Environmental Impacts of Closed-Loop Pumped Storage Hydropower

June 2024

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PNNL-36322

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HydroWIRES

The U.S. electricity system is changing rapidly with the large-scale addition of variable renewables, and the flexible capabilities of hydropower (including pumped storage hydropower) make it well-positioned to aid in integrating these variable resources while supporting grid reliability and resilience. Recognizing these challenges and opportunities, WPTO created the HydroWIRES (Water Innovation for a Resilient Electricity System) initiative. HydroWIRES is principally focused on understanding and supporting the changing role of hydropower in the evolving U.S. electricity system. Through the HydroWIRES initiative, WPTO seeks to understand and drive utilization of the full potential of hydropower resources to contribute to electricity system reliability and resilience, now and into the future.

HydroWIRES is distinguished in its close engagement with the DOE National Laboratories. Five National Laboratories—Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory—work as a team to provide strategic insight and develop connections across the DOE portfolio that add significant value to the HydroWIRES initiative.

HydroWIRES operates in conjunction with the DOE Grid Modernization Initiative, which focuses on the development of new architectural concepts, tools, and technologies that measure, analyze, predict, protect, and control the grid of the future, and on enabling the institutional conditions that allow for quicker development and widespread adoption of these tools and technologies.

Connections with the HydroWIRES Roadmap

This report on *Environmental Impacts of Closed-Loop Pumped Storage Hydropower* focuses primarily on addressing HydroWIRES Objective 3.3: Optimizing Hydropower Operations. It is informed by the 2020 report *A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower*, and results from it will feed into additional work on the environmental impacts of closed-loop pumped storage hydropower.

We thank our five external reviewers from the environmental, developer, consultant, and industry perspectives as well as one reviewer from Pacific Northwest National Laboratory and several reviewers from the DOE WPTO. Our report was much improved by the comments from these individuals.

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Abstract

This report was developed to assist technical specialists involved with license applications, resource and regulatory agencies, and other members of the hydropower community involved in the permitting and licensing process for closed-loop pumped storage hydropower (PSH). It aims to help streamline environmental reviews by focusing their scope, identifying project-related impacts more efficiently, and exploring potential mitigation measures. PSH is an energy storage technology that uses energy to pump water up from a lower reservoir to an upper reservoir where water is stored until electricity is needed when the water is released to a lower reservoir passing through turbines. Closed-loop PSH—PSH that is not continuously connected to a naturally flowing water feature—is one of the lowest greenhouse gas (GHG) emitting energy storage technologies and is therefore a critical part of the transition to renewable energy. Proposals for closed-loop PSH facilities in the United States currently account for more than 40% of original licenses and 99% of all potential hydropower generation capacity in the Federal Energy Regulatory Commission hydropower licensing pipeline including but not limited to PSH. While the design of closed-loop PSH facilities can avoid some environmental impacts common to open-loop PSH facilities, particularly to aquatic biodiversity and ecosystems, no closed-loop facilities have been constructed in the United States to enable direct comparison of project impacts and efficacy of mitigations. Many proposals for closed-loop PSH submitted to FERC are abandoned early in the permitting and licensing process prior to filing license applications and environmental assessments, so there is little documentation describing potential project impacts and proposed mitigations. The newness of closed-loop PSH proposals in the United States may mean that tribal, federal, and state agencies with authorities for cultural and natural resources protection and management involved in the FERC licensing process may not have experience with closed-loop PSH regulation. Our review of closed-loop PSH National Environmental Policy Act (NEPA) documents, expert interview responses, and scientific literature found that environmental impacts of closed-loop PSH are highly site-specific. As a result, generalizations about the types of environmental impacts across closed-loop PSH project sites are difficult to make such that a technology-specific programmatic Environmental Impact Statement is not possible. Environmental impacts of closed-loop PSH are like those for open-loop PSH (e.g., cultural resource destruction or disturbance, wildlife and terrestrial resource impacts, increased emissions from construction vehicles) with a few exceptions including closed-loop PSH having issues with water sourcing, which can lead to delays and contention due to potential complexities with water rights; generally fewer impacts to aquatic resources because it is not connected to a naturally flowing water feature; and lower reservoir GHG emission potential. Cultural resource impacts were commonly reported in NEPA documents and expert interviews, but in many cases these impacts cannot be mitigated. The authors recommend future research on 1) application and development of site selection techniques that can avoid impacts and 2) collecting additional data to test hypotheses about reservoir GHG emissions from closed-loop PSH.

