000,000	$65,000,000	$19,500,000	$19,500,000	$52,000,000	$39,000,000	$58,500,000	$19,500,000	$19,500,000	$26,000,000	$26,000,000	$13,000,000	$13,000,000
Access Tunnels	$16,857,084	$15,044,415	$26,970,084	$32,225,508	$50,538,578	$40,645,811	$25,857,216	$48,620,172	$25,062,246	$23,101,920	$9,679,560	$14,310,897	$24,194,520
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$3,396,000	$3,396,000	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500	$2,122,500
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$780,454,400	$1,158,636,600	$414,397,984	$403,567,718	$873,815,342	$774,908,640	$1,151,569,267	$368,738,656	$406,099,162	$530,376,000	$543,187,814	$268,416,720	$285,256,224
Switchyard	$66,000,000	$90,000,000	$18,300,000	$18,300,000	$75,000,000	$66,000,000	$81,000,000	$18,300,000	$18,300,000	$48,000,000	$48,000,000	$10,800,000	$10,800,000
Transmission	$58,500,000	$58,500,000	$34,200,000	$34,200,000	$58,500,000	$58,500,000	$58,500,000	$34,200,000	$34,200,000	$58,500,000	$58,500,000	$34,200,000	$34,200,000
Subtotal	$2,225,907,089	$2,728,320,899	$1,056,095,223	$922,390,516	$2,127,550,067	$1,881,699,505	$2,846,886,269	$955,023,606	$1,029,648,227	$1,432,664,697	$1,407,859,162	$675,835,435	$777,066,049
Temporary Facilities & Site Prep	$111,295,354	$136,416,045	$52,804,761	$46,119,526	$106,377,503	$94,084,975	$142,344,313	$47,751,180	$51,482,411	$71,633,235	$70,392,958	$33,791,772	$38,853,302
Subtotal Direct Costs	$2,337,202,443	$2,864,736,944	$1,108,899,984	$968,510,042	$2,233,927,570	$1,975,784,480	$2,989,230,582	$1,002,774,786	$1,081,130,639	$1,504,297,932	$1,478,252,120	$709,627,206	$815,919,352
Contingency (25%)	$584,300,611	$716,184,236	$277,224,996	$242,127,511	$558,481,892	$493,946,120	$747,307,645	$250,693,697	$270,282,660	$376,074,483	$369,563,030	$177,406,802	$203,979,838
Indirect Costs (25%)	$584,300,611	$716,184,236	$277,224,996	$242,127,511	$558,481,892	$493,946,120	$747,307,645	$250,693,697	$270,282,660	$376,074,483	$369,563,030	$177,406,802	$203,979,838
Total Construction Costs (2) (3)	$3,505,803,665	$4,297,105,415	$1,663,349,976	$1,452,765,063	$3,350,891,355	$2,963,676,720	$4,483,845,873	$1,504,162,179	$1,621,695,958	$2,256,446,897	$2,217,378,180	$1,064,440,809	$1,223,879,027
Estimated Cost ($/MW)	$2,246,002	$1,854,380	$2,087,225	$1,742,306	$1,856,034	$1,759,293	$1,666,496	$2,121,189	$2,092,515	$2,127,214	$2,057,407	$2,268,339	$2,179,551
Regional Cost Ranking $/MW	51	31	42	15	32	20	12	45	43	46	41	52	48

Table 4-5. Opinion of Probably Cost Summary – Pacific Northwest Region (5 of 5)

Pacific Northwest Region - Alternative	Anderson Ranch	Anderson Ranch	Anderson Ranch	Owyhee	Owyhee	Owyhee	Owyhee	Palisades	Palisades	Palisades
	1	2	3	1B	2B	5	6	1	2	3
Approximate Installed Capacity (MW)	486	923	1,278	1,911	1,682	1,118	769	1,070	516	478
Assumed Number of Units	2	4	6	8	6	4	4	4	2	2
Assumed Static Head (ft)	878	648	1,038	1,710	1,662	1,740	520	1,737	1,332	937
Assumed Usable Storage Volume (AF)	6,300	16,200	14,000	12,700	11,500	7,300	16,800	7,000	4,400	5,800
Energy Storage (MWH)	4,865	9,231	12,782	19,110	16,823	11,177	7,686	10,697	5,156	4,780
Hours of Storage	10	10	10	10	10	10	10	10	10	10
Tunnel Diameter (ft)	1 @ 21 ft	2 @ 27 ft	2 @ 27 ft	1 @ 36 ft	1 @ 34 ft	1 @ 22 ft	2 @ 27 ft	1 @ 24 ft	1 @ 21 ft	1 @ 22 ft
Penstock Diameter (ft)	2 @ 13 ft	4 @ 15 ft	6 @ 11 ft	8 @ 9 ft	6 @ 10 ft	4 @ 10 ft	4 @ 15 ft	4 @ 10 ft	2 @ 11 ft	2 @ 13 ft
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams										
Dam	$113,382,446	$81,993,078	$104,438,357	$54,873,341	$101,181,188	$40,470,966	$120,259,201	$173,761,490	$26,960,204	$105,265,430
Stream Diversion	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Spillway	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000	$5,000,000
Civil Works										
Power Station - Civil	$132,324,192	$243,672,000	$184,060,800	$214,030,235	$195,152,461	$143,067,105	$132,202,668	$141,198,288	$101,049,133	$120,453,379
Upper Reservoir Intake	$2,700,000	$9,600,000	$9,600,000	$11,100,000	$9,600,000	$3,000,000	$9,600,000	$3,600,000	$2,700,000	$3,000,000
Vertical Shaft	$10,266,750	$19,813,500	$31,747,500	$34,881,960	$32,416,800	$21,400,770	$15,908,940	$23,442,750	$15,578,550	$11,518,950
Horizontal Power Tunnel	$14,432,250	$50,598,000	$94,615,440	$151,304,448	$127,214,706	$28,832,232	$40,525,632	$48,162,600	$38,897,280	$22,143,000
Penstocks	$4,870,125	$8,352,750	$12,138,750	$30,778,200	$23,190,480	$17,746,980	$6,394,770	$18,233,250	$5,991,750	$5,197,575
Draft Tube Tunnels & DT Gates	$3,159,000	$5,516,700	$8,590,500	$13,952,784	$16,457,760	$12,527,280	$4,679,100	$11,044,140	$4,154,280	$2,921,880
Tailrace Tunnels	$17,895,990	$59,031,000	$92,125,560	$153,668,580	$125,021,349	$42,139,416	$44,791,488	$62,611,380	$42,138,720	$25,685,880
Discharge Structure & Channel	$18,900,000	$54,000,000	$43,200,000	$45,000,000	$39,000,000	$21,600,000	$54,000,000	$21,600,000	$13,500,000	$17,400,000
Surge Chamber		$42,993,585	$71,765,325	$115,375,792	$97,290,329		$33,689,979	$49,048,236	$32,028,174	$20,240,186
Draft Tube / Transformer Gallery	$13,000,000	$26,000,000	$39,000,000	$52,000,000	$39,000,000	$26,000,000	$26,000,000	$26,000,000	$13,000,000	$13,000,000
Access Tunnels	$13,104,483	$16,444,350	$30,501,030	$61,467,432	$56,369,275	$26,947,048	$11,997,720	$40,296,042	$40,680,072	$21,080,136
Underground Haul Tunnels	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000	$12,000,000
Site Roads	$2,547,000	$3,396,000	$2,547,000	$2,122,500	$3,820,500	$15,282,000	$5,094,000	$2,122,500	$2,122,500	$2,122,500
Miscellaneous civil works and structures	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Power Plant Equipment	$270,486,216	$509,496,000	$649,325,600	$924,916,372	$773,880,448	$532,030,798	$467,321,057	$522,005,792	$270,151,763	$263,850,259
Switchyard	$10,800,000	$24,000,000	$66,000,000	$75,000,000	$66,000,000	$48,000,000	$24,000,000	$48,000,000	$10,800,000	$10,800,000
Transmission	$34,200,000	$34,200,000	$58,500,000	$47,250,000	$47,250,000	$47,250,000	$27,000,000	$77,400,000	$52,200,000	$52,200,000
Subtotal	$709,068,452	$1,236,106,963	$1,545,155,862	$2,034,721,643	$1,799,845,295	$1,073,294,595	$1,070,464,554	$1,315,526,468	$718,952,426	$743,879,174
Temporary Facilities & Site Prep	$35,453,423	$61,805,348	$77,257,793	$101,736,082	$89,992,265	$53,664,730	$53,523,228	$65,776,323	$35,947,621	$37,193,959
Subtotal Direct Costs	$744,521,875	$1,297,912,311	$1,622,413,655	$2,136,457,725	$1,889,837,560	$1,126,959,324	$1,123,987,782	$1,381,302,792	$754,900,047	$781,073,133
Contingency (25%)	$186,130,469	$324,478,078	$405,603,414	$534,114,431	$472,459,390	$281,739,831	$280,996,946	$345,325,698	$188,725,012	$195,268,283
Indirect Costs (25%)	$186,130,469	$324,478,078	$405,603,414	$534,114,431	$472,459,390	$281,739,831	$280,996,946	$345,325,698	$188,725,012	$195,268,283
Total Construction Costs (2) (3)	$1,116,782,812	$1,946,868,467	$2,433,620,483	$3,204,686,588	$2,834,756,340	$1,690,438,987	$1,685,981,673	$2,071,954,188	$1,132,350,071	$1,171,609,700
Estimated Cost ($/MW)	$2,295,611	$2,109,110	$1,903,943	$1,676,982	$1,684,999	$1,512,410	$2,193,517	$1,936,978	$2,196,363	$2,451,120
Regional Cost Ranking $/MW	55	44	34	13	14	4	49	39	50	56

1. Costs to be estimated by Reclamation
2. Cost estimates are AACE Class 5 estimates with 25 percent contingency
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material

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4.3 Cost of Pumped Storage Projects Constructed in the US 1960 – 1988

For the purpose of comparing the costs opinions provided within this report, a parametric study was performed to estimate the historical costs in 2012 $/kW for pumped storage projects constructed in the US between the years of 1960 and 1988. Listed below in Table 4-6 are the results of this study for fourteen (14) pumped storage projects (EPRI 1990).

Table 4-6. Estimated Costs Pumped Storage Projects Constructed in the US 1960 - 1988 [1]

Project [3]	Stated Installed Capacity (MW) [1]	Estimated Direct Construction Cost ($/kW) [1, 4]	Year of Cost [1]	Escalation Factor 1988 - 2012 [2]	Estimated Cost 2012 ($/kW)	Maximum Gross Head (ft) [1]
Tom Sauk	350	462	1988	2.8	1,294	267
Yards Creek	330	332	1988	2.8	930	760
Muddy Run	855	322	1988	2.8	902	127
Cabin Creek	280	404	1988	2.8	1,131	373
Seneca	380	505	1988	2.8	1,414	165
Northfield	1000	288	1988	2.8	806	252
Blenheim-Gilboa	1030	321	1988	2.8	899	1,143
Ludington	1890	376	1988	2.8	1,053	364
Jocassee	628	422	1988	2.8	1,182	335
Bear Swamp	540	507	1988	2.8	1,420	235
Raccoon Mountain	1530	296	1988	2.8	829	1,042
Fairfield	512	586	1988	2.8	1,641	169
Helms	1050	616	1988	2.8	1,725	1,745
Bath County	2100	639	1988	2.8	1,789	1,260
				Average	**1,215**	**588**

Notes:
[1] EPRI 1990, P. ES-8
[2] Bureau of Reclamation
[3] Single Speed Technology
[4] Excludes transmission costs and AFUDC

4.4 Life Cycle Costs

This section presents annual costs associated with pumped storage projects. These costs are not included in the opinions of probable costs described above. These costs should be considered in future analyses.

4.4.1 Annual Routine Operations and Maintenance Costs

EPRI provides the following equation for estimating the annual operations and maintenance (O&M) costs for a pump-generation project in 1985 dollars:

$$\text{O\&M Costs (\$/yr)} = 34{,}730 \times C^{0.32} \times E^{0.33}$$

Where: C = Plant Capacity (MW)

E = Annual Energy (GWh)

Estimated annual O&M costs assuming 6 hours of operation per day for 365 days per year are provided in Appendix B assuming an average annual inflation rate of 3 percent, the EPRI annual O&M cost relationship escalates by a factor of 2.5.

These expenses include annual Federal Energy Regulatory Commission (FERC) fees, labor, contracts, consumables, inventory, and other routine operation and maintenance activities. O&M costs do not incorporate pump power costs.

4.4.2 Bi-Annual Outage Costs

Units should be taken out of service for approximately 3 weeks every 2 years for routine bi-annual inspection and maintenance at a cost of approximately $150,000 (per unit).

4.4.3 Major Maintenance

Approximately $1,500,000 (per unit) should be budgeted for a major unit overhaul around year 20. A unit would be out of service for approximately 6 to 8 months, and the outages occur once per year.

Chapter 5
Operations and Environmental Screening

This chapter presents the operations and environmental screening methods and evaluation results for the proposed pumped storage alternatives. The alternatives that passed the technical evaluation screening were evaluated relative to operations, environmental, and regulatory screening criteria. Appendix E includes descriptions of operations and environmental features of the reservoirs considered in the screening evaluation. Appendix F includes detailed screening results for each reservoir.

5.1 Screening Methods

Operations and environmental factors could also affect the likelihood that a pumped storage project could be implemented. The screening criteria consider key issues to determine if some pumped storage alternatives would have fewer impacts or constraints than others.

5.1.1 Screening Criteria

The screening criteria represent a suite of potential operations, environmental and regulatory issues. For the operations criteria, Reclamation requires that pumped storage operations cannot affect existing operations of the reservoir for other uses, including water supply, hydropower, flood control, fish and wildlife, recreations and others. The operations criteria evaluate if or how pumped storage would fit into existing operations of the reservoirs.

5.1.1.1 Operations Criteria

- Water Supply and Release Requirements: pumped storage operations have the potential to affect the lower reservoir's ability to meet water supply and release requirements. Generally, larger upper reservoirs could have more of an effect on the operations of the lower reservoir.

- Water Quality/Temperature Requirements: moving water between the upper and lower reservoirs could increase water temperatures. Additionally, construction could produce short-term effects to water quality. This criterion considers existing water quality at potential sites to determine if quality or temperature could be an issue for implementation.

- System Reoperation: in some places, proposed lower reservoirs are part of a system of interconnected reservoirs, and changing water levels may be difficult or cause operational changes at many different sites. For example, a regulating reservoir (used to reregulate flows from a power generation facility at a larger reservoir) would not work well for pumped storage projects.

5.1.1.2 Environmental and Regulatory Criteria

- Special Status and Sport Fisheries: the presence of special status or sports fisheries in the lower reservoir or the downstream river could restrict pumped storage operations.

- Special Status Terrestrial Species/Sensitive Habitat: the presence of special status terrestrial species or sensitive habitat at a proposed upper reservoir site or near pumped storage infrastructure at the lower reservoir could increase the potential for environmental impacts.

- Recreation: recreation areas could be affected by pumped storage if they are in the area of construction.

- Cultural and Historic Resources: cultural and historic resources could be affected by pumped storage if they are in the area of construction.

- Native American Resources: some potential sites are in or near Indian lands. At other sites, tribes could have water rights in the lower reservoir. These factors could restrict or prevent construction.

- Land Use/Regulatory Designations: some land use designations, such as wildlife areas, could restrict construction of the upper reservoir or ancillary facilities.

- Access/Construction Impacts: sites that are more difficult to access could have greater impacts associated with construction. Some sites have existing roads that can easily access potential areas for construction, but others have no access (and could be in areas where construction of roads is very difficult because of topography).

- Stakeholder Issues: stakeholders in the area of each reservoir may have concerns about new construction, and these concerns vary at each site. Areas with more potential concerns could increase the coordination effort associated with design and construction of a project.

5.1.1.3 Rating Scales

Rating scales were developed for each criterion prior to screening the alternatives. The purpose of the rating scales is to characterize the differences among alternatives using a consistent system. The rating scales were applied to screen the alternatives and determine how well each alternative performed relative to each criterion. The screening is based on available public documentation. Comparing the results of this evaluation then illustrates which alternatives would minimize potential environmental effects (and if any alternatives should be removed from further consideration because of potential effects). Table 5-1 shows the rating scales.

It is important to note that implementation of any of these alternatives would be challenging and a green rating does not indicate that there are no potential project impacts. This screening evaluation is set up for a relative comparison among the alternatives to understand which ones may have fewer challenges relative to others.

5.2 Screening Results

This section presents the screening evaluation results of the alternatives relative to each criterion. The purpose of this screening analysis is to identify and compare potential issues and impacts of the alternatives against one another. Fatal flaws of potential alternatives were identified during the technical screening step, as described in Chapter 2. This screening step rates the alternatives based on the challenges of development. A red rating means that the issue will likely be a fatal flaw to development of the particular alternative. Fatal flaws were identified in the technical screening step, so there are not any red ratings applied under this subsequent screening step. Appendix D provides detailed screening results, including explanations for each rating for each reservoir. This presents a summary table of the results by region and some key notes or observations in the evaluation.