Executive Summary

This report was developed to assist technical specialists involved with license applications, resource and regulatory agencies, and other members of the hydropower community involved in the permitting and licensing process for closed-loop pumped storage hydropower (PSH). It aims to help streamline environmental reviews by focusing their scope, identifying project-related impacts more efficiently, and exploring potential mitigation measures.

Background and Motivation

Pumped storage hydropower (PSH) is an energy storage technology that uses energy to pump water up from a lower reservoir to an upper reservoir where water is stored until electricity is needed when the water is passed through turbines to generate electricity and released to a lower reservoir. Closed-loop PSH

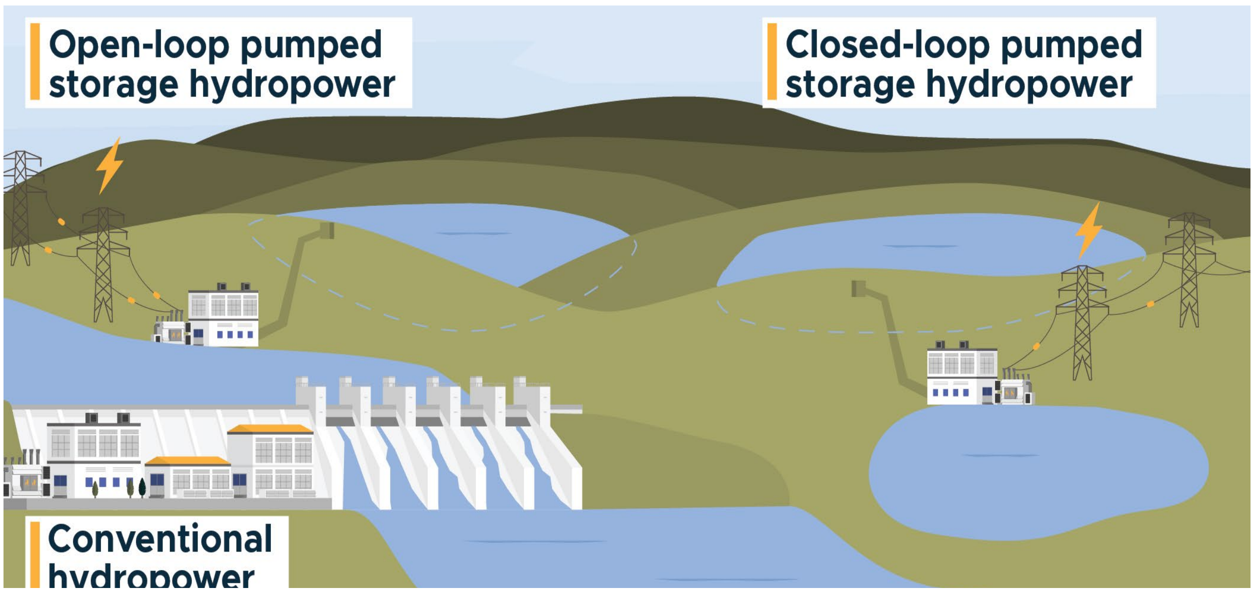

Figure ES 1 PSH is a long-duration energy storage technology that uses energy to pump water from a lower reservoir to an upper reservoir where it can be stored and later released to the lower reservoir when energy is needed. This figure illustrates differences between types of hydropower facilities with different configurations including open-loop PSH—PSH that is continuously connected to a naturally flowing water feature (top left), closed-loop PSH—PSH that is not continuously connected to a naturally flowing water feature (top right), and conventional hydropower—hydropower that uses dams or impoundments in a river to generate electricity (bottom left). Please note that these are generalized illustrations to provide a conceptual understanding of these hydropower technologies. Sizes, footprint, and specific design of these different types of hydropower facilities are highly variable based on factors such as landscape configuration, power and ancillary service needs, and water availability. Design and configuration approaches, such as siting closed-loop PSH in abandoned mines or quarries or creating a PSH facility by adding an upper reservoir onto an existing reservoir, may also reduce construction impacts and the need for new ground disturbing activities.

(Figure ES 1) is one of the lowest greenhouse gas (GHG) emitting energy storage technologies and is therefore a critical part of the transition to renewable energy (Simon et al. 2023). Although PSH represents only 2% of hydropower projects in the United States, it provides 21% of total generation capacity (Figure 1-2) and 96% of all energy storage (Uría-Martínez and Johnson 2023). Proposals for closed-loop PSH facilities (i.e., facilities that have been proposed but are not yet permitted or constructed) in the United States currently account for more than 40% of original licenses and 99% of potential generating capacity in the Federal Energy Regulatory Commission hydropower licensing pipeline (Johnson et al. 2023; Figure ES 2). While closed-loop PSH facilities can have lower environmental

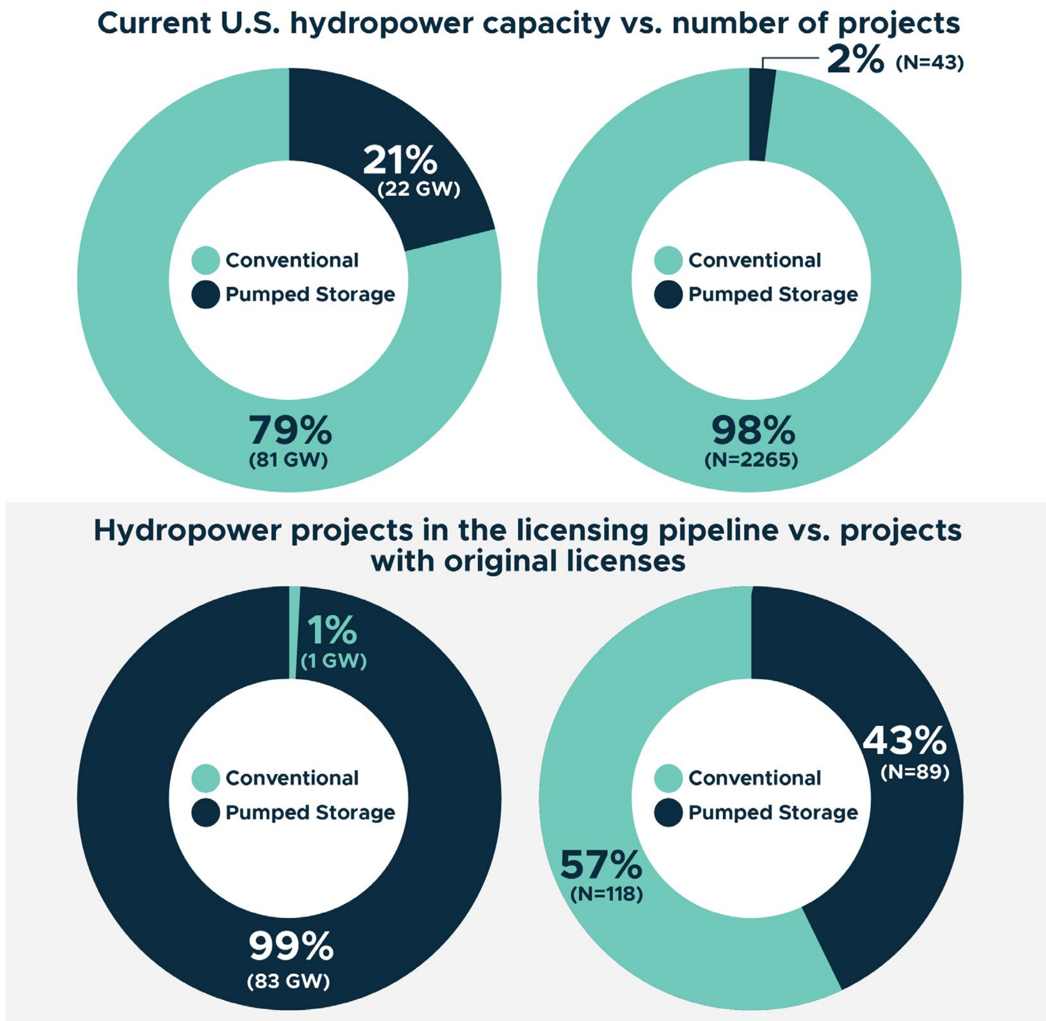

Figure ES 2 PSH makes up 96% of utility-scale energy storage in the U.S. (Uría-Martinez et al. 2023) and, based on the number of facilities, an outsized portion of installed capacity for the current U.S. hydropower fleet (Johnson et al. 2023). While PSH only makes up 2% of the total number of plants in the hydropower fleet, PSH contributes 21% of total installed capacity. On the other hand, the future of the U.S. hydropower fleet may be much more reliant on PSH for supplying storage, electricity, and many of the other grid services hydropower typically provides. Based on projects in the pipeline that have filed an application for a preliminary permit for exploring a FERC hydropower license, a large percentage of projects are PSH facilities (including open- and closed-loop) and PSH facilities make up nearly all new generation proposed (FERC 2024).

impacts than open-loop PSH facilities (Saulsbury 2020), no closed-loop facilities have been constructed in the United States that would allow for empirical assessments of impacts and their mitigations.

Many proposals for FERC licenses for closed-loop PSH facilities are determined infeasible early in the regulatory process (i.e., prior to filing the final license application) and are abandoned prior to issuance of the National Environmental Policy Act (NEPA) document (i.e., Environmental Assessments, Environmental Impact Statements; Uría-Martínez and Johnson 2023) thus there is little documentation of potential project impacts and mitigations for closed-loop PSH facilities. In fact, PSH projects can