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Table 5-1 Operations and Environmental Screening Rating Scales

Operations Criteria	**Green**	**Yellow**	**Orange**	**Red**
Water Supply and Release Requirements	1-5%	6-9% or the proposed area of the lower reservoir intake may have low water levels during some months	>10%, no significant operations issues or minimum downstream flow requirements	>10%, with significant operations issues (downstream flows requirements, listed species, storage allocations, flood requirements, stakeholder operation issue groups, etc.)
Water Quality/Temperature Requirements	No issues	Existing water quality/temperature issues in lower reservoir	Significant water quality issues or temp requirements in lower reservoir or downstream river	No effects to water quality or temperature from new operations or construction allowed
System Reoperation	Lower reservoir is not part of a system or is the only reservoir	Reservoir is part of a system, , but is generally the larger reservoir or at the end of the system	Flow and storage requirements for other reservoirs in the system are dependent on the reservoir	Lower reservoir is a smaller reregulating reservoir with frequent fluctuations in water levels and cannot support pumped storage
Environmental and Regulatory Criteria				
Special Status and Sport Fisheries	Reservoir and downstream river supports sport fisheries, but is not well known for fishing, no special status fish species	Reservoir or downstream waterbody has special status fish species and/or the downstream river has a well-known sport fisheries	Reservoir or downstream waterbody has special status fish species and/or well-known sport fisheries with operations or flow requirements	Reservoir or downstream has sensitive fish habitat and special status species that cannot be affected
Special Status Terrestrial Species/Sensitive Habitat	No special status species or critical habitat is documented in upper reservoir site	Special status species/critical habitat has been documented in the project area (general vicinity of reservoir)	Special status species/critical habitat has been documented in the exact upper reservoir locations	Upper reservoir requires inundation of a sensitive and rare habitat type where special status species are known to exist
Recreation	Some general recreation occurs at reservoir but not in the immediate vicinity of the project construction or infrastructure	Project construction would directly affect recreation areas, but is short-term and can be mitigated	Project infrastructure or operations permanently affects popular recreational areas or facilities, such as campgrounds or marinas, but can be mitigated	Requires inundation or removal of popular campground or trails or has significant impacts to recreation activities that cannot be mitigated
Cultural and Historic Resources	No cultural or resources have been documented in the area	Cultural and historic resources in the reservoir area, but no known resources are documented at the upper reservoir sites	Known cultural/historic resources are documented within the upper reservoir site	National historic or cultural resources have been documented at the upper reservoir site and construction is not allowed
Native American Resources	No Native American issues regarding land or water	Access to upper reservoir site goes through Indian lands or Tribes have water rights or cultural interests in lower reservoir	Upper reservoir site is within an Indian Reservation	Upper reservoir site is within an Indian Reservation and no construction is allowed due to known restrictions
Land Use/Regulatory Designations	Upper reservoir is not within a regulatory designation, no known private land issues	Upper reservoir is within a regulatory designation where permitting and coordination will be required though no major issues anticipated	Upper reservoir is located within a land use that would require significant permit requirements or high costs for purchase	Upper reservoir is in a resource area or land use that does not allow construction
Access/Construction Impacts	Site is readily accessible with roads	Requires some new access roads, topography is relatively flat to allow construction of access areas. Impacts to minor roadways, which can be mitigated.	No access roads present, topography includes steep canyons, banks, mountains, etc. Impacts to existing major roadways, but can be mitigated.	No roads present, construction of roads not permitted in area. Permanent impacts to major roadways.
Stakeholder Issues	No anticipated stakeholder issues or coordination	No established stakeholder issue groups, but some level of coordination is anticipated	Existing stakeholder issue groups and significant stakeholder coordination is necessary	Stakeholders issues will likely prevent the project from occurring even with significant coordination

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5.2.1 Great Plains Region

Table 5-2 presents the operations and environmental screening for the alternatives within the Great Plains Region. Some notable observations include the following.

- At Buffalo Bill Reservoir, both of the upper reservoir sites are in a proposed Area of Critical Environmental Concern (ACEC) on Sheep Mountain, which is why special status species and land use designation received orange ratings. If the area is accepted as an ACEC, this would likely become a fatal flaw to development.
- At Bull Lake Reservoir, the upper reservoir sites are within the Wind River Indian Reservation, and the project would require significant coordination with the tribe. This results in the orange ratings for the Native American, land use, and stakeholder criteria. Recreation impacts may also be a concern with drawdown of the reservoir to support pumped storage operations.
- Canyon Ferry Reservoir is a major recreation destination because of the proximity to Helena, MT. Horsetooth Reservoir is a major recreation destination for Fort Collins, CO. Construction and potential impacts to recreation at the reservoirs would likely garner substantial public interest.

Table 5-2. Operations and Environmental Evaluation Summary – Great Plains Region

	Buffalo Bill		Bull				Canyon Ferry		Horsetooth
	1	2	1B	2C	3	4	5	2	1
Operations Criteria									
Water Supply and Release Requirements									
Water Quality/Temperature Requirements									
System Reoperation									
Environmental and Regulatory Criteria									
Special Status and Sport Fisheries									
Special Status Terrestrial Species/Sensitive Habitat									
Recreation									
Cultural and Historic Resources									
Native American Resources									
Land Use/Regulatory Designations									
Access/Construction Impacts									
Stakeholder Issues									

5.2.2 Upper Colorado Region

Table 5-3 presents the operations and environmental screening for alternatives within the Upper Colorado Region. Some notable observations include the following.

- Blue Mesa Reservoir, Flaming Gorge Reservoir and Lake Powell support special status fish species in the Colorado Basin and coordination would be necessary with the Upper Colorado River Endangered Fish Recovery Program to evaluate potential effects.
- There were no major operational constraints identified at Lake Powell; however; coordination would be necessary to evaluate and mitigate potential effects to downstream special status fish, recreation in the National Recreation Area, and the Navajo nation.
- Alternatives at Jordanelle Reservoir do not appear to have substantial constraints at this level of analysis relative to operations or environmental issues. There may be some impacts to recreation that should be further investigated, but it’s expected that they can be mitigated.
- Strawberry Reservoir is the only site without any orange ratings, which indicates that is has the fewest operations and environmental issues compared to other sites. The ratings do not mean that there would not be any issues to development.
- The upper reservoirs at Vallecito Reservoir are a relatively higher percentage of the volume of the lower reservoir. Vallecito Reservoir usable volume is 125,400 AF. Pumped storage could result in fatal flaw impacts to operations upon further investigation.

Table 5-3. Operations and Environmental Evaluation Summary – Upper Colorado Region

	Blue Mesa			Flaming Gorge		Powell			Jordanelle			Strawberry	Vallecito				
	1A	1B	1C	1C	2F	1B	2B	2C	1	2C	2D	1	1A	1B	2C	3A	3B
Operations Criteria																	
Water Supply and Release Requirements																	
Water Quality/Temperature Requirements																	
System Reoperation																	
Environmental and Regulatory Criteria																	
Special Status and Sport Fisheries																	
Special Status Terrestrial Species/Sensitive Habitat																	
Recreation																	
Cultural and Historic Resources																	
Native American Resources																	
Land Use/Regulatory Designations																	
Access/Construction Impacts																	
Stakeholder Issues																	

5.2.3 Lower Colorado Region

Table 5-3 presents the operations and environmental screening for alternatives within the Lower Colorado Region. Some notable observations include the following.

- Water levels at Lake Mead are at historically low levels and could conflict with pumped storage operations. There are also environmental issues at Lake Mead. All sites are within the Lake Mead National Recreation Area (NRA) and may result in recreation impacts. Lake Mead is also identified as critical habitat for fish species such as the razorback sucker and land surrounding the lake supports listed species, such as the desert tortoise and Bighorn sheep. Major coordination would be required during planning and environmental processes.
- There is an existing pumped storage project at Apache Reservoir, which would require coordination with the proposed alternatives and may conflict with water supplies.

Table 5-4. Operations and Environmental Evaluation Summary – Lower Colorado Region

	Mead										Apache	
	1	2D	3	4	5	6	7D	7E	8C	9C	1B	1C
Operations Criteria												
Water Supply and Release Requirements												
Water Quality/Temperature Requirements												
System Reoperation												
Environmental and Regulatory Criteria												
Special Status and Sport Fisheries												
Special Status Terrestrial Species/Sensitive Habitat												
Recreation												
Cultural and Historic Resources												
Native American Resources												
Land Use/Regulatory Designations												
Access/Construction Impacts												
Stakeholder Issues												

5.2.4 Mid-Pacific Region

Table 5-4 presents the operations and environmental screening for alternatives within the Mid-Pacific Region. Some notable observations include the following.

- New Melones Reservoir was developed with estimates of water availability that are higher than current availability. Reclamation has difficulty maintaining minimum water levels, and the reservoir is typically well below storage capacity. Low water levels could reduce the utility of a pumped storage facility.

- Shasta Reservoir is a large facility; the potential upper reservoir sites represent a very small portion of the water in storage and are not likely to affect water supply or flow requirements. Special status fish, however, are a concern in the Sacramento River downstream of Shasta Reservoir. Temperature increases within Shasta Reservoir could affect Reclamation's ability to manage temperature according to the biological opinions that govern operations of this facility. Shasta Reservoir water levels may also be low during dry hydrologic conditions at the upper arms of the reservoir.
- Whiskeytown Reservoir is part of the Trinity River Division Project, which is the focus of a large, multi-agency restoration effort. The specific upper reservoir site under consideration, however, would have limited direct environmental effects.
- Millerton Reservoir is on the San Joaquin River system. Reclamation is an implementing agency in the San Joaquin River Restoration Program, which is working to restore salmon to the San Joaquin River downstream of Millerton Reservoir. Temperature is one of the main concerns in the restoration program, and increased temperatures from pumped storage could affect the restoration efforts.

Table 5-5. Operations and Environmental Evaluation Summary – Mid-Pacific Region

	New Melones			Shasta									Whiskeytown	Millerton
	1A	1B	2	1	2C	3A	3B	5A	5B	5C	6	7	1	1D
Operations Criteria														
Water Supply and Release Requirements	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Water Quality/Temperature Requirements	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
System Reoperation	Orange	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Green
Environmental and Regulatory Criteria														
Special Status and Sport Fisheries	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange
Special Status Terrestrial Species/Sensitive Habitat	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
Recreation	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green
Cultural and Historic Resources	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Native American Resources	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Land Use/Regulatory Designations	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
Access/Construction Impacts	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
Stakeholder Issues	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange

5.2.5 Pacific Northwest Region

Table 5-5 presents the operations and environmental screening for alternatives within the Pacific Northwest Region. Some notable observations include the following.

- Cle Elum, Keechelus, and Kachess reservoirs are operated together to meet water supply, fishery, and ecosystem restoration in the Yakima Basin. Reclamation is implementing the Yakima River Basin Integrated Water Resources Management Plan that consists of various projects involving the three reservoirs. One of the projects is conveyance from Keechelus to Little Kachess Reservoir. Pumped storage would need to be coordinated with these efforts.
- Native American tribes have interests in multiple reservoirs in the Pacific Northwest Region, as indicated by the number of orange and yellow ratings for the Native American Resources criterion. Pumped storage projects need to be coordinated with appropriate tribal interests.
- Pumped storage may be affected by irrigation operations and low water levels in summer months. At Prineville Reservoir, pumped storage might complicate irrigation releases. Water levels in Owyhee Reservoir fluctuate frequently and run very low in summer months. The reservoir can run out of water in some years. Palisades Reservoir has similar issues with low water levels.
- The technical evaluation identified 23 potential alternatives at Franklin D. Roosevelt Reservoir, including an alternative utilizing Banks Lake as an upper reservoir. Based on the rating scales, the operations criteria all received a green rating at Roosevelt Reservoir; however, there may be stakeholder concerns relative to water supplies and operations of a pumped storage project.
- Two alternatives in the Pacific Northwest Region involve existing upper and lower reservoirs, Keechelus to Little Kachess and Banks to Roosevelt. These alternatives would have fewer environmental and construction related impacts because there would not be a new upper reservoir required.

Table 5-6. Operations and Environmental Evaluation Summary – Pacific Northwest Region

	Cle Elum		Keechelus		Little Kachess		Prineville		Rimrock			Banks				Hungry Horse								Franklin D Roosevelt				
	1B	2B	2B	to Little Kachess	2B	3B	2	3	1	2	3B	1	2	3	4	1B	2	3	4	5	7B	8	9B	1	2	3	4	5
Operations Criteria																												
Water Supply and Release Requirements																												
Water Quality/Temperature Requirements																												
System Reoperation																												
Environmental and Regulatory Criteria																												
Special Status and Sport Fisheries																												
Special Status Terrestrial Species/Sensitive Habitat																												
Recreation																												
Cultural and Historic Resources																												
Native American Resources																												
Land Use/Regulatory Designations																												
Access/Construction Impacts																												
Stakeholder Issues																												

Table 5-6. Operations and Environmental Evaluation Summary – Pacific Northwest Region

	Franklin D Roosevelt (cont.)																		Anderson Ranch			Owhyee				Palisades		
	6	7	8	9B	10	11	12	13	14B	15B	16	17	18	19	20	21	22	To Banks	1	2	3	1B	2B	5	6	1	2	3
Operations Criteria																												
Water Supply and Release Requirements																												
Water Quality/Temperature Requirements																												
System Reoperation																												
Environmental and Regulatory Criteria																												
Special Status and Sport Fisheries																												
Special Status Terrestrial Species/Sensitive Habitat																												
Recreation																												
Cultural and Historic Resources																												
Native American Resources																												
Land Use/Regulatory Designations																												
Access/Construction Impacts																												
Stakeholder Issues																												

Chapter 6
Economic Evaluation

This chapter presents the cost effectiveness and market evaluation for the proposed pumped storage evaluation. This evaluation is performed on the 108 alternatives that were evaluated for cost opinions that passed the technical and fatal flaw environmental screening.

6.1 Cost Effectiveness

Cost effectiveness is calculated using the resulting installed capacity based on a 10-hour run time and the total construction cost opinions. Chapters 2, 3, and 4 describe the technical evaluation completed to estimate installed capacity and costs. Table 6-1 ranks the alternatives on costs only. Operations and environmental considerations are not incorporated into this ranking. Chapter 7 includes a ranking that incorporates the operations and environmental evaluation.

Lake Mead and Apache Reservoir in the Lower Colorado Region represent 8 of the top 10 alternatives based on $/MW, including the top seven alternatives. Alternatives for Little Kachess Reservoir and Hungry Horse Reservoir in the Pacific Northwest Region complete the top 10 ranked sites for cost effectiveness.

The 108 alternatives evaluated for costs range from approximately $840,000/MW to $3.0 million/MW. As further described below, compared to existing projects, costs in the range of $1.0 million/MW to $2.0 million/MW are competitive costs for construction of pumped storage. There are 76 alternatives with costs below $2.0 million/MW and 15 alternatives with costs below $1.5 million/MW.

In comparison to the Pumped Storage Evaluation Special Study for Yellowtail, Seminoe and Trinity Sites Final Phase 2 Report (2013), Yellowtail Alternative 5A had estimated costs of $1.38 million/MW and Seminoe 5A3 had estimated costs of $1.74 million/MW. The remainder of the alternatives evaluated at Trinity and Seminoe reservoirs had costs above $2.0 million/MW.

Table 6-1. Cost Effectiveness Ranking for Pumped Storage Alternatives

Region	Reservoir	No.	Approximate Installed Capacity (MW)	Total Construction Costs (millions)	Estimated Costs ($/MW)	Cost Ranking ($/MW)
Lower Colorado	Mead	2D	1,745	$2,399	$1,374,313	1
Pacific Northwest	Little Kachess	3B	2,539	$3,541	$1,394,322	2
Pacific Northwest	Hungry Horse	1B	2,285	$3,222	$1,410,023	3
Lower Colorado	Apache	1B	1,759	$2,546	$1,447,357	4
Upper Colorado	Flaming Gorge	2F	1,918	$2,795	$1,457,510	5
Upper Colorado	Lake Powell	1B	2,210	$3,226	$1,459,878	6
Pacific Northwest	Hungry Horse	7B	2,328	$3,414	$1,466,793	7
Mid-Pacific	Shasta	5A	2,248	$3,309	$1,472,148	8
Pacific Northwest	Owyhee	5	1,118	$1,690	$1,512,410	9
Pacific Northwest	Hungry Horse	9B	2,085	$3,202	$1,536,110	10
Lower Colorado	Mead	7D	1,595	$2,462	$1,543,407	11
Lower Colorado	Mead	9C	1,540	$2,400	$1,557,980	12
Pacific Northwest	Franklin D Roosevelt	4	2,650	$4,191	$1,581,488	13
Lower Colorado	Mead	3	1,363	$2,158	$1,583,239	14
Pacific Northwest	Keechelus	2B	2,054	$3,300	$1,606,711	15
Pacific Northwest	Hungry Horse	8	1,160	$1,870	$1,612,912	16
Lower Colorado	Apache	1C	1,402	$2,266	$1,616,500	17
Great Plains	Buffalo Bill	1	1,594	$2,584	$1,621,495	18
Pacific Northwest	Rimrock	2	1,525	$2,483	$1,628,255	19
Pacific Northwest	Franklin D Roosevelt	1	2,203	$3,593	$1,630,934	20
Lower Colorado	Mead	7E	1,133	$1,854	$1,636,337	21
Pacific Northwest	Rimrock	3B	2,061	$3,380	$1,640,372	22
Great Plains	Bull	2C	2,043	$3,387	$1,657,500	23
Pacific Northwest	Franklin D Roosevelt	16	2,691	$4,484	$1,666,496	24
Mid-Pacific	Shasta	7	2,621	$4,368	$1,666,907	25
Upper Colorado	Flaming Gorge	1C	1,269	$2,125	$1,674,800	26
Pacific Northwest	Owyhee	1B	1,911	$3,205	$1,676,982	27
Pacific Northwest	Owyhee	2B	1,682	$2,835	$1,684,999	28
Great Plains	Bull	5	977	$1,647	$1,685,621	29
Upper Colorado	Vallecito	3B	1,601	$2,734	$1,707,609	30
Upper Colorado	Blue Mesa	1C	1,789	$3,058	$1,709,134	31
Great Plains	Bull	1B	1,982	$3,425	$1,727,695	32
Mid-Pacific	New Melones	1B	1,399	$2,419	$1,729,404	33
Great Plains	Buffalo Bill	2	1,885	$3,271	$1,735,278	34
Pacific Northwest	Franklin D Roosevelt	13	834	$1,453	$1,742,306	35
Pacific Northwest	Franklin D Roosevelt	2B	1,074	$1,873	$1,743,303	36
Pacific Northwest	Franklin D Roosevelt	8	2,745	$4,786	$1,743,318	37
Lower Colorado	Mead	8C	1,742	$3,042	$1,746,261	38
Pacific Northwest	Hungry Horse	2	1,578	$2,764	$1,751,739	39

Table 6-1. Cost Effectiveness Ranking for Pumped Storage Alternatives

Region	Reservoir	No.	Approximate Installed Capacity (MW)	Total Construction Costs (millions)	Estimated Costs ($/MW)	Cost Ranking ($/MW)
Pacific Northwest	Franklin D Roosevelt	3	1,307	$2,296	$1,756,981	40
Mid-Pacific	Shasta	2C	2,360	$4,147	$1,757,047	41
Pacific Northwest	Franklin D Roosevelt	15B	1,685	$2,964	$1,759,293	42
Pacific Northwest	Franklin D Roosevelt	5	2,113	$3,725	$1,762,808	43
Pacific Northwest	Franklin D Roosevelt	6	1,201	$2,126	$1,770,065	44
Pacific Northwest	Prineville	3	1,081	$1,915	$1,771,969	45
Mid-Pacific	Millerton	1D	2,206	$3,917	$1,775,328	46
Pacific Northwest	Prineville	2	1,696	$3,017	$1,779,015	47
Pacific Northwest	Little Kachess	2B	2,105	$3,748	$1,780,389	48
Pacific Northwest	Banks	3	894	$1,596	$1,786,147	49
Pacific Northwest	Cle Elum	1B	1,483	$2,654	$1,789,479	50
Pacific Northwest	Hungry Horse	4	893	$1,604	$1,797,172	51
Pacific Northwest	Cle Elum	2B	2,147	$3,886	$1,810,189	52
Mid-Pacific	New Melones	1A	816	$1,483	$1,817,681	53
Upper Colorado	Strawberry	1	1,521	$2,788	$1,832,647	54
Pacific Northwest	Banks	1	845	$1,565	$1,852,841	55
Pacific Northwest	Franklin D Roosevelt	11	2,317	$4,297	$1,854,380	56
Pacific Northwest	Franklin D Roosevelt	14B	1,805	$3,351	$1,856,034	57
Upper Colorado	Jordenelle	2C	2,084	$3,886	$1,865,012	58
Pacific Northwest	Banks	4	708	$1,332	$1,882,532	59
Mid-Pacific	Shasta	6	2,184	$4,112	$1,883,042	60
Pacific Northwest	Anderson Ranch	3	1,278	$2,434	$1,903,943	61
Pacific Northwest	Rimrock	1	1,119	$2,131	$1,905,214	62
Pacific Northwest	Banks	to FDR	968	$1,844	$1,905,287	63
Upper Colorado	Vallecito	3A	1,004	$1,920	$1,912,815	64
Pacific Northwest	Franklin D Roosevelt	9B	2,022	$3,871	$1,914,980	65
Upper Colorado	Blue Mesa	1B	1,240	$2,382	$1,921,401	66
Pacific Northwest	Banks	2	1,030	$1,991	$1,932,131	67
Pacific Northwest	Palisades	1	1,070	$2,072	$1,936,978	68
Upper Colorado	Vallecito	1A	1,335	$2,600	$1,947,515	69
Upper Colorado	Jordenelle	2D	1,656	$3,237	$1,954,672	70
Great Plains	Canyon Ferry	2	1,919	$3,778	$1,968,467	71
Upper Colorado	Vallecito	1B	1,211	$2,388	$1,972,420	72
Upper Colorado	Lake Powell	2C	1,536	$3,045	$1,981,742	73

Table 6-1. Cost Effectiveness Ranking for Pumped Storage Alternatives

Region	Reservoir	No.	Approximate Installed Capacity (MW)	Total Construction Costs (millions)	Estimated Costs ($/MW)	Cost Ranking ($/MW)
Lower Colorado	Mead	5	696	$1,387	$1,992,701	74
Upper Colorado	Blue Mesa	1A	759	$1,530	$2,016,460	75
Lower Colorado	Mead	6	873	$1,762	$2,017,490	76
Mid-Pacific	Whiskeytown	1	1,481	$2,991	$2,018,993	77
Pacific Northwest	Hungry Horse	3	1,346	$2,749	$2,041,689	78
Pacific Northwest	Franklin D Roosevelt	20	1,078	$2,217	$2,057,407	79
Mid-Pacific	Shasta	5C	950	$1,979	$2,083,588	80
Pacific Northwest	Franklin D Roosevelt	12	797	$1,663	$2,087,225	81
Pacific Northwest	Franklin D Roosevelt	18	775	$1,622	$2,092,515	82
Pacific Northwest	Anderson Ranch	2	923	$1,947	$2,109,110	83
Mid-Pacific	Shasta	3B	1,293	$2,740	$2,119,145	84
Upper Colorado	Vallecito	2C	995	$2,109	$2,119,514	85
Pacific Northwest	Franklin D Roosevelt	17	709	$1,504	$2,121,189	86
Pacific Northwest	Franklin D Roosevelt	19	1,061	$2,256	$2,127,214	87
Mid-Pacific	Shasta	5B	791	$1,696	$2,143,983	88
Great Plains	Bull	4	639	$1,370	$2,145,625	89
Pacific Northwest	Hungry Horse	5	651	$1,405	$2,159,333	90
Pacific Northwest	Franklin D Roosevelt	22	562	$1,224	$2,179,551	91
Mid-Pacific	Shasta	3A	862	$1,880	$2,182,327	92
Pacific Northwest	Owyhee	6	769	$1,686	$2,193,517	93
Pacific Northwest	Palisades	2	516	$1,132	$2,196,363	94
Upper Colorado	Lake Powell	2B	732	$1,620	$2,213,029	95
Pacific Northwest	Franklin D Roosevelt	10	1,561	$3,506	$2,246,002	96
Pacific Northwest	Franklin D Roosevelt	21	469	$1,064	$2,268,339	97
Pacific Northwest	Franklin D Roosevelt	7	1,440	$3,273	$2,273,600	98
Pacific Northwest	Keechelus	to Little Kachess	322	$732	$2,275,432	99
Lower Colorado	Mead	1	891	$2,031	$2,279,561	100
Pacific Northwest	Anderson Ranch	1	486	$1,117	$2,295,611	101
Mid-Pacific	Shasta	1	553	$1,298	$2,348,243	102
Great Plains	Bull	3	527	$1,278	$2,423,917	103
Pacific Northwest	Palisades	3	478	$1,172	$2,451,120	104
Upper Colorado	Jordenelle	1	1,006	$2,466	$2,451,703	105
Great Plains	Horsetooth	1	709	$1,755	$2,476,336	106
Lower Colorado	Mead	4	449	$1,113	$2,478,009	107
Mid-Pacific	New Melones	2	294	$907	$3,085,420	108

As a basis of comparison, EPRI sponsored a study, Quantifying the Value of Hydropower in the Electric Grid: Final Report (2013), in which cost data for 34 pumped storage projects at various stages of development and configuration were escalated to 2010 dollars (EPRI 2013). The study can be found at: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001023144

The 2010 cost of most projects evaluated within this study ranged from $500 to $2,500 per kilowatt (kW). New large scale pumped storage projects were estimated to cost between $1,000 and $2,500 per kW. Upgrades to existing facilities were significantly less (EPRI 2013).

6.2 Market Conditions Evaluation

Pumped storage projects can be used for energy arbitrage or to provide ancillary services to increase the functionality of wind and solar energy production. Wind and solar energy sources are subject to natural variability that can create challenges for integration into the larger power grid. Wind generation can change suddenly which affects moment-to-moment power output and increases the balancing requirements of dispatchable resources. Peak wind generation also typically occurs during off-peak demand periods and cannot support peak loads. Pumped storage is recognized as one of the most useful methods for regulating intermittent renewable generation resources. Pumped storage projects will have the most economic potential in areas with wind and solar power, markets to encourage development of new projects, and high power demands. The market conditions evaluation discusses how these factors vary in the different states with pumped storage alternatives.

6.2.1 Wind and Solar Energy Development

There has been significant research done on the development potential of wind and solar across the U.S. State and federal agencies have also established goals to increase development of renewable energy. Areas where wind and solar potential are high and where agencies support development through funding or permitting are favorable market conditions for pumped storage.

Wind and Solar Potential

The National Renewable Energy Laboratory (NREL) has conducted significant research on renewable energy resource availability throughout the U.S. and developed maps to show the availability of resources. Figures 6-1 and 6-2 show wind and solar resource availability maps. In general, the centrally located states have the highest wind potential and the southwestern states have the highest solar potential. These states could benefit from bulk energy storage projects as renewable energy development projects are implemented.

Table 6-2 summarizes the wind energy potential estimated in the states with pumped storage alternatives.

Table 6-2. Windy Land Area >= 30% Gross Capacity Factor at 80m and Wind Energy Potential in States with Pumped Storage Alternatives

	Windy Land Area >= 30% Gross Capacity Factor at 80m					Wind Energy Potential	
State	Total (km^2)	Excluded[1] (km^2)	Available (km^2)	Available % of State	% of Total Windy Land Excluded	Installed Capacity (MW)	Annual Generation (GWh)
Arizona	4,545.0	2,364.1	2,180.8	0.74%	52.0%	10,904.1	30,616
California	26,901.3	20,079.2	6,822.0	1.67%	74.6%	34,110.2	105,646
Colorado	95,830.4	18,386.5	77,443.9	28.73%	19.2%	387,219.5	1,288,490
Idaho	13,420.4	9,805.3	3,615.1	1.67%	73.1%	18,075.6	52,118
Montana	232,768.6	43,967.7	188,800.9	49.60%	18.9%	944,004.4	3,228,620
Nevada	5,873.6	4,424.2	1,449.4	0.51%	75.3%	7,247.1	20,823
Oregon	17,109.8	11,689.7	5,420.1	2.16%	68.3%	27,100.3	80,855
Utah	5,273.6	2,652.8	2,620.7	1.19%	50.3%	13,103.7	37,104
Washington	11,932.6	8,236.9	3,695.7	2.12%	69.0%	18,478.5	55,550
Wyoming	146,166.2	35,751.7	110,414.5	43.58%	24.5%	552,072.6	1,944,340
U.S. Total	2,988,328	796,945	2,191,382	22.36%	26.7%	10,956,912	38,552,706

Source: NREL and AWS Truepower 2010

[1] Excluded lands include protected lands (national parks, wilderness, etc.), incompatible land use (urban, airport, wetland, and water features), and other considerations.

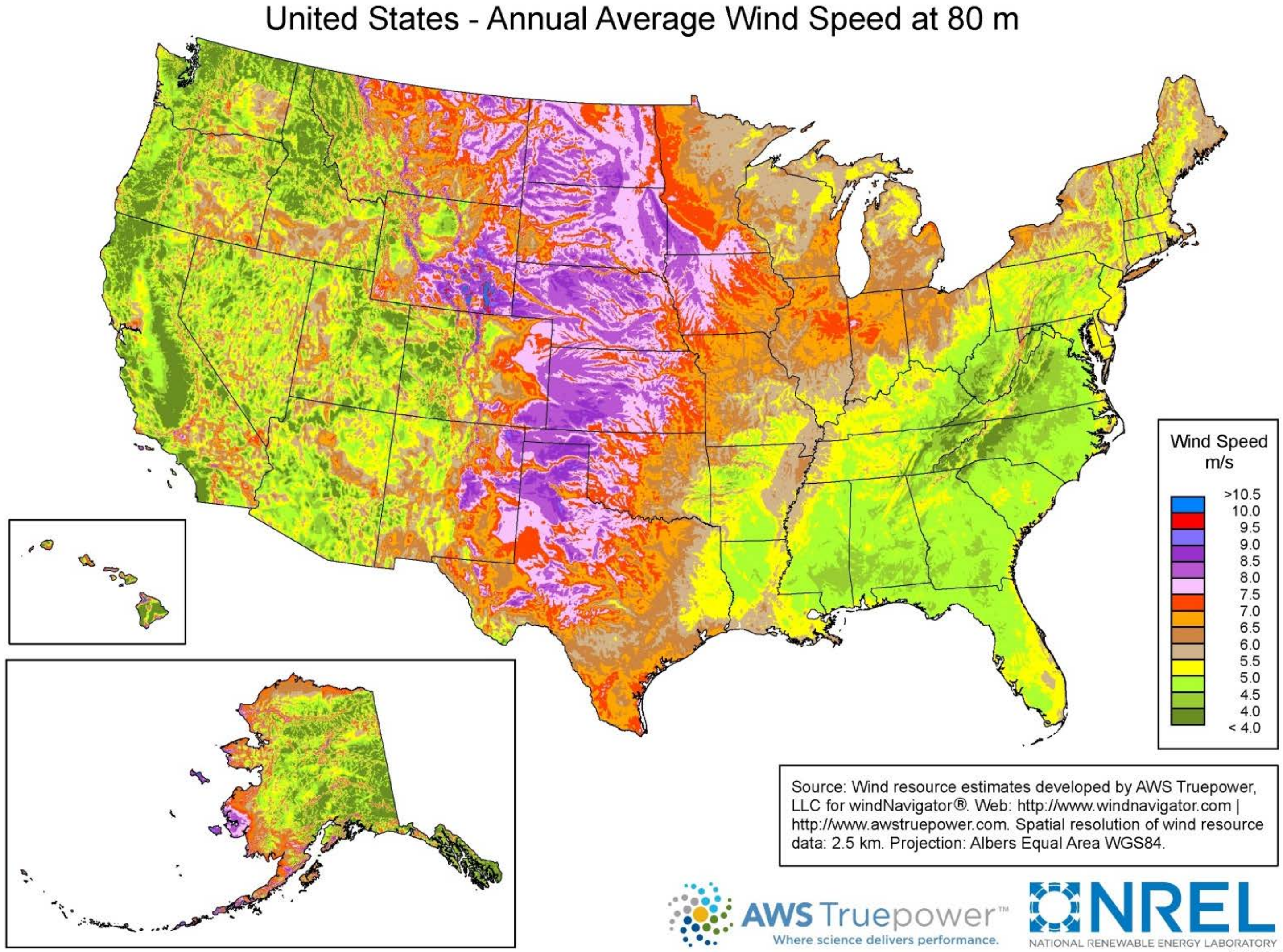


Figure 6-1. Wind Resources Map (NREL 2012a)

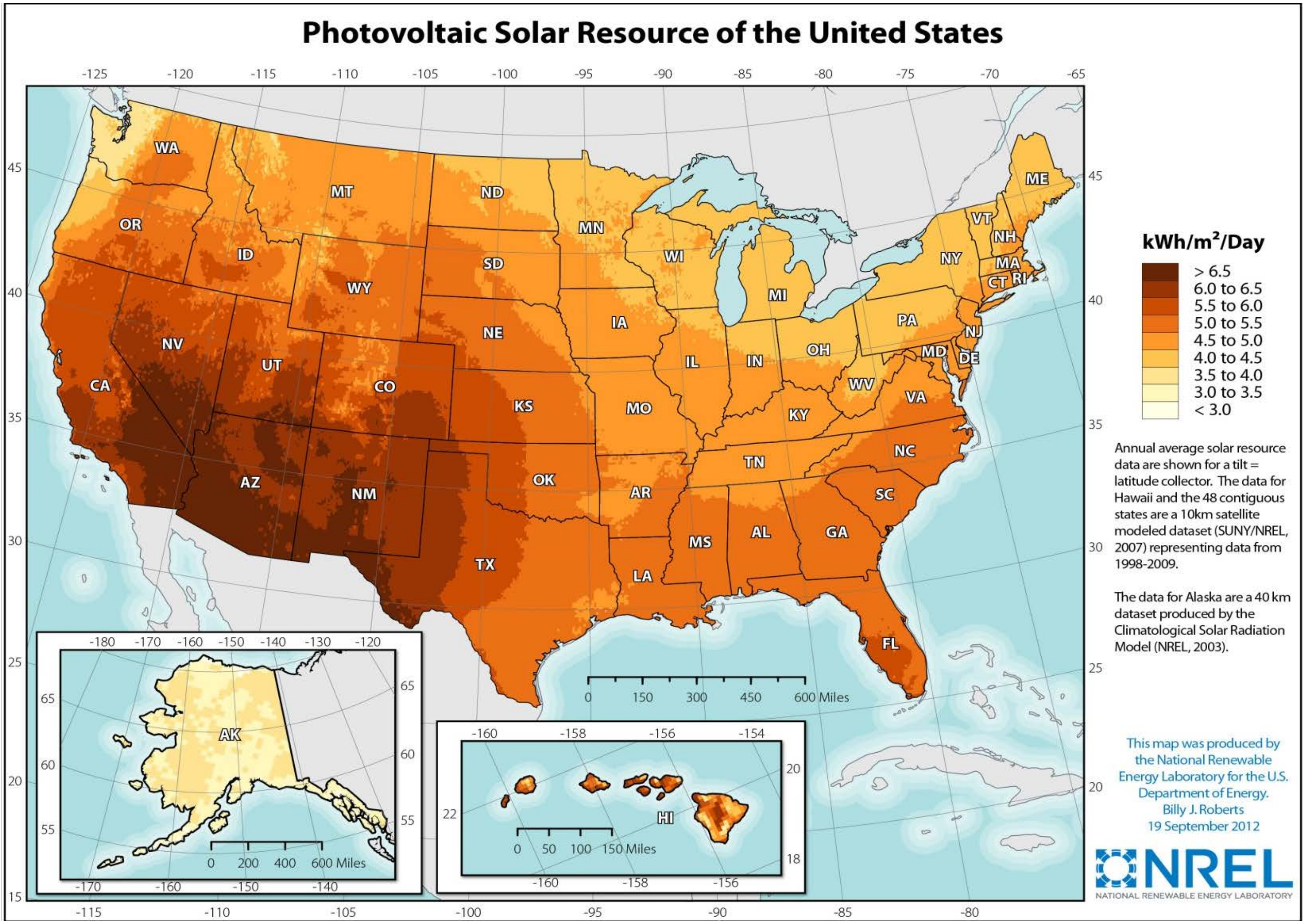


Figure 6-2. Photovoltaic Map (NREL 2012b)

Renewable Energy Standards and Development

Many states have renewable portfolio standards (RPS) or renewable electricity standards (RES) designed to increase electricity generation from renewable resources. These policies mandate or encourage a certain percentage of all electricity sold within a specific jurisdiction supply a certain minimum share of electricity from designated renewable resources. Eligible renewable technologies vary by state, but generally include solar, wind, ocean wave, geothermal, biomass, landfill gas, fuel cells using renewable fuels, and small hydroelectric. All states within Reclamation's service area, except Idaho, Wyoming, and Nebraska, have either a RPS or RPS goal. RPS standards are mandated, while RPS goals are voluntary. The RPSs are resulting in utilities planning and implementing new renewable energy projects, including wind and solar, which will require bulk energy storage. The following paragraphs summarize the status of RPSs in each state with pumped storage alternatives. Additional information on utilities and their energy portfolios is provided for states with proposed alternatives that were ranked in the top 15.

Montana (Great Plains Region)

Montana's RPS was enacted April of 2005. The regulation requires public utilities and competitive electricity suppliers serving 50 or more customers to obtain a percentage of their retail electricity sales from eligible renewable resources. The RPS includes an implementation schedule with 10 percent of energy supplies from renewable resources for years 2010-2014, and 15 percent for year 2015 and every year thereafter. Eligible renewable resources include wind, solar, geothermal, existing hydroelectric projects (10 megawatts or less), certain new hydroelectric projects (up to 15 megawatts installed at an existing reservoir or on an existing irrigation system that did not have hydroelectric generation as of April 16, 2009), landfill or farm-based methane gas, wastewater-treatment gas, low-emission, non-toxic biomass, and fuel cells where hydrogen is produced with renewable fuels (DSIRE 2014). In 2012, Montana had an installed renewable energy capacity of 3,251 MW with a wind power capacity of 645 MW, and hydropower capacity of 2,604 MW. Montana is currently working through development of additional renewable resources to accomplish the 15 percent RPS by 2015. Developers are investing in the renovation and expansion of older hydropower plants, including the $245 million expansion of Rainbow Dam, completed in July 2013. Additionally, over 250 MW of wind power was installed in 2012 to help meet 2015 standards (ACORE 2013).