be so short-lived in the early stages of the licensing process that the number of these facilities can vary widely over the course of the year. Even so, 43% of projects in the permitting and licensing pipeline for original licenses are for closed-loop PSH facilities (FERC 2024). The novelty of closed-loop PSH NEPA documents in the United States may mean that tribal, federal, and state cultural and natural resource agencies with authority over resource protection and management involved in the FERC licensing process may only have experience with licensing of conventional hydropower or open-loop PSH. Moreover, many of the locations of proposed closed-loop PSH are areas that do not have high concentrations of conventional hydropower, so cultural and natural resource agencies may be generally unfamiliar with the FERC hydropower licensing process.

We created this report to build upon an earlier Department of Energy Water Power Technologies Office report (Saulsbury 2020) to focus singularly on environmental impacts of closed-loop PSH. In this report, we review potential environmental impacts and proposed mitigations identified in draft and final NEPA documents from six proposed projects and by the hydropower community involved in the closed-loop PSH licensing process. None of these projects have been constructed. Facilities in our review included three with active licenses that are awaiting construction, one project with a license that was issued but abandoned, and two projects that were abandoned before receiving a license. To our knowledge, the six projects reviewed in this report were the only six projects meeting our inclusion criteria (the project has a draft or final NEPA document and is not currently going through the licensing process) at the time the report was written. Therefore, to supplement our document review, we obtained interviews from people with a cross-section of perspectives that have engaged with or been affected by the closed-loop PSH development process (e.g., natural resource agency, environmental non-governmental organization, developer). We further supplement this information by presenting a review of environmental documents from five international closed-loop PSH projects. The international projects we review are at various stages in the project life cycle, including closed-loop PSH projects that are proposed, under construction, and operational.