Northwestern Energy serves approximately 340,000 customers in Montana. The service area covers approximately 73 percent of Montana (Northwestern Energy 2013a). The 2013 peak demand was 1,730 MW with approximately 1,227 MWs per hour on average (Northwestern Energy 2013a). In the 2013 Electric Supply Resource Planning and Procurement Plan, Northwestern Energy identified the need to meet Montana RPS statutes. Currently, the company is operating with 10 percent of retail sales from eligible renewable resources including a fleet of wind and small hydroelectric projects. In September 2013, the company entered an agreement with PPL Montana, LLC to purchase PPL Montana's hydro-electric facilities and associated assets, which includes approximately 633 MW of hydro-electric generation capacity (Northwestern Energy 2013b). This Hydro Acquisition is expected to assist the company is meeting the state's 15 percent RPS standard by 2015. According to the 2013 Resource Procurement Plan, there may be a 350 MW capacity deficit by 2017. While the forecast observed that the region will develop adequate resources to meet that capacity need, the planned elimination of several coal-fired plants raise resource adequacy concerns (Northwestern Energy 2013b). Northwestern Energy currently relies heavily on purchases in the wholesale electricity market, but as the region's surplus energy supply diminishes, the ability to rely on the market to meet peak demands will become more costly and the risk to physical reliability will become greater.

Wyoming (Great Plains and Upper Colorado Regions)

Wyoming does not have a RPS. In 2013, almost 89 percent of net electricity generation in the state came from coal, and 10 percent came from renewable energy resources, primarily wind (EIA 2014f). However, there is current development in renewable energy production from wind, solar, and geothermal resources. In 2009, the BLM established the Wyoming Renewable Energy Coordination Office to facilitate development of renewable energy projects on BLM-administered public lands in Wyoming. Wyoming is also the location of the proposed Chokecherry and Sierra Madre Wind Energy Project, which could include up to 1,000 wind turbines with a capacity of 2,000 to 3,000 MW, making it the largest wind farm in North America. A Record of Decision was signed in October 2012, which determined that more than 200,000 acres within the project site are suitable for wind energy development. Scoping for the project began in September 2013 (BLM 2014). Wind power is currently the greatest utilized source of renewable energy in the state, with an installed renewable energy capacity for wind power of 1,410 MW in 2012 (ACORE 2013). Wyoming exports its wind power to Colorado, Utah, and Oregon. A state net metering law and interconnection standards have been enacted to support distributed generation, but they do not offer significant financial incentives for renewable energy production. The state also has the only wind producing tax in the nation.

Idaho Power is a major utility serving Idaho and part of the Pacific Northwest. The number of customers in Idaho Power's service area is expected to increase from approximately 500,000 in 2012 to over 670,000 by the end of the planning period in 2032. Even with the recent recession, population growth in Idaho Power's service area will require the company to add physical resources to meet the energy demands of its growing customer base (Idaho Power 2013). The median or peak-hour load forecast predicts peak-hour load will grow from 3,245 MW in 2012 to 4,147 MW in 2032. Median average monthly energy use is forecasted to increase from 1,759 MW in 2013 to 2,154 MW in 2032 (Idaho Power 2013).

Rocky Mountain Power serves areas in Wyoming, Utah (including Salt Lake City), and eastern Idaho. Rocky Mountain Power is a part of PacifiCorp, which also serves areas in the Pacific Northwest. The company serves 138,512 customers in Wyoming (Service area map provided in Figure 6-3). PacifiCorp estimates future resource needs in its 2013 Integrated Resource Plan. Without new resources, the company estimates a 2022 deficit of 2,308 MW. The company is currently exploring options for additional resources to avoid this future gap in supply (PacifiCorp 2013).

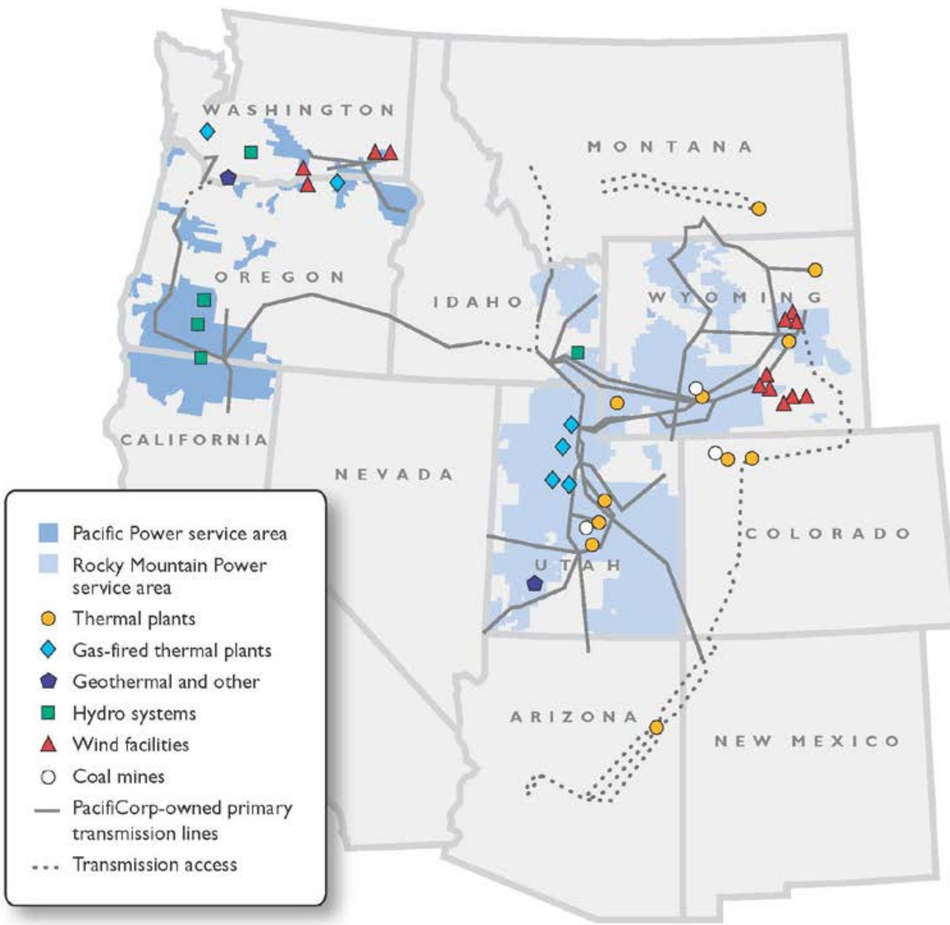


Figure 6-3. PacifiCorp Service Area Map (Source: Rocky Mountain Power 2014)

Colorado (Great Plains and Upper Colorado Regions)

Colorado created a RPS in November of 2004, and was the first state to create the standard by means of a ballot initiative. The current RPS for 2020 is 30 percent eligible renewable energy resources for investor-owned utilities, 20 percent for electric cooperatives serving 100,000 meters or more, and 10 percent for electric cooperatives serving less than 100,000 meters and municipal utilities serving more than 40,000 meters. Eligible renewable energy resources include solar-electric energy, wind energy, geothermal-electric energy, biomass facilities that burn nontoxic plants, landfill gas, animal waste, hydropower, recycled energy, and fuel cells using hydrogen derived from eligible renewables (DSIRE 2014). The state is known to have one of the most ambitious RPSs in the nation, along with a substantial rebate program, a strong net metering policy, and a number of market incentives. Colorado has the fifth largest solar photovoltaic (PV) market and the 10th largest wind market in the U.S. Installed renewable energy capacity in 2012 was 3,273 MW, including major sources of 2,301 MW of wind power, 650 MW of hydropower, and 300 MW of solar PV power. Additionally, the U.S. Forest Service partnered with the Gypsum biomass power plant in November 2012 to use dead timber for biomass power production (ACORE 2013).

Xcel Energy is the largest utility in the state and provides 55 percent of the state's electricity to more than 1.3 million customers (SWEEP 2011). The company operates in Colorado as the Public Service Company of Colorado and holds 16 plants in the state including 13 generating stations, 2 energy centers, and a wind farm. According to their 2011 Electric Resource Plan, the company is well positioned to continue to providing services to customers with no forecasted resource needs through 2017, but will need an additional 292 MW of capacity by 2018. The company plans to satisfy this additional need with short-term contracts from existing generation sources in the region (Xcel Energy 2011). Xcel Energy is expecting to be in compliance with and is working to exceed the state 30 percent renewable energy standard by 2020 through significant changes to the power supply.

Utah (Upper Colorado Region)

Utah enacted *The Energy Resource and Carbon Emission Reduction Initiative* in March 2008. Although this law contains some provisions similar to those found in RPSs adopted by other states, certain other provisions indicate that this law is a renewable portfolio goal. The law requires that utilities pursue renewable energy to the extent that it is cost-effective to do so. Under this law, investor-owned utilities, municipal utilities and cooperative utilities must use eligible renewables to the extent that it is cost-effective to do so, to account for 20 percent of their 2025 adjusted retail electric sales. Adjusted retail sales include the total kilowatt-hours (kWh) of retail electric sales reduced by the kWh attributable to nuclear power plants, demand-side management measures, and fossil fuel power plants that sequester their carbon emissions. For the purposes of the law, eligible renewables include electric generation facilities that became operational after January 1, 1995, and produce electricity from solar, wind, biomass, hydroelectric (under certain conditions), wave, tidal or ocean-thermal energy, geothermal, municipal solid waste, compressed air energy storage, or waste gas and waste heat (DSIRE 2014). In order to encourage renewable energy development, the state does provide a number of tax incentives and programs to help residents, commercial, and industrial entities provide clean energy. In 2012, the installed renewable energy capacity for the state was 652 MW, with the largest sources being wind power at 325 MW and hydropower at 262 MW (ACORE 2014).

Rocky Mountain Power is considered a business unit of PacifiCorp, and delivers electricity to customers in Utah, Wyoming, and Idaho. A service area map including all PacifiCorp business units is provided in Figure 6-3, above. The company serves 829,322 customers in Utah, and has a total company-owned generation capacity of 10,595 MW with 74 generating plants (Rocky Mountain Power 2014).

Net electric generation in Utah has decreased 8 percent from 2008 through 2013, mainly as a result of lower demand from Nevada and California (EIA 2014e). Figure 6-4 illustrates statewide demand trends from 1960 through 2012. Despite this decrease in generation in recent years, Utah's 10-year Strategic Energy Plan estimates that Rocky Mountain Power's total Utah load is expected to increase from approximately 4,700 MW in 2011 to approximately 5,600 MW in 2022. The plan states that to meet future demands, the state should continue to use existing fossil fuel resources while augmenting them with new, cost-effective energy efficient measures and alternative and renewable energy resources Utah Office of Energy Development 2014a).

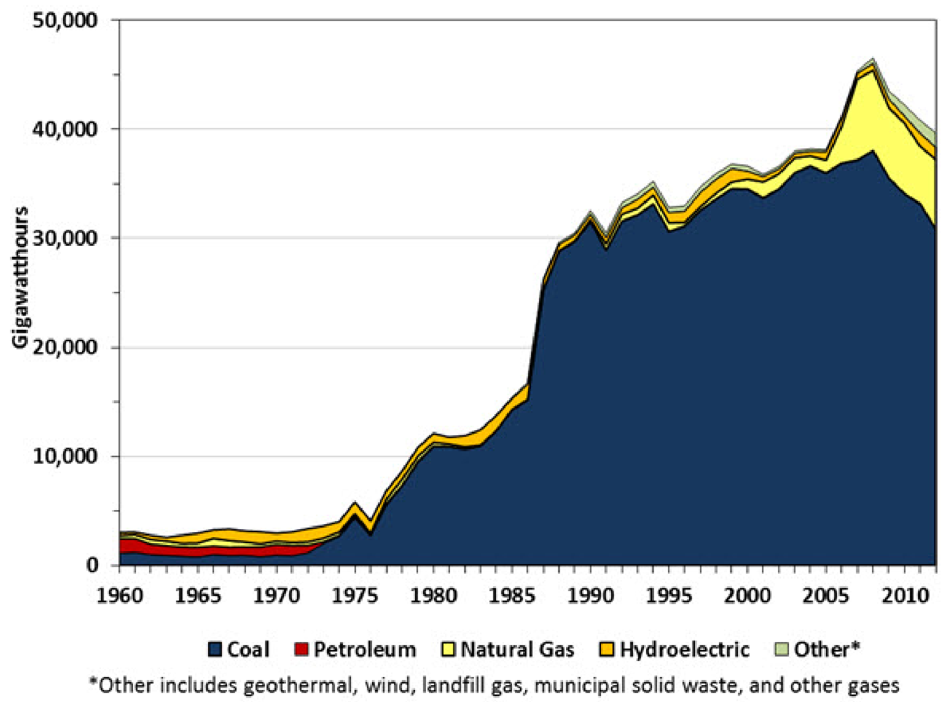


Figure 6-4. Utah Electricity Generation 1960-2012 (Source: Utah Office of Energy Development 2014b)

Arizona (Lower Colorado Region)

Arizona ranks 12th nationwide in Energy Efficiency Policies according to the *American Council for an Energy Efficient Economy* (ACEEE 2014). Arizona's current RES was adopted in November 2006 and requires utilities to obtain 15 percent of their retail electric load from renewable resources by 2025 and thereafter. Of this amount, 30 percent is to be derived from distributed renewable energy technologies by 2012 and thereafter. One-half of the distributed renewable energy requirement must come from residential applications and the remaining one-half from nonresidential, non-utility applications. Those subject to the standard include investor-owned utilities and electric power cooperatives serving retail customers in Arizona, with the exception of distribution companies with more than half of their customers outside Arizona (DSIRE 2014). The state has the second highest solar PV capacity of any state, as well as the most installed PV per capita. In 2012, the total installed renewable energy capacity was 4,107 MW with the main sources being hydropower at 2,718 MW and solar PV at 1,106 MW (ACORE 2013).

Arizona Public Service (APS) is the largest Arizona Utility Company and serves approximately 1.147 million customers, totaling 39 percent of customers in the state. The Salt River Project (SRP) is the second largest utility and serves approximately 969,000 customers, totaling 33 percent of Arizona customers (EmPower Arizona 2013). APS operates the Palo Verde Nuclear Generating Station, the largest power producer of any kind in the United States. The plant is rated at 3,937 net MW and is owned by a consortium of seven utilities in the southwestern United States (APS 2014a). According to their 2014 Integrated Resource Plan, APS expects a projected increase from an 8,124 MW peak requirement in 2014 to a 12,982 MW peak requirement in 2029. This increase would require an additional 6,600 MW of additional resources based on contract expirations and unit retirements (APS 2014b). SRP also anticipates growth, specifically in the Phoenix Valley area, and is working to increase efficiencies to meet these future demands. SRP aims to meet 20 percent of its expected retail energy requirements with energy efficiency programs and supply-side sustainable resources, including wind, geothermal, solar, landfill gas, hydropower, and fuel cell technology by the year 2020 (SRP 2013a).

The major electrical generating sources for the state are coal, natural gas, and nuclear, however, a significant portion of the resources used for electricity generation are imported from outside the state, including coal and natural gas (EmPower Arizona 2013). Figure 6-6 provides an illustration of energy consumption estimates for Arizona in 2011. High summer temperatures cause high summer energy demands from air conditioning, and meeting these summer energy demands continues to be an ongoing challenge and concern. Projections for Arizona's population are expected to continue to rise 20 percent from 2013 through 2023, and as a result, utilities expect an increase of 15 to 20 percent in Arizona's peak load over this 10 year period (EmPower Arizona 2013).

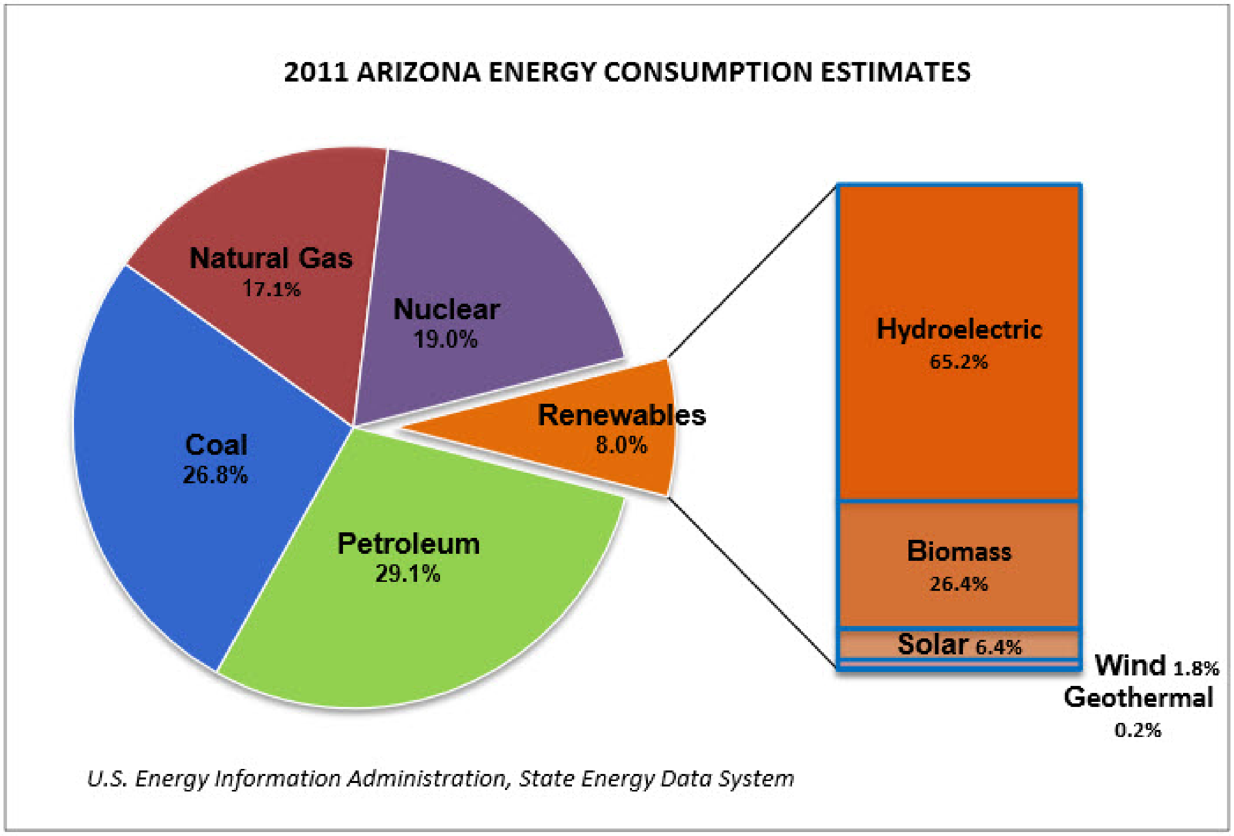


Figure 6-6. 2011 Arizona Energy Consumption Estimates (Source: EmPower Arizona 2013)

Hydroelectric generation is the largest source of renewable energy in Arizona. From 2001 through 2012, the average hydroelectric generation was 7.2 Megawatt hours (MWh). While hydroelectric power represents a small portion of the state's total energy production, smaller-scale hydroelectric generation is gaining support. Environmental issues, such as decreased precipitation and water management in environmentally sensitive areas are key challenges for hydroelectric generation in the state (EmPower Arizona 2013).

Nevada (Lower Colorado Region)

Nevada established a RPS as part of its 1997 restructuring legislation. Under the standard, NV Energy must use eligible renewable energy resources to supply a minimum percentage of the total electricity it sells. In 2001, the state increased the minimum requirement by 2 percent every two years, culminating in a 15 percent requirement by 2013. A 2009 revision increased the requirement to 25 percent by 2025. The 2009 amendments also raised the solar carve-out, requiring utilities to meet 6 percent of their portfolio requirement through solar energy beginning in calendar year 2016. The solar carve-out remains at 5 percent through the end of calendar year 2015. In addition to solar, qualifying renewable energy resources include biomass, geothermal energy, wind, certain hydropower, energy recovery processes, and waste tires (DSIRE 2014). In June 2013, Nevada passed legislation that would close its remaining coal-fired plants and increase renewable energy production in the state. The state also has strong net metering and interconnection policies designed to encourage distributed generation. Nevada ranks second in per capita solar PV installations. Additionally, the largest polycrystalline solar project in the world, the 250MW Copper Mountain 3 solar plant, is slated for completion in Nevada in 2015. Installed renewable energy capacity in 2012 for Nevada was 2,138 MW, with the main sources being hydroelectric power (1,052 MW), geothermal power (517 MW), and solar PV (350 MW) (ACORE 2013).

Nevada is the fastest growing state in the nation in terms of both population and electrical consumption (NRDC 2014). Nevada Energy serves 1.3 million customers with a service area covering 45,592 square miles of the state. The company generates electricity at power plants located in southern Nevada and augments its resources with renewable energy and other power supplies. The 2013 peak load was 7,574 MW (1,720 MW in the northern portion of the service area and 5,854 MW in the southern portion), and the peak generating capacity is 6,078 MW (1,508 in the north and 4,570 in the south) (NV Energy 2014). Figure 6-7 provides a map of the company’s generating plants. The company has a three part strategy that includes increasing energy efficiency and conservation, expanding renewable energy initiatives and investments, and adding new, efficient generating plants and transmission lines to meet the energy needs of Nevada. They currently have more than 1,240 MW of renewable energy under contract or development. There are currently plans in development for the One Nevada Line (ON Line), a transmission project to connect the northern and southern electric systems (NV Energy 2014).

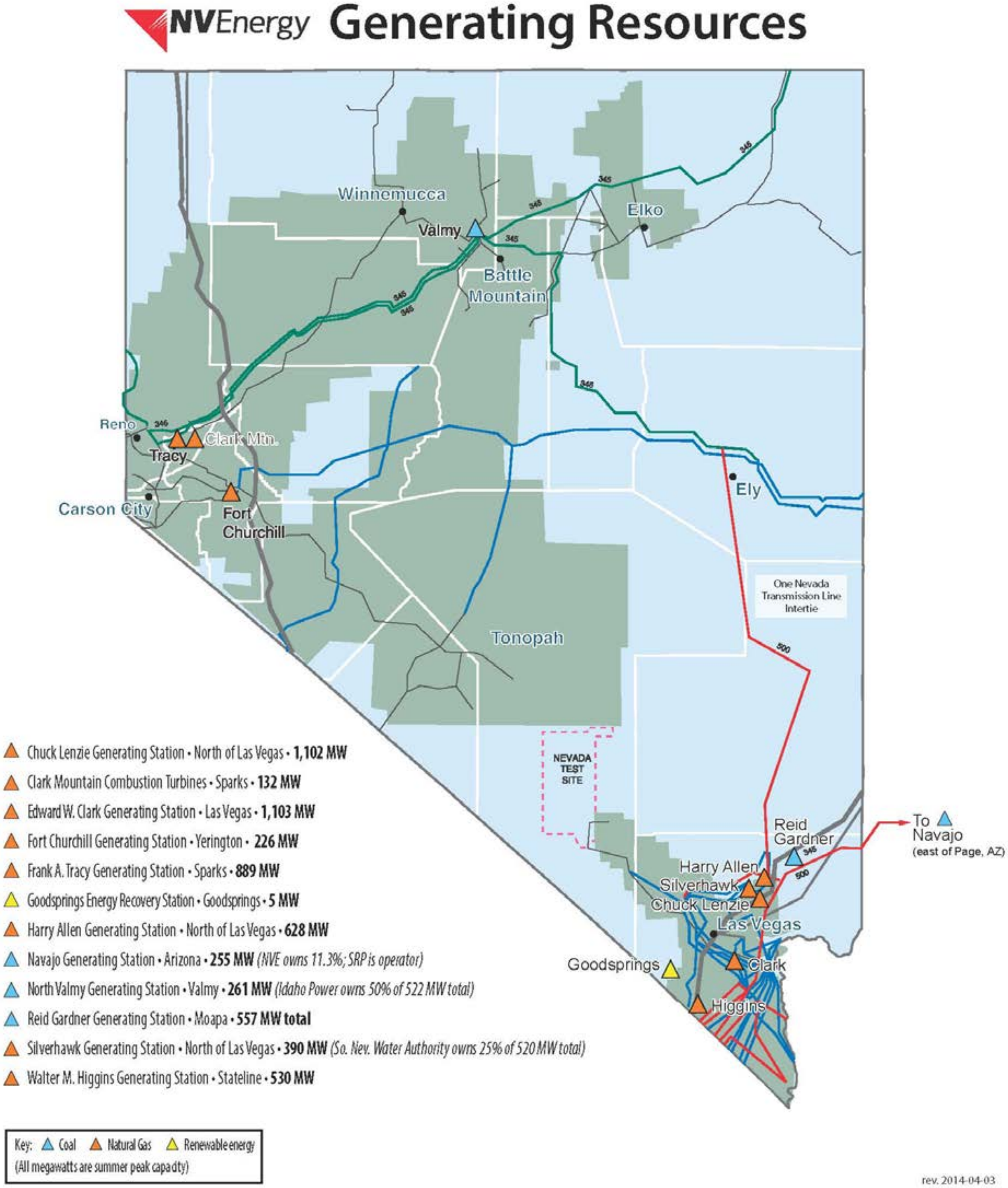


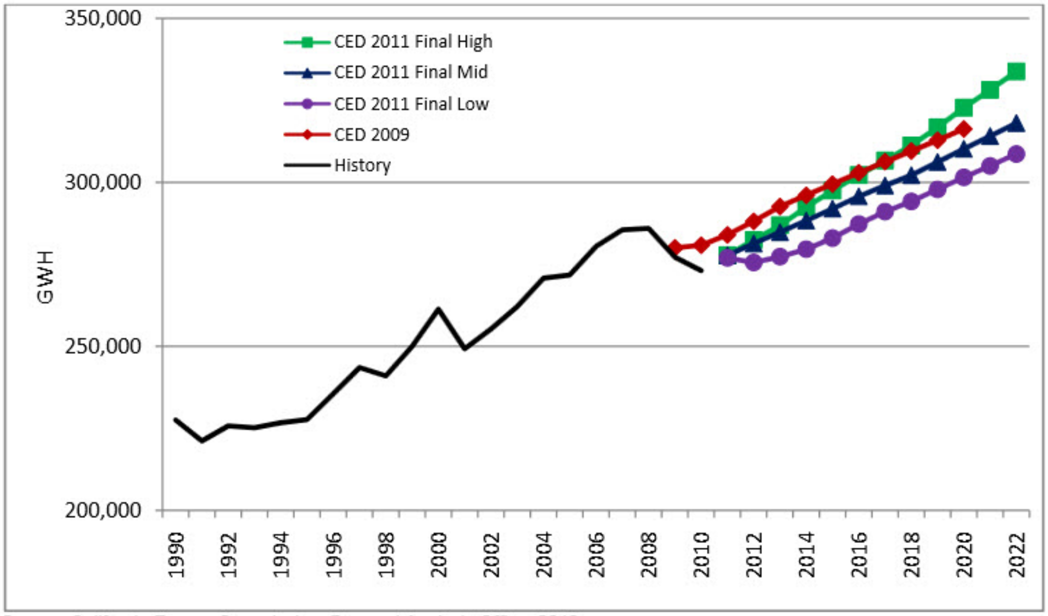
Figure 6-7. NV Energy-Owned Generating Resources (Source: NV Energy 2014)

California (Mid-Pacific Region)

California's RPS was originally established in 2002. Subsequent amendments to this law have resulted in the current requirement for electric utilities to have 33 percent of their retail sales derived from eligible renewable energy resources in 2020 and all subsequent years, with an interim target of 25 percent of retail sales by 2016. Technologies eligible for the RPS include solar PV; solar thermal electric; wind; certain biomass resources; geothermal electric; certain hydroelectric facilities; ocean wave, thermal and tidal energy; fuel cells using renewable fuels; landfill gas; and municipal solid waste conversion, not the direct combustion of municipal solid waste (DSIRE 2014). California leads the nation in generation capacity from geothermal, biomass, solar PV, and solar thermoelectric projects, and places second in wind and hydropower generation capacity. Installed renewable energy capacity in 2012 was 22,699 MW, with the main sources being hydropower (10,054 MW), wind power (5,544 MW), geothermal power (2,732 MW), solar PV (2,559 MW), and biomass power (1,416 MW) (ACORE 2013). Also in 2012, California's three largest investor-owned utilities (Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison) had served 19.8 percent of their retail electricity sales with renewable power (California Public Utilities Commission 2013). In 2013, California ranked fourth in the nation in conventional hydroelectric generation, second in net electricity generation from other renewable energy resources, and first as a producer of electricity from geothermal energy (EIA 2014d).

Pacific Gas and Electric Company (PG&E) provides electrical service to approximately 16 million people throughout a 70,000 square mile service area in central and northern California. In 2012, PG&E retail customers used 76,205 GWh of electricity, of which 31,671 GWh were generated by PG&E's own facilities. By the end of 2012, 19 percent of the electricity delivered came from RPS eligible resources, and the company expects to meet and sustain the 33 percent mandate by 2021 and beyond. The majority of renewable energy is secured through contracts with third parties; however, PG&E owns and operates the nation's largest investor owned hydroelectric system consisting of 68 powerhouses and a pumped storage facility with a total generating capacity of 3,896 MW (PG&E 2012).

A 2012 study completed by the California Energy Commission found that statewide annual electricity consumption is likely to increase from 273,103 GWh in 2010 to up to an estimated 333,838 GWh in 2022. An illustration of these estimates is provided in Figure 6-8.



Source: California Energy Commission, Demand Analysis Office, 2012

Figure 6-8. California Statewide Annual Electricity Consumption

An important aspect of the market conditions assessment for a pumped storage project in California is the existence of an ancillary services market. The California Independent System Operator Corporation (CAISO) manages the flow of electricity across power lines that make up 80 percent of California's power grid. CAISO serves as the only independent grid operator in the western United States. CAISO procures four ancillary services (regulation up, regulation down, spinning reserves, and non-spinning reserves) in the day-ahead and real-time markets. System-wide requirements are set for each ancillary service to meet or exceed minimum operating reliability criteria and control performance standards. CAISO expects that ancillary service procurement will continue to increase with future increases in renewable energy resources to meet the California RPS (CAISO 2013a). Additionally, one of the largest utilities in the West, PacifiCorp, is set to launch a partnership with CAISO in October 2014 in a resource sharing or energy imbalance market (EIM) that will optimize available energy supplies (CAISO 2013b).

Oregon (Mid-Pacific and Pacific Northwest Regions)

Oregon established a RPS for electric utilities and retail electric suppliers as part of the Oregon Renewable Energy Act of 2007. RPS targets are based on the utility's size. Large utilities (those with 3 percent or more of the state's load) must ensure that 25 percent of the electricity sold to retail customers in the state be derived from newer eligible renewable energy resources (with interim requirements of 15 percent by 2015 and 20 percent by 2020). Smaller utilities are subject to lower standards. Utilities with less than 1.5 percent of state load must meet a 5 percent RPS by 2025. Utilities with more than 1.5 percent, but less than 3 percent of state load must meet a 10 percent RPS by 2025. Eligible renewable resources include electricity generated from solar, wind, hydropower, ocean thermal, wave, and tidal power, geothermal, hydrogen using anhydrous ammonia derived from certain renewable sources, municipal solid waste, and biomass, including biogas. The legislation also established a goal that at least 8 percent of Oregon’s retail electric load comes from small-scale, community renewable energy projects with a capacity of 20MW or less (DSIRE 2014). Oregon is one of the few states in the country undertaking wave power development and is also home to the second largest wind farm in the U.S., Shepherds Flat wind farm. State tax credits for renewable energy have attracted a number of clean energy companies. In 2012 the installed renewable energy capacity for the state was 11,887 MW, with the main sources being 8,241 MW from hydropower and 3,153 MW from wind power (ACORE 2013).

Washington (Pacific Northwest Region)

Washington produced 29 percent of the nation’s net hydroelectric generation in 2013 and is currently the leading producer of electricity from hydroelectric sources (EIA 2014b). Washington passed its renewable energy standard in 2006, which calls for electric utilities that serve more than 25,000 customers in the state of Washington to obtain 15 percent of their electricity from renewable resources by 2020 and to undertake all cost-effective energy conservation. Utilities subject to this standard include investor-owned utilities, municipal utilities, rural electric cooperatives, and public utility districts (all of which represent approximately 84 percent of Washington’s load). Interim standards include a 3 percent target for 2012-2015, and a 9 percent target for 2016-2019. Renewable resources include electricity produced from: water; wind; solar energy; geothermal energy; landfill gas; wave, ocean, or tidal power; gas from sewage treatment facilities; biodiesel fuel; and biomass energy based on organic byproducts of the pulp and wood manufacturing process, animal waste, solid organic fuels from wood, forest, or field residues, or dedicated energy crops (DSIRE 2014). Hydropower accounts for the largest portion of Washington’s electricity generation, at 77 percent of total electrical generation in 2012, and the state’s wind power capacity has grown significantly in recent years. In 2012, the state had a capacity of 24,133 MW of installed renewable energy, with the highest contributors being hydropower at 20,903MW and wind power at 2,808 MW (ACORE 2013).

The Bonneville Power Administration (BPA) transports and markets the electricity generated at federal dam facilities located within the Columbia River Basin, including Grand Coulee Dam located on Lake Roosevelt. BPA promotes energy efficiency, renewable resources, and new technologies (BPA 2012). Avista Energy and Puget Sound Energy (PSE) are the two largest investor-owned utilities in the state. PSE services more than one million electric customers over a 6,000 square mile region mostly in western Washington. Avista Energy provides electric service to approximately 680,000 customers in a 30,000 square mile service territory which includes portions of Eastern Washington and Northern Idaho.

According to Puget Sound Energy's 2013 Integrated Resource Plan, the Pacific Northwest will soon reach load-resource balance, due in part to the planned retirement of as much as 2,000 MW of electric generation in Washington and Oregon through 2020 (PSE 2013). In the past, the Pacific Northwest had been capable of generating more electrical energy than the region's utilities required; however, future needs will require regional utilities to construct new resources or purchase long-term power agreements. The company anticipates the need for an additional 12 MW of peak hour capacity by the year 2017, and that need grows to an additional 100 MW by 2020. The Integrated Resource Plan states that the company anticipates sufficient eligible renewable resources and renewable energy certificate (REC) purchases to meet RES requirements through 2022 (PSE 2013). According to Avista Energy's 2013 Integrated Resource Plan, the company plans to meet 2020 RPSs through a combination of qualifying hydroelectric upgrades, a new wind project, a new generating station, and selective REC purchases (Avista Corp 2013). Based on future growth projections, however, Avista Corp anticipates a long-term capacity deficit in 2020 and an energy deficit beginning in 2026.

Idaho (Pacific Northwest Region)

Idaho does not currently have a RPS to drive renewable energy development in the state. Despite this lack of legislation, hydropower supplies approximately three quarters of the state's total electricity, making electrical rates among the lowest in the U.S. In 2012, installed renewable energy capacity totaled 3,674 MW, with the main sources being hydropower (2,536 MW), wind power (973 MW), and biomass power (148 MW) (ACORE 2013).

Federal Wind and Solar Programs

Federal agencies have also established programs to promote development of wind and solar. The programs have included Programmatic Environmental Impact Statements to facilitate the environmental compliance process and permitting for projects. Therefore, implementation of projects in areas covered by federal programs may be more efficient, making the market for pumped storage in these areas is more favorable.

In 2005, the Bureau of Land Management (BLM) approved a Record of Decision (ROD) for the Wind Energy Development Program to support development of wind energy resources on BLM-administered lands in 11 western states that are also in Reclamation's service area. The decision established policies and Best Management Practices (BMPs) for the administration of wind energy development activities and established minimum requirements for mitigation measures. The BLM has authorized 39 wind energy development projects, including connected-action projects that include electric transmission support authorizations, with a total approved capacity of 5,557 megawatts. Projects are in Arizona, California, Idaho, Nevada, Oregon, Utah, and Wyoming (BLM 2014a). In Wyoming, BLM approved the proposed Chokecherry and Sierra Madre Wind Energy Project, which could include up to

1,000 wind turbines with a capacity of 2,000 to 3,000 MW, making it the largest wind farm in North America (BLM 2012).

In 2012, BLM approved a ROD for Solar Energy Development to site utility-scale solar projects on public lands in six southwestern states, Arizona, California, Colorado, Nevada, New Mexico, and Utah. The program would allow the permitting of future solar energy development projects to proceed in a more efficient, standardized, and environmentally responsible manner. As part of the program, BLM has identified Solar Energy Zones that are areas well suited for utility scale solar production. Figure 6-9 shows the existing Solar Energy Zones (BLM 2014b).