Chapter Summary

This report is divided into six chapters and discusses the following:

- **Chapter 1** introduces the study and explains the information gaps and needs to properly evaluate closed-loop PSH potential impacts and mitigations.
- **Chapter 2** provides a summary of impacts and mitigations from NEPA documents of proposed projects. This chapter generally describes potential environmental impacts and potential mitigations based on aggregated information compiled from six FERC draft and final NEPA documents.
- **Chapter 3** provides perspectives on environmental impacts and mitigations for closed-loop PSH. This chapter describes potential impacts and proposed mitigations reported in interviews of experts in closed-loop hydropower.

- **Chapter 4** focuses on international case studies. This chapter describes environmental impacts and proposed mitigations of closed-loop PSH based on information from environmental documents prepared for five case study sites outside of the United States.
- **Chapter 5** discusses needs for future investigation and expert-identified lessons learned from the regulatory process associated with closed-loop PSH.

Key Report Findings

1. **There is not a single, standard definition of closed-loop PSH.**

In this report, we discuss three definitions of closed-loop PSH including those specified by 1) United States Department of Energy and United States FERC for standard licensing proceedings (default definition used in this report), 2) United States FERC for determining whether a closed-loop PSH project qualifies for the 2-year expedited licensing process, and 3) International Hydropower Association (IHA). The definition of open-loop PSH used by the United States Department of Energy, United States FERC, and the IHA is the same as used in this report; that is, a PSH facility that is continuously connected to a naturally flowing water feature. However, the IHA definition of closed-loop PSH differs from what is used in this report, and both differ from the FERC definition of closed-loop used to qualify a project for the 2-year expedited licensing process. Definitions for closed-loop PSH are as follows:

- **United States Department of Energy and FERC:** Hydropower facilities that are not continuously connected to a naturally flowing waterbody.
- **FERC 2-year expedited licensing process:** PSH projects that (1) cause little to no change to existing surface and groundwater flows and uses; (2) are unlikely to adversely affect species listed as a threatened species or endangered species, or designated critical habitat for such species, under the Endangered Species Act of 1973; (3) utilize only reservoirs situated at locations other than natural waterways, lakes, wetlands, and other natural surface water features; and (4) rely only on temporary withdrawals from surface waters or groundwater for the sole purposes of initial fill and periodic recharge needed for project operation.
- **IHA:** An 'off-river' site that produces power from water pumped to an upper reservoir without a significant natural inflow.

Because there are different definitions of closed-loop PSH, it's important to define what characteristics are being used to determine if a PSH project is closed-loop.

2. **Very little is known about environmental impacts of closed-loop PSH and this report summarizes most of the available information.**

   Closed-loop PSH is relatively rare globally and non-existent in the United States and obtaining information on environmental impacts is difficult. The IHA reports 664 PSH facilities of all types globally at some stage of development ranging from pre-construction to operational. This number includes 240 classified as closed-loop PSH, 392 open-loop PSH, and 32 storage PSH. A minority of the closed-loop PSH plants are operational (N = 38) while most plants are in the pre-construction or construction stage (N = 202; Table ES 1).

PSH stage/type	Pre-construction	Construction	Operational	Total
Open-loop	50	4	338	392
Closed-loop	160	42	38	240
Storage		2	30	32

All stages/types	664

Table ES 1 Number of closed-loop PSH facilities globally from the IHA Pumped Storage Tracking Tool dataset (IHA 2024). "All stages" includes open-loop, closed-loop, and storage PSH facilities at pre-construction, construction, and operational phases.

3. **Environmental impacts of all PSH are highly site-specific.**

   There can be wide variability in impacts among projects even among projects with similar landscape characteristics, land uses, or societal and community needs and governance structures. For example, projects being built in abandoned mines, other brownfield sites, greenfield sites, or on or near tribal lands or resources can have very different impacts. Assessing impacts must be done on a site-by-site basis.

   Based on the site-specificity of impacts, a large-scale Programmatic Environmental Impact Statement-type document that generally addresses these impacts is not likely to be useful in regulatory reviews.