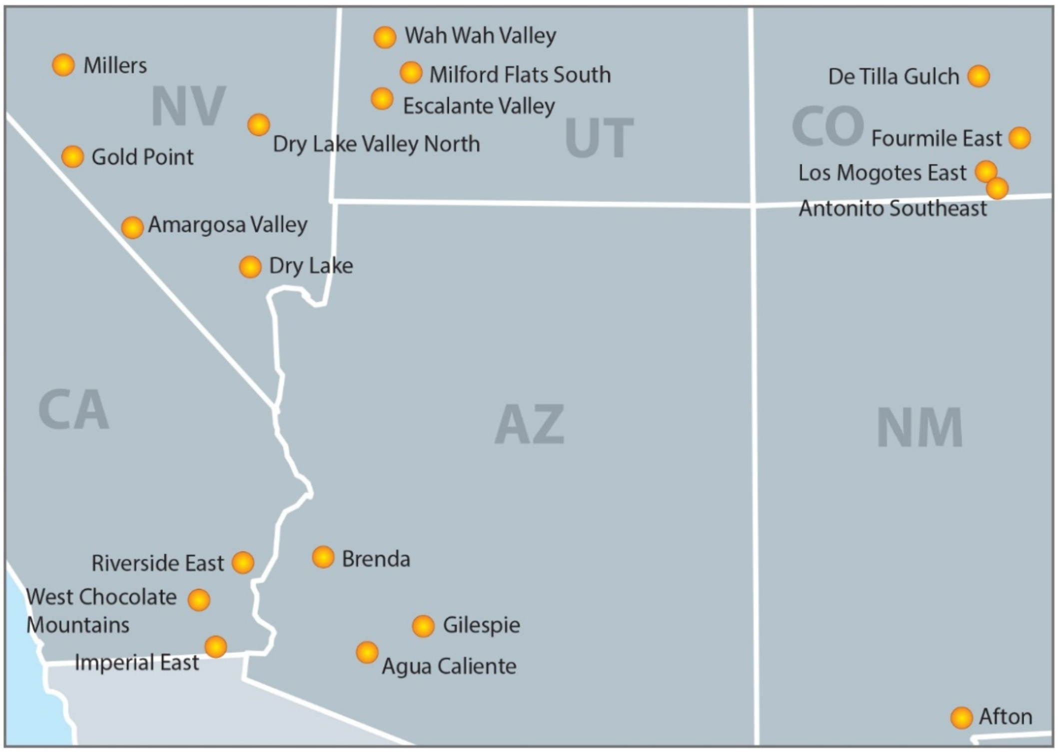


Figure 6-9. BLM Solar Program Solar Energy Zones

Since 2010, the BLM has approved 29 utility-scale solar energy projects, including connected-action projects that include electric transmission support authorizations, with a total approved capacity of over 8,500 megawatts (BLM 2014c). BLM is currently processing 13 renewable energy projects (11 solar and 2 wind) representing about 3,030 MW (BLM 2014d).

Updates on the BLM wind and solar energy programs are available on this website: http://www.blm.gov/wo/st/en/prog/energy/renewable_energy.html.

Reclamation is also researching wind and solar potential on Reclamation-owned lands. Reclamation worked with NREL to identify lands suitable for wind and solar development. Reclamation lands with the greatest wind resources are generally in the northern Rocky Mountains and northern plains in Wyoming, Montana, and North Dakota (NREL 2013). Southern Arizona and New Mexico and southeast California have the greatest potential for utility-scale photovoltaic (NREL 2013).

6.2.2 Ancillary Services Market

Independent system operators or regional transmission organizations develop ancillary services markets to encourage parties to develop ancillary services to help address the variability in wind and solar sources. In the states with pumped storage alternatives, only California currently has a market for ancillary services. Several other areas of the country, particularly on the east coast and in the mid-west, have active ancillary services markets, and additional markets may develop in the future within the western states (Ela et al. 2011).

6.2.3 Proximity to Demand Centers

The installed capacities of the proposed pumped storage alternatives are generally on the order of 1,000 MW to 2,000 MW. These are large scale projects that can provide significant energy loads. It more cost effective if the projects are near urban demand centers where electricity is in demand and would be consumed. Therefore, areas with a high population generally provide more favorable market conditions for pumped storage projects than areas with low populations. These areas are mostly located near major cities or metropolitan areas, such as Phoenix, the San Francisco Bay Area, Seattle, Denver, or Salt Lake City. Pumped storage projects in less populated states, such as Montana and Wyoming, or in more rural areas would require long-distance transmission to move energy to demand centers.

The technical screening identified the distance to the near transmission line. For some alternatives, the distance to nearest transmission line is up to 60 miles. In general, alternatives in the Great Plains Region and Upper Colorado Region are the furthest distance to transmission relative to the other Reclamation regions. This analysis did not evaluate available capacity of transmission infrastructure. In some areas, some significant transmission upgrades may be needed to accommodate the pumped storage project. This must be further evaluated in subsequent studies and would affect the economic viability of a project.

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Chapter 7 Conclusions

This section summarizes screening evaluation results and compares alternatives relative to one another based on technical features, operational, environmental and regulatory characteristics. The project team initially identified 203 pumped storage alternatives at the 60 sites. Based on technical criteria, the 108 alternatives remained that had technical merit for further evaluation, including conceptual layouts, cost opinions, operational, regulatory and environmental screening, and an economic evaluation.

7.1 Screening Summary and Comparison

Table 7-1 presents the overall ranking for the alternatives in all of Reclamation's five regions. The table also shows the cost-only ranking and an operations/environmental-only ranking. Both the $/MW installed capacity cost and the operations and environmental evaluation are considered in the overall ranking. The cost ranking assigned based on the $/MW installed capacity cost, with higher costs receiving lower ranking.

To achieve a "score" for the qualitative operations and environmental ranking, the color ratings were weighted according to performance, with more environmentally favorable alternatives receiving a lower value. Green ratings were assigned one point; yellow ratings were assigned two points; orange ratings were assigned three points; and red ratings were assigned four points. The points for all criteria were then summed for each alternative and assigned a ranking starting at 1 for the alternative with the lowest score. The environmental ranking goes up to 11, which reflects the alternative with the most anticipated adverse environmental effects. The environmental evaluation was similar among most alternatives, in part because the poorly performing alternatives were removed from consideration. Therefore, numerous alternatives received the same score and ranking because they had the exact same number of green, yellow, or orange ratings or the ratings balanced each other out. Table 7-1 shows the environmental ranking (1 through 11); alternatives with a "1" ranking performed the best relative to operations, environmental, and regulatory criteria.

The cost and environmental scores were added together to determine the overall rating. Because the environmental scores were similar for most alternatives, the overall ratings are similar to the cost ratings with small changes up or down to reflect environmental performance. Costs have a higher weight in the overall ranking because operations and environmental evaluations are not major distinguishers among alternatives at this level of analysis.

The top 10 alternatives in the overall ranking and cost-only ranking are mostly the same except for two sites. The Lower Colorado Region has the majority of the top 10 alternatives with five. The Pacific Northwest Region has three sites in the top 10. The Upper Colorado and Mid-Pacific have one each. The $/MW installed capacity for the top 10 alternatives ranges from $1.37 million to $1.56 million. Each of the alternatives in the top 10 received 4 or more green ratings.

Table 7-1. Pumped Storage Alternative Evaluation Ranking Summary

Region	Site	Alternative	$/MW Installed Capacity	Cost Ranking Only	Environmental Ranking	Overall Ranking
Lower Colorado	Mead	2D	$1,374,313	1	3	1
Pacific Northwest	Hungry Horse	1B	$1,410,023	3	3	2
Lower Colorado	Apache	1B	$1,447,357	4	3	3
Pacific Northwest	Little Kachess	3B	$1,394,322	2	7	4
Pacific Northwest	Hungry Horse	7B	$1,466,793	7	3	5
Upper Colorado	Flaming Gorge	2F	$1,457,510	5	6	6
Upper Colorado	Lake Powell	1B	$1,459,878	6	6	7
Mid-Pacific	Shasta	5A	$1,472,148	8	6	8
Lower Colorado	Mead	7D	$1,543,407	11	3	9
Lower Colorado	Mead	9C	$1,557,980	12	3	10
Pacific Northwest	Hungry Horse	9B	$1,536,110	10	6	11
Pacific Northwest	Franklin D Roosevelt	4	$1,581,488	13	4	12
Lower Colorado	Mead	3	$1,583,239	14	3	13
Pacific Northwest	Owyhee	5	$1,512,410	9	9	14
Lower Colorado	Apache	1C	$1,616,500	17	3	15
Pacific Northwest	Hungry Horse	8	$1,612,912	16	5	16
Great Plains	Buffalo Bill	1	$1,621,495	18	5	17
Lower Colorado	Mead	7E	$1,636,337	21	3	18
Pacific Northwest	Keechelus	2B	$1,606,711	15	11	19
Pacific Northwest	Rimrock	2	$1,628,255	19	7	20
Pacific Northwest	Franklin D Roosevelt	1	$1,630,934	20	8	21
Pacific Northwest	Franklin D Roosevelt	16	$1,666,496	24	5	22
Pacific Northwest	Rimrock	3B	$1,640,372	22	9	23
Mid-Pacific	Shasta	7	$1,666,907	25	6	24
Upper Colorado	Flaming Gorge	1C	$1,674,800	26	6	25
Great Plains	Bull	2C	$1,657,500	23	10	26
Upper Colorado	Vallecito	3B	$1,707,609	30	3	27
Pacific Northwest	Owyhee	1B	$1,676,982	27	9	28
Pacific Northwest	Owyhee	2B	$1,684,999	28	9	29
Great Plains	Bull	5	$1,685,621	29	8	30
Upper Colorado	Blue Mesa	1C	$1,709,134	31	6	31
Mid-Pacific	New Melones	1B	$1,729,404	33	4	32
Great Plains	Buffalo Bill	2	$1,735,278	34	5	33
Pacific Northwest	Franklin D Roosevelt	13	$1,742,306	35	5	34

Region	Site	Alternative	$/MW Installed Capacity	Cost Ranking Only	Environmental Ranking	Overall Ranking
Pacific Northwest	Franklin D Roosevelt	2B	$1,743,303	36	4	35
Lower Colorado	Mead	8C	$1,746,261	38	3	36
Great Plains	Bull	1B	$1,727,695	32	10	37
Pacific Northwest	Hungry Horse	2	$1,751,739	39	3	38
Pacific Northwest	Franklin D Roosevelt	3	$1,756,981	40	4	39
Pacific Northwest	Franklin D Roosevelt	8	$1,743,318	37	8	40
Mid-Pacific	Shasta	2C	$1,757,047	41	5	41
Pacific Northwest	Franklin D Roosevelt	5	$1,762,808	43	4	42
Pacific Northwest	Franklin D Roosevelt	15B	$1,759,293	42	8	43
Pacific Northwest	Franklin D Roosevelt	6	$1,770,065	44	7	44
Pacific Northwest	Prineville	3	$1,771,969	45	7	45
Pacific Northwest	Prineville	2	$1,779,015	47	7	46
Pacific Northwest	Banks	3	$1,786,147	49	5	47
Mid-Pacific	Millerton	1D	$1,775,328	46	9	48
Pacific Northwest	Little Kachess	2B	$1,780,389	48	7	49
Pacific Northwest	Hungry Horse	4	$1,797,172	51	4	50
Upper Colorado	Strawberry	1	$1,832,647	54	1	51
Pacific Northwest	Cle Elum	1B	$1,789,479	50	6	52
Mid-Pacific	New Melones	1A	$1,817,681	53	4	53
Pacific Northwest	Cle Elum	2B	$1,810,189	52	6	54
Pacific Northwest	Banks	1	$1,852,841	55	5	55
Pacific Northwest	Franklin D Roosevelt	11	$1,854,380	56	4	56
Pacific Northwest	Franklin D Roosevelt	14B	$1,856,034	57	4	57
Upper Colorado	Jordenelle	2C	$1,865,012	58	5	58
Pacific Northwest	Banks	4	$1,882,532	59	6	59
Pacific Northwest	Banks to FDR	5	$1,905,287	63	2	60
Mid-Pacific	Shasta	6	$1,883,042	60	6	61
Upper Colorado	Vallecito	3A	$1,912,815	64	3	62
Pacific Northwest	Anderson Ranch	3	$1,903,943	61	7	63
Pacific Northwest	Rimrock	1	$1,905,214	62	7	64
Upper Colorado	Blue Mesa	1B	$1,921,401	66	6	65
Pacific Northwest	Banks	2	$1,932,131	67	5	66
Upper Colorado	Vallecito	1A	$1,947,515	69	3	67
Pacific Northwest	Franklin D Roosevelt	9B	$1,914,980	65	8	68
Pacific Northwest	Palisades	1	$1,936,978	68	6	69
Upper Colorado	Jordenelle	2D	$1,954,672	70	5	70
Upper Colorado	Vallecito	1B	$1,972,420	72	3	71
Great Plains	Canyon Ferry	2	$1,968,467	71	6	72
Lower Colorado	Mead	5	$1,992,701	74	3	73
Upper Colorado	Lake Powell	2C	$1,981,742	73	5	74
Lower Colorado	Mead	6	$2,017,490	76	3	75
Upper Colorado	Blue Mesa	1A	$2,016,460	75	6	76
Pacific Northwest	Hungry Horse	3	$2,041,689	78	3	77
Mid-Pacific	Whiskeytown	1	$2,018,993	77	5	78
Pacific Northwest	Franklin D Roosevelt	20	$2,057,407	79	4	79
Mid-Pacific	Shasta	5C	$2,083,588	80	6	80

Region	Site	Alternative	$/MW Installed Capacity	Cost Ranking Only	Environmental Ranking	Overall Ranking
Pacific Northwest	Franklin D Roosevelt	18	$2,092,515	82	5	81
Pacific Northwest	Franklin D Roosevelt	12	$2,087,225	81	8	82
Upper Colorado	Vallecito	2C	$2,119,514	85	2	83
Pacific Northwest	Anderson Ranch	2	$2,109,110	83	7	84
Pacific Northwest	Franklin D Roosevelt	17	$2,121,189	86	6	85
Pacific Northwest	Franklin D Roosevelt	19	$2,127,214	87	5	86
Mid-Pacific	Shasta	3B	$2,119,145	84	9	87
Pacific Northwest	Hungry Horse	5	$2,159,333	90	3	88
Mid-Pacific	Shasta	5B	$2,143,983	88	6	89
Pacific Northwest	Franklin D Roosevelt	22	$2,179,551	91	5	90
Great Plains	Bull	4	$2,145,625	89	8	91
Upper Colorado	Lake Powell	2B	$2,213,029	95	5	92
Mid-Pacific	Shasta	3A	$2,182,327	92	9	93
Pacific Northwest	Palisades	2	$2,196,363	94	7	94
Pacific Northwest	Franklin D Roosevelt	21	$2,268,339	97	4	95
Pacific Northwest	Owyhee	6	$2,193,517	93	9	96
Pacific Northwest	Franklin D Roosevelt	10	$2,246,002	96	7	97
Lower Colorado	Mead	1	$2,279,561	100	3	98
Pacific Northwest	Franklin D Roosevelt	7	$2,273,600	98	7	99
Mid-Pacific	Shasta	1	$2,348,243	102	5	100
Pacific Northwest	Keechelus to Little Kachess	3	$2,275,432	99	9	101
Pacific Northwest	Anderson Ranch	1	$2,295,611	101	7	102
Upper Colorado	Jordenelle	1	$2,451,703	105	3	103
Lower Colorado	Mead	4	$2,478,009	107	3	104
Great Plains	Bull	3	$2,423,917	103	8	105
Pacific Northwest	Palisades	3	$2,451,120	104	7	106
Mid-Pacific	New Melones	2	$3,085,420	108	4	107
Great Plains	Horsetooth	1	$2,476,336	106	8	108

Table 7-2 (at the end of this chapter) summarizes the alternatives evaluation relative to the quantitative and qualitative criteria. The alternatives are presented in the same order as the overall ranking identified in Table 7-1. The quantitative criteria are listed first and show the project capacity and costs. The qualitative criteria are listed below the quantitative criteria with the appropriate color ratings for each alternative.

Not shown in the table, but some important considerations for the evaluation of alternatives are the existence of an operational ancillary services market, availability for renewable energy integration, available high voltage transmission capacity and grid impacts, demand for power in the region, available pump-back power, access, distance from the load centers and constructability (including challenges associated with tapping into an existing reservoir). Montana and Wyoming, particularly, have opportunities for development of wind power, which can integrate into a pumped storage project, and potentially spur the development of an ancillary services market. Table 7-3 summarizes existing market factors reported in September 2014 for the revised top 10 ranked alternatives. Market factors will change in the future, so it is important to monitor changes to understand an area's need for a pumped storage project.

Table 7-3. Summary of Market Factors (Reported in September 2014) for Top 10 Ranked Alternatives

Site	Alt	State (upper reservoir location)	Summary of Market Factors
Mead	2D	Nevada	RPS Requirements: 25% by 2025, 6% of requirement through solar energy beginning in 2016 Distance to Demand Centers: Approximately 25 miles from Las Vegas Distance to Transmission Substation: 5 miles to 500 kV line Electric Utility Supply Portfolio and Demand: Nevada Energy is a major utility and have over 1,240 MW of renewable energy under contract or development. Nevada has grown in both population and electric consumption. Nevada Energy is planning the transmission project One Transmission Line to connect systems. Wind and Solar Potential: Solar potential is high, wind potential is low Ancillary Market Status: No regional market at this time
Hungry Horse	1B	Montana	RPS Requirements: Distance to Demand Centers: Far from any population centers, 153 miles from Missoula with a 2010 population of about 67,000 and 270 miles from Spokane, WA Distance to Transmission Substation: 5 miles to 230 kV line Electric Utility Supply Portfolio and Demand: Wind and Solar Potential: Wind potential is not as high in the immediate reservoir area, but eastern areas have very high wind potential. Solar potential is low. Ancillary Market Status: No regional market at this time
Apache	1B	Arizona	RPS Requirements: 15% by 2025 Distance to Demand Centers: Approximately 70 miles from Phoenix Distance to Transmission Substation: 30 miles to 500 kV line Electric Utility Supply Portfolio and Demand: APS estimates increased peak requirement of 12,982 by 2029. APS operates the Palo Verde Nuclear Station. SRP anticipates energy efficiency and renewable energy to be 20% of retail requirements by 2020. Populations are expected to continue to rise. Wind and Solar Potential: Solar potential is high, wind potential is low Ancillary Market Status: No regional market at this time
Little Kachess	3B	Washington	RPS Requirements: 15% by 2020 Distance to Demand Centers: 75 miles from Seattle Distance to Transmission Substation: 5 miles to 230/500 kV line
Hungry Horse	7B	Montana	RPS Requirements: Distance to Demand Centers: Far from any population centers, 153 miles from Missoula with a 2010 population of about 67,000 and 270 miles from Spokane, WA Distance to Transmission Substation: 5 miles to 230 kV line Electric Utility Supply Portfolio and Demand: Wind and Solar Potential: Wind potential is not as high in the immediate reservoir area, but eastern areas have very high wind potential. Solar potential is low. Ancillary Market Status: No regional market at this time

Site	Alt	State (upper reservoir location)	Summary of Market Factors
Flaming Gorge	2F	Utah	RPS Requirements: Distance to Demand Centers: Far from a major population center, 220 miles from Salt Lake City Distance to Transmission Substation: 20 miles to 230 kV line Electric Utility Supply Portfolio and Demand: Rocky Mountain Power's Utah load is expected to increase 900 MW to 5,700 MW by 2022. Renewable capacity in the state was 652 MW. Wind and Solar Potential: Solar potential is low in northern Utah, wind potential is high, including wind potential in Wyoming Ancillary Market Status: No regional market at this time
Lake Powell	1B	Utah	RPS Requirements: Similar to a RPS, Utah passed the Energy Resource and Carbon Emission Reduction Initiative to implement cost effective measures to have renewables to account for 20% by 2025. Distance to Demand Centers: Far from a major population center, 260 miles from Las Vegas, 137 miles from Flagstaff, AZ with a 2010 population of about 68,000 Distance to Transmission Substation: 60 miles to 230 kV line Electric Utility Supply Portfolio and Demand: Rocky Mountain Power's Utah load is expected to increase 900 MW to 5,700 MW by 2022. Renewable capacity in the state was 652 MW. Wind and Solar Potential: Solar potential is high in southern Utah, wind potential is low in the area Ancillary Market Status: No regional market at this time
Shasta	5A	California	RPS Requirements: 33% by 2020 and 25% by 2015 Distance to Demand Centers: 170 miles from Sacramento, 14 miles from Redding, CA with a 2010 population of about 90,000 Distance to Transmission Substation: 10 miles to 230/500 kV line Electric Utility Supply Portfolio and Demand: PG&E provides service to northern CA with 19% of RPS eligible resources by 2012. PG&E expects to meet RPS goal by 2021. In 2012, customers used 76,205 GWh. California Energy Commission estimates state's consumption will increase. Wind and Solar Potential: Solar and wind potential are both marginal in the area Ancillary Market Status: California ISO has an established market
Mead	7D	Nevada	RPS Requirements: 25% by 2025, 6% of requirement through solar energy beginning in 2016 Distance to Demand Centers: Approximately 25 miles from Las Vegas Distance to Transmission Substation: 5 miles to 500 kV line Electric Utility Supply Portfolio and Demand: Nevada Energy is a major utility and have over 1,240 MW of renewable energy under contract or development. Nevada has grown in both population and electric consumption. Nevada Energy is planning the transmission project One Transmission Line to connect systems. Wind and Solar Potential: Solar potential is high, wind potential is low Ancillary Market Status: No regional market at this time

Site	Alt	State (upper reservoir location)	Summary of Market Factors
Mead	9C	Arizona	RPS Requirements: 25% by 2025, 6% of requirement through solar energy beginning in 2016 Distance to Demand Centers: Approximately 25 miles from Las Vegas Distance to Transmission Substation: 5 miles to 500 kV line Electric Utility Supply Portfolio and Demand: Nevada Energy is a major utility and have over 1,240 MW of renewable energy under contract or development. Nevada has grown in both population and electric consumption. Nevada Energy is planning the transmission project One Transmission Line to connect systems. Wind and Solar Potential: Solar potential is high, wind potential is low Ancillary Market Status: No regional market at this time

7.2 Comparison to Pumped Storage Study for Yellowtail, Seminoe, and Trinity Reservoirs

In 2013, Reclamation completed an analysis of potential pumped storage projects at Yellowtail, Seminoe, Pathfinder, and Trinity reservoirs. The study involved two phases: Phase 1 was a screening evaluation similar to this Reclamation-Wide pumped storage evaluation; and Phase 2 was a more detailed evaluation of technical, operations, and environmental aspects of the potential projects. Phase 2 focused on Yellowtail, Seminoe, and Trinity reservoirs. Table 7-4 summarizes results of the 2013 analysis, which can be compared to the alternatives evaluated in this report.

Table 7-4. Pumped Storage Project Alternatives - Preliminary Site Characteristics

Assumed Feature (Conceptual)	Yellowtail 5A	Seminoe 5A2	Seminoe 5A3	Seminoe 5C	Trinity 5G2A
Max Upper Reservoir Elev (msl)	5,260	7,290	7,440	7,300	3,105
Min Upper Reservoir Elev (msl)	5,100	7,100	7,250	7,165	3,015
Estimated Dam Fill Volume (CY)	5,987,000	7,000,000	7,380,000	7,231,000	2,912,000
Max Lower Reservoir Elev (msl)	3,657	6,357	6,357	6,357	2,370
Min Lower Reservoir Elev (msl)	3,580	6,290	6,290	6,290	2,200
Upper Reservoir Drawdown (ft)	160	190	190	135	90
Min Head / Max Head Ratio (>.70)	0.86	0.74	0.78	0.80	0.71
Approx. Static Head (ft) (<2650 ft)	1,562	872	1,022	909	775
Maximum Dam Height (ft) (<400ft)	298	407	371	336	139
Required Submergence Below TW (ft)	270	205	205	180	130
Est. Conveyance Length (L)	7,950	8,700	6,625	7,160	8,875
Conveyance Length (L)/Static Head (H)	5.09	9.98	6.49	7.88	11.45
L/H General Guideline Criteria	< 12	< 12	< 12	< 12	< 12
Upper Reservoir Usable Vol (AF)	12,081	11,202	12,277	7,145	15,022
Lower Reservoir Usable Vol (AF)	336,103	985,603	985,603	985,603	1,859,688
Energy Storage (MWh)	16,601	8,591	11,036	5,716	10,245
Assumed Hours of Storage	10	10	10	10	10
Resulting Installed Capacity (MW)	1,660	859	1,104	572	1,024

Table 7-5 summarizes the cost opinions for the Yellowtail, Seminoe, and Trinity sites. Based on the $/MW, Yellowtail 5A alternative ranks 2nd among the Reclamation-wide sites, and the remaining sites rank outside of the top 15 sites.

Table 7-5. Opinion of Probable Cost Summary (Million $)

	Yellowtail 5A	Seminoe 5A2	Seminoe 5A3	Seminoe 5C	Trinity 5G2A
Land and Land Rights	See Note 1	See Note 1	See Note 1	See Note 1	See Note 1
Upper Reservoir and Dams					
Dam	$134.71	$157.50	$166.05	$162.70	$65.52
Stream Diversion	$5.00	$5.00	$5.00	$5.00	$5.00
Upper Reservoir Liner	$4.00	-	-	-	-
Spillway	$5.00	$5.00	$5.00	$5.00	$5.00
Civil Works					
Power Station - Civil	$199.21	$164.95	$180.99	$125.75	$225.39
Upper Reservoir Intake	$6.60	$12.00	$11.70	$6.60	$13.20
Vertical Shaft	$26.10	$12.60	$19.95	$12.35	$26.51
Horizontal Power Tunnel	$65.10	$96.00	$60.00	$46.50	$144.00
Penstocks	$27.00	$15.12	$18.00	$9.72	$20.28
Draft Tube Tunnels & DT Gates	$24.90	$23.10	$21.00	$14.70	$28.80
Tailrace Tunnels	$51.60	$73.50	$52.50	$31.35	$109.20
Discharge Structure & Channel	$39.00	$35.40	$39.00	$22.50	$49.20
Surge Chamber	-	$66.10	-	-	$98.64
Draft Tube / Transformer Gallery	$26.00	$26.00	$26.00	$13.00	$26.00
Access Tunnels	$21.60	$18.72	$18.72	$18.72	$19.44
Underground Haul Tunnels	$12.00	$12.00	$12.00	$12.00	$12.00
Site Roads	$5.60	$5.60	$5.60	$11.10	$11.10
Miscellaneous civil works and structures	$25.00	$25.00	$25.00	$25.00	$25.00
Power Plant Equipment	$697.24	$463.92	$573.87	$310.93	$545.03
Switchyard	$42.00	$24.00	$24.00	$10.50	$24.00
Transmission - Plant to Interconnect	$15.00	$2.40	$3.00	$3.60	$18.00
Transmission - Infrastructure Upgrades	$122.50	$41.60	$41.60	$41.60	$70.60
Subtotal	$1,555.16	$1,285.50	$1,308.99	$888.62	$1,541.90
Temporary Facilities & Site Prep	$77.76	$64.27	$65.45	$44.43	$77.10
Subtotal Direct Costs	$1,632.92	$1,349.77	$1,374.43	$933.05	$1,619.00
Contingency (20%)	$326.58	$269.95	$274.89	$186.61	$323.80
Indirect Costs (20%)	$326.58	$269.95	$274.89	$186.61	$323.80
Total Construction Costs (2) (3)	$2,286.08	$1,889.68	$1,924.21	$1,306.27	$2,266.60
Estimated Cost (million $/MW)	$1.38	$2.20	$1.74	$2.29	$2.21
Cost Ranking (based on $/MW)	1	3	2	5	4

1. Costs not included at this level of analysis.
2. Cost estimates are AACE Class 4 estimates with 20 percent contingency.
3. Cost estimates are in 2012 US dollars and exclude cost for pumping, life cycle operations and maintenance, lost revenue due to any plant outage, time cost of money, and escalation for labor/material.

The environmental evaluation approach differed slightly this study and an environmental score or ranking was not generated for each alternative. However, in general, the qualitative results were similar and none of the alternatives had fatal flaws at this level of analysis. The market evaluation was also similar relative to sites in this study located in Montana, Wyoming, and California.

7.3 Considerations for Further Study

This evaluation represents a screening level analysis for pumped storage projects at 60 of Reclamation's existing reservoirs. The results of this evaluation provide Reclamation with information necessary to evaluate each site on a comparative basis. Table 7-1 above shows the overall ranking results for all of the alternatives. Prior to initiating more definitive studies on any of the sites, Reclamation should consider the following factors:

- Cost – The target $/MW cost for economically viable pumped storage projects should be in the range equal to or less than $1.5 million to $2.0 million per MW. For comparison purposes, Table 4-6 shows costs of past projects that have been implemented in the range of $0.8 million to $1.7 million per MW using single-speed technology. Variable speed technology is more expensive than single speed technology, but also provides increased benefits for renewable energy integration (see Appendix C for benefits of variable speed technologies).
- Market Conditions – Monitoring market conditions and energy utilities short- and long-term plans is needed to understand an area's demand for a pumped storage project. In general, areas with higher demand for a pumped storage project include places where utilities are developing large-scale wind or solar projects that require energy storage, states with emerging or developed ancillary service markets, states with increasing renewable energy standards that will result in more wind and solar coming online in the future, and areas where utilities are anticipating substantial increases in energy demand. These are all changing conditions that affect the timing of a pumped storage project.
- Stakeholder Support – It is important to understand both support and opposition to a potential project. Projects could be in a regulatory environment with stakeholders that will not be supportive of a project. This could be for biological, fisheries, tribal, cultural, recreation or other purposes. Coordination with Reclamation area offices will help to understand local reactions to a potential pumped storage project.
- Agency Partnerships – There will be operations and environmental challenges in implementing any pumped storage project. Reclamation should first consider projects that have local interest and could provide mutual benefits to other state, federal, or local agencies. Other agencies could include local energy utilities, water districts, or state and federal agencies working to progress renewable energy development.

All aspects, including technical, operations, environmental, and regulatory, of the pumped storage alternatives need to be analyzed in more detail. This screening evaluation did not consider potential evaporation losses in reservoirs and potential effects on pumped storage operations. Further, an operations analysis must consider hydrologic conditions, including droughts, impacts on reservoir water levels and pumped storage operations. This analysis only included transmission costs from the new power station to the nearest substation. Impacts/upgrades to existing transmission infrastructure will need further evaluation and could add substantial costs to the project.

The environmental evaluation for this screening analysis is very preliminary with the main purpose of identifying potential fatal flaws for an alternative. Detailed environmental evaluation is needed if any alternative is further investigated, including biological resource surveys, fisheries analysis, and air quality and greenhouse gas emissions analysis.

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Table 7-2. Alternatives Evaluation Summary

Region	Lower Co.	Pacific NW	Lower Co.	Pacific NW	Pacific NW	Upper Co.	Upper Co.	Mid-Pacific	Lower Co.	Lower Co.	Pacific NW
Site	**Mead**	**Hungry Horse**	**Apache**	**Little Kachess**	**Hungry Horse**	**Flaming Gorge**	**Lake Powell**	**Shasta**	**Mead**	**Mead**	**Hungry Horse**
Alternative	2D	1B	1B	3B	7B	2F	1B	5A	7D	9C	9B
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	12,000	15,700	11,600	10,550	5,700	14,800	12,700	18,900	14,500	7,400	23,000
Lower Reservoir Usable Vol (acre-ft)	17,350,000	29,982,026	245,138	239,000	29,982,026	3,515,500	320,000	3,970,000	17,350,000	17,350,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	0	1	5	4	0	0	4	0	0	0	0
Approx. Static Head (ft) (<2650 ft)	1,653	1,142	1,723	2,735	2,312	1,473	900	1,352	1,250	2,365	1,089
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	1,745	2,285	1,759	2,539	2,328	1,918	2,210	2,248	1,595	1,540	2,085
Energy Storage (MWh)	17,453	15,778	17,588	25,393	11,597	19,178	10,058	22,478	15,953	15,402	22,031
Estimated Dam Volume (CY)	2,307,992	7,036,719	6,176,494	6,277,805	1,111,263	7,038,706	10,573,317	14,391,874	6,639,662	6,143,288	4,413,021
Maximum Dam Height (ft) (<400 ft)	294	317	347	236	126	132	399	297	330	330	226
L/H Ratio	5.81	7.7	4.56	3.72	6.15	4	10.43	4.94	5.87	4.92	8.67
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	0
Assumed Distance to Transmission (mi.)	5	5	30	5	5	20	50	10	5	5	40
Cost Opinions											
Construction Cost (million)	$2,399	$3,222	$2,546	$3,541	$3,414	$2,795	$3,226	$3,309	$2,462	$2,400	$3,202
$/MW Installed Capacity	$1,374,313	$1,410,023	$1,447,357	$1,394,322	$1,466,793	$1,457,510	$1,459,878	$1,472,148	$1,543,407	$1,557,980	$1,536,110
Cost Ranking based on $/MW	1	3	4	2	7	5	6	8	11	12	10
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	3	3	3	7	3	6	6	6	3	3	6
Summary											
Overall Ranking	1	2	3	4	5	6	7	8	9	10	11

Table 7-2. Alternatives Evaluation Summary

Region	Pacific NW	Lower Co.	Pacific NW	Lower Co.	Pacific NW	Great Plains	Lower Co.	Pacific NW	Pacific NW	Pacific NW	Pacific NW
Site	**Franklin D Roosevelt**	**Mead**	**Owyhee**	**Apache**	**Hungry Horse**	**Buffalo Bill**	**Mead**	**Keechelus**	**Rimrock**	**Franklin D Roosevelt**	**Franklin D Roosevelt**
Alternative	4	3	5	1C	8	1	7E	2B	2	1	16
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	24,600	12,800	7,300	9,300	8,800	11,700	10,400	13,500	18,700	9,700	6,100
Lower Reservoir Usable Vol (acre-ft)	5,185,000	17,350,000	715,000	245,138	29,982,026	601,404	17,350,000	158,000	198,000	5,185,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	0	0	1	4	0	2	0	9	9	0	0
Approx. Static Head (ft) (<2650 ft)	976	1,210	1740	1,713	2,692	1,548	1,238	1,729	927	1,259	1,321
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	2,650	1,363	1,118	1,402	1,160	1,594	1,133	2,054	1,525	2,203	2,691
Energy Storage (MWh)	21,128	13,632	11,177	14,019	20,847	15,938	11,327	20,541	15,246	10,743	7,091
Estimated Dam Volume (CY)	9,014,091	4,468,372	1,625,340	5,284,243	3,057,423	5,000,000	5,437,567	5,393,990	5,247,852	6,232,851	2,477,356
Maximum Dam Height (ft) (<400 ft)	399	400	96	326	224	304	305	255	226	340	95
L/H Ratio	7.7	5.19	4.25	4.58	6.78	6.28	5.92	7.36	4.51	5.16	9.66
L/H General Acceptance Criteria	0	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	0	0
Assumed Distance to Transmission (mi.)	40	5	25	30	5	30	5	5	50	40	40
Cost Opinions											
Construction Cost (million)	$4,191	$2,158	$1,690	$2,266	$1,870	$2,584	$1,854	$3,300	$2,483	$3,593	$4,484
$/MW Installed Capacity	$1,581,488	$1,583,239	$1,512,410	$1,616,500	$1,612,912	$1,621,495	$1,636,337	$1,606,711	$1,628,255	$1,630,934	$1,666,496
Cost Ranking based on $/MW	13	14	9	17	16	18	21	15	19	20	24
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	4	3	9	3	5	5	3	11	7	8	5
Summary											
Overall Ranking	12	13	14	15	16	17	18	19	20	21	22

Table 7-2. Alternatives Evaluation Summary

Region	Pacific NW	Mid-Pacific	Upper Co.	Great Plains	Upper Co.	Pacific NW	Pacific NW	Great Plains	Upper Co.	Mid-Pacific	Great Plains
Site	**Rimrock**	**Shasta**	**Flaming Gorge**	**Bull**	**Vallecito**	**Owyhee**	**Owyhee**	**Bull**	**Blue Mesa**	**New Melones**	**Buffalo Bill**
Alternative	3B	7	1C	2C	3B	1B	2B	5	1C	1B	2
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	10,400	31,800	8,700	12,400	18,900	12,700	11,500	6,600	20,540	12,700	15,000
Lower Reservoir Usable Vol (acre-ft)	198,000	3,970,000	3,515,500	151,700	125,400	715,000	715,000	151,701	748,500	2,420,000	601,404
Upper Reservoir/Lower Reservoir (%)	5	1	0	8	15	2	2	4	3	1	2
Approx. Static Head (ft) (<2650 ft)	2,252	937	1,658	1,873	963	1710	1662	1,683	990	1,252	1,428
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	2,061	2,621	1,269	2,043	1,601	1,911	1,682	977	1,789	1,399	1,885
Energy Storage (MWh)	20,606	26,207	12,690	20,433	16,008	19,110	16,823	9,772	17,894	13,987	18,850
Estimated Dam Volume (CY)	6,858,280	8,993,289	7,376,816	6,679,841	8,741,403	2,300,769	4,380,138	4,066,862	5,274,318	8,103,468	3,900,000
Maximum Dam Height (ft) (<400 ft)	360	399	132	283	254	190	329	218	85	106	404
L/H Ratio	6.34	8.47	3.68	7.45	5.83	9.22	8.8	4.6	10.04	7.16	8.53
L/H General Acceptance Criteria	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12
Assumed Distance to Transmission (mi.)	50	10	20	50	50	25	25	50	10	40	30
Cost Opinions											
Construction Cost (million)	$3,380	$4,368	$2,125	$3,387	$2,734	$3,205	$2,835	$1,647	$3,058	$2,419	$3,271
$/MW Installed Capacity	$1,640,372	$1,666,907	$1,674,800	$1,657,500	$1,707,609	$1,676,982	$1,684,999	$1,685,621	$1,709,134	$1,729,404	$1,735,278
Cost Ranking based on $/MW	22	25	26	23	30	27	28	29	31	33	34
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	9	6	6	10	3	9	9	8	6	4	5
Summary											
Overall Ranking	23	24	25	26	27	28	29	30	31	32	33