4. **Closed-loop PSH water sourcing, aquatic resources, and reservoir GHG emissions impacts differ from open-loop PSH.**

   Impacts unique to closed-loop PSH include impacts to ground or surface water quantity for initial and refill reservoir fill and safety or contamination issues related to using abandoned mine sites as reservoirs, where groundwater contamination from an unlined reservoir is of primary concern. Unlike open-loop PSH, closed-loop PSH does not typically have aquatic resource impacts like fish impingement and entrainment because they are not continuously connected to a naturally flowing body of water. Increased siting flexibility for closed-loop compared to open-loop facilities provides some opportunity to avoid some impacts through site selection.

   Potential for reservoir GHG emissions may also be relatively lower in closed-loop PSH compared to open-loop PSH, particularly if closed-loop PSH reservoirs have liners that create a barrier between the water and sediment where GHG is produced (Wang et al. 2024). However, empirical data measuring reservoir GHG emissions from open- and closed-loop PSH are needed to fully test these hypotheses (IHASWG 2021; Wang et al. 2024).

5. **Closed-loop PSH mitigations are like those in terrestrial ecosystems but differ from mitigations for existing, conventional hydropower.**

   There do not appear to be mitigations unique to closed-loop PSH except for mitigations for impacts to ground or surface water quantity caused by initial and refill reservoir fill. In fact, mitigations and impacts for closed-loop PSH are similar to impacts caused by development in terrestrial ecosystems, such as roads and other forms of energy infrastructure, than impacts caused by conventional hydropower in aquatic ecosystems. Mitigations proposed for closed-loop PSH may also resemble those for new stream reach development of conventional hydropower because of similarities in impacts of construction and land disturbance, but comparison of NEPA documents between these types of hydropower projects was beyond the scope of this report.

6. **Impacts to wildlife were the most reported impacts in documents reviewed for this report.**

   - Impacts to wildlife varied among projects, but most projects listed reservoirs creating an attractive
   - nuisance to wildlife including ungulates, bats, and migratory birds, drowning hazards for wildlife that

- fall into a reservoir, disturbance and safety hazards caused by construction activities, and habitat
- fragmentation and vehicle collision hazards caused by new roads. For this report, impacts related to
- transmission lines such as fragmentation and bird collision or electrocution were catalogued
- separately although those impacts were frequently expected across projects reviewed for this report.

7. **Cultural resource impacts of closed-loop PSH are common and in many cases, cannot be mitigated.**

   Potential cultural resource impacts were diverse and included impacts to important sites, plants and other biological resources, as well as the viewshed from traditional cultural properties. Commonly, these impacts are difficult or impossible to mitigate because the significance of the cultural site or resource is inextricable from the site. Destruction or damage to special sites or items during project development may not be avoidable and may therefore lead to licensing delays or project abandonment. For example, at least one of the abandoned licensed projects reviewed for this report had substantial cultural resource impacts.

8. **There are more operational closed-loop PSH facilities in other countries with similar impacts and mitigations to the United States.**

   Review of environmental documents developed for projects in other countries suggests that potential impacts and mitigations reported are like those reported in the United States, although environmental documents in the United States typically review a more diverse set of impacts. For example, there is limited reference to the following impacts among international sites: seismic risk, biofouling, reservoir seepage or leakage, fish entrainment, fire risk, and wildlife predation, wildlife drowning, and collision with transmission lines (for bats and birds). That said, international sites also identified some impacts not emphasized in the United States projects, including the use of a PSH reservoir as a water source for firefighting, cultural resource impacts to industrial heritage sites of local importance (e.g., agriculture, mining, hydropower), sociocultural conflicts that could arise from an influx of non-local populations during project construction, and increased disease spread from temporary housing of construction workers at the project site.

9. **Globally, China operates and is constructing the most closed-loop PSH and the United States is proposing the most closed-loop PSH but there are relatively few of these facilities.**

   According to data from the IHA Pumped Storage Tracking Tool (2024), nine countries in Europe and four countries in Asia have operational closed-loop PSH although the age of plants in Europe (mean ± SD: 50 ± 20-years; range: 3 – 94-years; N = 23 plants) is older than those in Asia (mean ± SD: 13 ± 9-years; range: 2 – 32-years; N = 15 plants).