Table 7-2. Alternatives Evaluation Summary

Region	Pacific NW	Pacific NW	Lower Co.	Great Plains	Pacific NW	Pacific NW	Pacific NW	Mid-Pacific	Pacific NW	Pacific NW	Pacific NW
Site	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Mead**	**Bull**	**Hungry Horse**	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Shasta**	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Franklin D Roosevelt**
Alternative	13	2B	8C	1B	2	3	8	2C	5	15B	6
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	16,700	14,300	23,700	14,700	15,500	29,000	29,700	13,300	10,800	29,800	24,200
Lower Reservoir Usable Vol (acre-ft)	5,185,000	5,185,000	17,350,000	151,700	29,982,026	5,185,000	5,185,000	3,970,000	5,185,000	5,185,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	0	0	0	10	1	1	1	0	0	1	0
Approx. Static Head (ft) (<2650 ft)	1,229	1,039	835	1,533	987	1,039	774	2,017	1,264	1,026	676
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	834	1,074	1,742	1,982	1,578	1,307	2,745	2,360	2,113	1,685	1,201
Energy Storage (MWh)	18,054	13,068	17,419	19,824	13,463	26,503	20,216	23,601	12,008	26,906	14,396
Estimated Dam Volume (CY)	5,345,442	9,017,961	7,870,063	4,541,696	10,109,579	7,921,140	9,181,434	3,160,871	6,801,450	20,405,001	14,511,094
Maximum Dam Height (ft) (<400 ft)	214	371	364	343	403	399	343	296	334	396	290
L/H Ratio	10.76	4.24	7	8.73	8.46	8.29	8.16	9.7	5.97	6.94	7.7
L/H General Acceptance Criteria	0	0	< 12	< 12	< 12	1	1	< 12	0	1	0
Assumed Distance to Transmission (mi.)	40	40	5	50	5	40	40	10	40	40	40
Cost Opinions											
Construction Cost (million)	$1,453	$1,873	$3,042	$3,425	$2,764	$2,296	$4,786	$4,147	$3,725	$2,964	$2,126
$/MW Installed Capacity	$1,742,306	$1,743,303	$1,746,261	$1,727,695	$1,751,739	$1,756,981	$1,743,318	$1,757,047	$1,762,808	$1,759,293	$1,770,065
Cost Ranking based on $/MW	35	36	38	32	39	40	37	41	43	42	44
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	5	4	3	10	3	4	8	5	4	8	7
Summary											
Overall Ranking	34	35	36	37	38	39	40	41	42	43	44

Table 7-2. Alternatives Evaluation Summary

Region	Pacific NW	Pacific NW	Pacific NW	Mid-Pacific	Pacific NW	Pacific NW	Upper Co.	Pacific NW	Mid-Pacific	Pacific NW	Pacific NW
Site	**Prineville**	**Prineville**	**Banks**	**Millerton**	**Little Kachess**	**Hungry Horse**	**Strawberry**	**Cle Elum**	**New Melones**	**Cle Elum**	**Banks**
Alternative	3	2	3	1D	2B	4	1	1B	1A	2B	1
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	17,900	18,600	14,600	34,300	16,300	8,200	19,100	15,500	7,500	16,400	10,900
Lower Reservoir Usable Vol (acre-ft)	152,800	152,800	715,000	433,800	239,000	29,982,026	951,000	437,000	2,420,000	437,000	715,000
Upper Reservoir/Lower Reservoir (%)	12	12	2	8	7	0	2	4	0	4	2
Approx. Static Head (ft) (<2650 ft)	686	1,036	696	731	1,468	902	905	1,088	1,237	1,488	881
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	1,081	1,696	894	2,206	2,105	893	1,521	1,483	816	2,147	845
Energy Storage (MWh)	10,806	16,957	8,936	22,065	21,052	6,509	15,211	14,835	8,161	21,468	8,446
Estimated Dam Volume (CY)	1,799,165	6,414,506	2,786,661	5,673,189	7,734,138	5,699,347	11,674,572	2,651,063	4,679,869	8,309,774	3,431,860
Maximum Dam Height (ft) (<400 ft)	65	131	177	290	330	220	399	187	119	340	87
L/H Ratio	4.8	8.95	4.94	7.53	10.59	7.91	6.01	8.55	7.23	11.04	6.34
L/H General Acceptance Criteria	< 10	< 12	< 10	< 10	< 12	< 12	< 12	< 12	< 12	< 12	< 12
Assumed Distance to Transmission (mi.)	20	20	10	10	5	5	40	20	40	20	10
Cost Opinions											
Construction Cost (million)	$1,915	$3,017	$1,596	$3,917	$3,748	$1,604	$2,788	$2,654	$1,483	$3,886	$1,565
$/MW Installed Capacity	$1,771,969	$1,779,015	$1,786,147	$1,775,328	$1,780,389	$1,797,172	$1,832,647	$1,789,479	$1,817,681	$1,810,189	$1,852,841
Cost Ranking based on $/MW	45	47	49	46	48	51	54	50	53	52	55
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	7	7	5	9	7	4	1	6	4	6	5
Summary											
Overall Ranking	45	46	47	48	49	50	51	52	53	54	55

Table 7-2. Alternatives Evaluation Summary

Region	Pacific NW	Pacific NW	Upper Co.	Pacific NW	Pacific NW	Mid-Pacific	Upper Co.	Pacific NW	Pacific NW	Upper Co.	Pacific NW
Site	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Jordanelle**	**Banks**	**Banks to FDR**	**Shasta**	**Vallecito**	**Anderson Ranch**	**Rimrock**	**Blue Mesa**	**Banks**
Alternative	11	14B	2C	4	5	6	3A	3	1	1B	2
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	11,900	18,000	10,800	9,800	9,600	26,500	12,100	1,400	14,800	14,300	16,030
Lower Reservoir Usable Vol (acre-ft)	5,185,000	5,185,000	20,320,000	715,000	2,982,026	3,970,000	125,400	423,000	198,000	748,500	715,000
Upper Reservoir/Lower Reservoir (%)	0	0	0	1	0	1	10	3	7	2	2
Approx. Static Head (ft) (<2650 ft)	761	1,064	770	821	2,705	937	943	1038	859	985	731
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	2,317	1,805	2,084	708	968	2,184	1,004	1,278	1,119	1,240	1,030
Energy Storage (MWh)	7,969	16,846	7,318	7,076	22,848	21,839	10,036	12,782	11,188	12,395	10,305
Estimated Dam Volume (CY)	1,532,897	2,321,408	3,618,992	3,374,647	6,002,459	6,475,671	5,883,684	4,521,141	2,348,917	3,943,186	2,109,320
Maximum Dam Height (ft) (<400 ft)	130	140	166	83	301	373	214	177	202	75	132
L/H Ratio	9.72	10.15	7.68	4.6	5.34	10.25	5.93	8	7.43	10.08	7.15
L/H General Acceptance Criteria	0	0	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 10
Assumed Distance to Transmission (mi.)	40	40	60	10	5	10	50	30	50	10	10
Cost Opinions											
Construction Cost (million)	$4,297	$3,351	$3,886	$1,332	$1,844	$4,112	$1,920	$2,434	$2,131	$2,382	$1,991
$/MW Installed Capacity	$1,854,380	$1,856,034	$1,865,012	$1,882,532	$1,905,287	$1,883,042	$1,912,815	$1,903,943	$1,905,214	$1,921,401	$1,932,131
Cost Ranking based on $/MW	56	57	58	59	63	60	64	61	62	66	67
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	4	4	5	6	2	6	3	7	7	6	5
Summary											
Overall Ranking	56	57	58	59	60	61	62	63	64	65	66

Table 7-2. Alternatives Evaluation Summary

Region	Upper Co.	Pacific NW	Pacific NW	Upper Co.	Upper Co.	Great Plains	Lower Co.	Upper Co.	Lower Co.	Upper Co.	Pacific NW
Site	**Vallecito**	**Franklin D Roosevelt**	**Palisades**	**Jordanelle**	**Vallecito**	**Canyon Ferry**	**Mead**	**Lake Powell**	**Mead**	**Blue Mesa**	**Hungry Horse**
Alternative	1A	9B	1	2D	1B	2	5	2C	6	1A	3
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	17,000	24,100	7,000	22,100	15,500	16,400	8,280	12,800	12,800	8,800	10,600
Lower Reservoir Usable Vol (acre-ft)	125,400	5,185,000	1,200,000	20,320,000	125,400	1,506,597	17,350,000	320,000	17,350,000	748,500	29,982,026
Upper Reservoir/Lower Reservoir (%)	14	0	1	0	12	1	0	4	0	1	0
Approx. Static Head (ft) (<2650 ft)	893	736	1737	790	888	1,330	955	1,470	775	980	957
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	1,335	2,022	1,070	1,656	1,211	1,919	696	1,536	873	759	1,346
Energy Storage (MWh)	13,352	15,609	10,697	15,364	12,106	19,195	6,960	16,558	8,732	7,589	8,927
Estimated Dam Volume (CY)	10,439,219	23,422,564	7,621,118	8,141,476	9,707,042	13,400,000	5,784,260	11,713,590	3,888,990	2,720,669	7,352,875
Maximum Dam Height (ft) (<400 ft)	363	178	391	206	353	351	343	329	268	65	240
L/H Ratio	5.75	6.55	6.16	7.51	5.78	11.11	3.9	8.98	7.46	10.13	5.26
L/H General Acceptance Criteria	< 12	0	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12	< 12
Assumed Distance to Transmission (mi.)	50	40	60	60	50	20	5	50	5	10	5
Cost Opinions											
Construction Cost (million)	$2,600	$3,871	$2,072	$3,237	$2,388	$3,778	$1,387	$3,045	$1,762	$1,530	$2,749
$/MW Installed Capacity	$1,947,515	$1,914,980	$1,936,978	$1,954,672	$1,972,420	$1,968,467	$1,992,701	$1,981,742	$2,017,490	$2,016,460	$2,041,689
Cost Ranking based on $/MW	69	65	68	70	72	71	74	73	76	75	78
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	3	8	6	5	3	6	3	5	3	6	3
Summary											
Overall Ranking	67	68	69	70	71	72	73	74	75	76	77

Table 7-2. Alternatives Evaluation Summary

Region	Mid-Pacific	Pacific NW	Mid-Pacific	Pacific NW	Pacific NW	Upper Co.	Pacific NW	Pacific NW	Pacific NW	Mid-Pacific	Pacific NW
Site	**Whiskeytown**	**Franklin D Roosevelt**	**Shasta**	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Vallecito**	**Anderson Ranch**	**Franklin D Roosevelt**	**Franklin D Roosevelt**	**Shasta**	**Hungry Horse**
Alternative	1	20	5C	18	12	2C	2	17	19	3B	5
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	13,000	7,500	9,800	14,000	7,200	12,600	16,200	12,300	16,200	15,200	18,800
Lower Reservoir Usable Vol (acre-ft)	214,000	5,185,000	3,970,000	5,185,000	5,185,000	125,400	423,000	5,185,000	5,185,000	3,970,000	29,982,026
Upper Reservoir/Lower Reservoir (%)	6	0	0	0	0	10	4	0	0	0	1
Approx. Static Head (ft) (<2650 ft)	1,295	711	1,102	861	1,316	898	648	716	756	967	1,407
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	1,481	1,078	950	775	797	995	923	709	1,061	1,293	651
Energy Storage (MWh)	14,815	4,693	9,499	10,608	8,338	9,951	9,231	7,750	10,778	12,928	23,277
Estimated Dam Volume (CY)	7,743,801	2,328,176	8,279,997	8,397,906	1,598,128	10,404,960	3,526,584	1,057,649	12,292,906	4,994,788	15,975,533
Maximum Dam Height (ft) (<400 ft)	400	138	398	335	135	405	293	114	158	332	349
L/H Ratio	8.92	5.86	7.31	7.45	6.64	6.41	7.23	9.64	3.88	6.57	4.69
L/H General Acceptance Criteria	< 12	0	< 12	0	0	< 12	< 10	0	0	< 12	< 12
Assumed Distance to Transmission (mi.)	20	40	10	40	40	50	30	40	40	10	5
Cost Opinions											
Construction Cost (million)	$2,991	$2,217	$1,979	$1,622	$1,663	$2,109	$1,947	$1,504	$2,256	$2,740	$1,405
$/MW Installed Capacity	$2,018,993	$2,057,407	$2,083,588	$2,092,515	$2,087,225	$2,119,514	$2,109,110	$2,121,189	$2,127,214	$2,119,145	$2,159,333
Cost Ranking based on $/MW	77	79	80	82	81	85	83	86	87	84	90
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	5	4	6	5	8	2	7	6	5	9	3
Summary											
Overall Ranking	78	79	80	81	82	83	84	85	86	87	88

Table 7-2. Alternatives Evaluation Summary

Region	Mid-Pacific	Pacific NW	Great Plains	Upper Co.	Mid-Pacific	Pacific NW	Pacific NW	Pacific NW	Pacific NW	Lower Co.	Pacific NW
Site	**Shasta**	**Franklin D Roosevelt**	**Bull**	**Lake Powell**	**Shasta**	**Palisades**	**Franklin D Roosevelt**	**Owyhee**	**Franklin D Roosevelt**	**Mead**	**Franklin D Roosevelt**
Alternative	5B	22	4	2B	3A	2	21	6	10	1	7
Technical Screening											
Upper Reservoir Usable Vol (acre-ft)	7,300	36,000	4,600	16,000	10,400	4,400	6,000	16,800	35,900	12,815	42,100
Lower Reservoir Usable Vol (acre-ft)	3,970,000	5,185,000	151,700	320,000	3,970,000	1,200,000	5,185,000	715,000	5,185,000	17,350,000	5,185,000
Upper Reservoir/Lower Reservoir (%)	0	1	3	5	0	0	0	2	1	0	1
Approx. Static Head (ft) (<2650 ft)	1,232	306	1,578	1,480	942	1332	1,064	520	734	790	741
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	791	562	639	732	862	516	469	769	1,561	891	1,440
Energy Storage (MWh)	7,911	9,678	6,386	20,838	8,617	5,156	5,615	7,686	23,173	8,911	27,453
Estimated Dam Volume (CY)	6,830,515	0	2,308,473	13,913,144	3,441,684	1,032,958	4,805,792	5,206,026	22,110,008	9,938,044	11,944,215
Maximum Dam Height (ft) (<400 ft)	345	0	174	349	292	98	337	374	238	104	370
L/H Ratio	5.78	27.31	4.84	8.93	6.72	8.11	6.32	6.84	5.95	6.77	7.87
L/H General Acceptance Criteria	< 12	< 7	< 12	< 12	< 12	< 12	0	< 10	1	< 12	1
Assumed Distance to Transmission (mi.)	10	30	50	50	10	60	40	25	40	5	40
Cost Opinions											
Construction Cost (million)	$1,696	$1,224	$1,370	$1,620	$1,880	$1,132	$1,064	$1,686	$3,506	$2,031	$3,273
$/MW Installed Capacity	$2,143,983	$2,179,551	$2,145,625	$2,213,029	$2,182,327	$2,196,363	$2,268,339	$2,193,517	$2,246,002	$2,279,561	$2,273,600
Cost Ranking based on $/MW	88	91	89	95	92	94	97	93	96	100	98
Operations and Environmental Criteria											
Water Supply and Release Requirements											
Water Quality/Temperature Requirements											
System Reoperation											
Special Status and Sport Fisheries											
Special Status Terrestrial Species/Sensitive Habitat											
Recreation											
Cultural and Historic Resources											
Native American Resources											
Land Use/Regulatory Designations											
Access/Construction Impacts											
Stakeholder Issues											
Environmental Ranking	6	5	8	5	9	7	4	9	7	3	7
Summary											
Overall Ranking	89	90	91	92	93	94	95	96	97	98	99

Table 7-2. Alternatives Evaluation Summary

Region	Mid-Pacific	Pacific NW	Pacific NW	Upper Co.	Lower Co.	Great Plains	Pacific NW	Mid-Pacific	Great Plains
Site	**Shasta**	**Keechelus to Little Kachess**	**Anderson Ranch**	**Jordanelle**	**Mead**	**Bull**	**Palisades**	**New Melones**	**Horsetooth**
Alternative	1	3	1	1	4	3	3	2	1
Technical Screening									
Upper Reservoir Usable Vol (acre-ft)	8,800	15,000	6,300	18,600	7,670	4,000	5,800	2,680	8,800
Lower Reservoir Usable Vol (acre-ft)	3,970,000	15,000	423,000	20,320,000	17,350,000	151,700	1,200,000	2,420,000	139,135
Upper Reservoir/Lower Reservoir (%)	0	10	1	0	0	3	0	0	6
Approx. Static Head (ft) (<2650 ft)	714	244	878	1,350	665	1,498	937	1,247	915
Assumed Hours of Storage	10	10	10	10	10	10	10	10	10
Resulting Installed Capacity (MW)	553	322	486	1,006	449	527	478	294	709
Energy Storage (MWh)	5,529	3,216	4,865	22,097	4,490	5,271	4,780	2,940	7,086
Estimated Dam Volume (CY)	8,979,497	0	4,908,331	10,478,812	6,152,513	2,700,000	4,556,945	2,496,589	10,600,000
Maximum Dam Height (ft) (<400 ft)	400		299	131	400	168	374	108	400
L/H Ratio	7.07	89.99	4.39	4.85	8.11	6.1	6.31	5.18	8.73
L/H General Acceptance Criteria	< 10	< 12	< 12	< 12	< 10	< 12	< 12	< 12	< 12
Assumed Distance to Transmission (mi.)	10	5	30	60	5	50	60	40	10
Cost Opinions									
Construction Cost (million)	$1,298	$732	$1,117	$2,466	$1,113	$1,278	$1,172	$907	$1,755
$/MW Installed Capacity	$2,348,243	$2,275,432	$2,295,611	$2,451,703	$2,478,009	$2,423,917	$2,451,120	$3,085,420	$2,476,336
Cost Ranking based on $/MW	102	98	101	105	107	103	104	108	106
Operations and Environmental Criteria									
Water Supply and Release Requirements									
Water Quality/Temperature Requirements									
System Reoperation									
Special Status and Sport Fisheries									
Special Status Terrestrial Species/Sensitive Habitat									
Recreation									
Cultural and Historic Resources									
Native American Resources									
Land Use/Regulatory Designations									
Access/Construction Impacts									
Stakeholder Issues									
Environmental Ranking	5	9	7	3	3	8	7	4	8
Summary									
Overall Ranking	100	101	102	103	104	105	106	107	108

Chapter 8
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