   China has begun construction on 30 closed-loop PSH facilities while other countries have begun construction on one or two plants. The United States has the most pre-construction closed-loop PSH projects of any country (N = 59) although there are no closed-loop PSH plants operational or under construction (IHA 2024).

Continent	Pre-construction	Construction	Operational
Africa	3	2	
Asia	61	34*	15
Australia	9	1	

Europe	24	5	23
North America	62		
South America	1		

Table ES 2 Number of pre-construction, under construction, and operational closed-loop PSH plants by continent from IHA Pumped Storage Tracking Tool data (2024).

10. Interviews identified impacts and provided insights not discussed in NEPA documents.

    Interviews with members of the domestic hydropower community provided additional insight and context into the potential impacts and mitigations associated with closed-loop PSH development. Interviewees noted the extent and significance of cultural resource impacts and challenges in identifying these sites, impacts to these cultural sites, and complexities or impossibilities associated with mitigating these impacts. We also gained insights on opportunities and challenges associated with developing brownfield sites, such as abandoned coal mines for closed-loop PSH, comparison of environmental impacts of closed-loop PSH with those of other renewable energy generation and storage projects, and concerns about reservoir GHG emissions associated with developing projects with two reservoirs with frequently fluctuating water levels. There was little difference among sectors of the hydropower community regarding resource impacts, including reservoir emissions.

Report Knowledge Gaps

Based on information synthesized for this report, including reviews of domestic and international environmental review documents, expert interviews, and reports and peer-review literature, we have identified the following knowledge gaps and areas where future work is needed to support closed-loop PSH development:

- **Closed-loop PSH site selection methods**: Closed-loop PSH can avoid some impacts through selecting sites with lower impacts or greater benefits. However, in making these assessments, it is critical to identify and consider what communities are accruing project impacts and benefits. Future work applying existing or creating new methods and approaches for site selection is needed.
- **Measurements of closed-loop PSH reservoir emissions**: The IHA Sustainability Working Group reports that reservoir emissions from PSH should be no higher than from other types of hydropower (IHASWG 2021) and Wang et al. (2024) suggest that closed-loop PSH has lower reservoir emissions than conventional or open-loop PSH. However, both publications state that there is not currently empirical data on this topic and future work collecting field data to validate these hypotheses is needed.

Acronyms and Abbreviations

DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EIS	Environmental Impact Statement
eNGO	Environmental non-governmental organization
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse gas
GW	Gigawatts
IHA	International Hydropower Association
MRO	Midwest Reliability Organization
MW	Megawatts
N	Number of observations
NEPA	National Environmental Policy Act
NERC	North American Electric Reliability Organization
NPCC	Northeast Power Coordinating Council
PSH	Pumped storage hydropower
RFC	ReliabilityFirst Corporation
SD	Standard deviation
SERC	SERC Reliability Corporation
SPP	Southwest Power Pool
TRE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

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Tables

1.0 Introduction

The goal of this report is to help license applicants, resource agencies, and other members of the hydropower community involved in the closed-loop pumped storage hydropower permitting and licensing process focus the scope of environmental reviews and more quickly identify impacts with project nexus as well as potential mitigation measures for these impacts.

Pumped storage hydropower (PSH) accounts for 96% of all utility-scale storage in the United States but is expected to become more important as additional wind and solar is integrated onto the grid (Uría-Martinez and Johnson 2023). PSH is a type of energy storage that uses energy to pump water from a lower reservoir to an upper reservoir where it is stored: essentially a water powered battery. When electricity is needed, water is released to the lower reservoir, passing through turbines to generate electricity along the way. PSH can be either open-loop, which includes continuous connection to a naturally flowing waterbody such as a river, reservoir, or lake or closed-loop, which does not have a continuous connection to a naturally flowing waterbody (Figure 1-1).

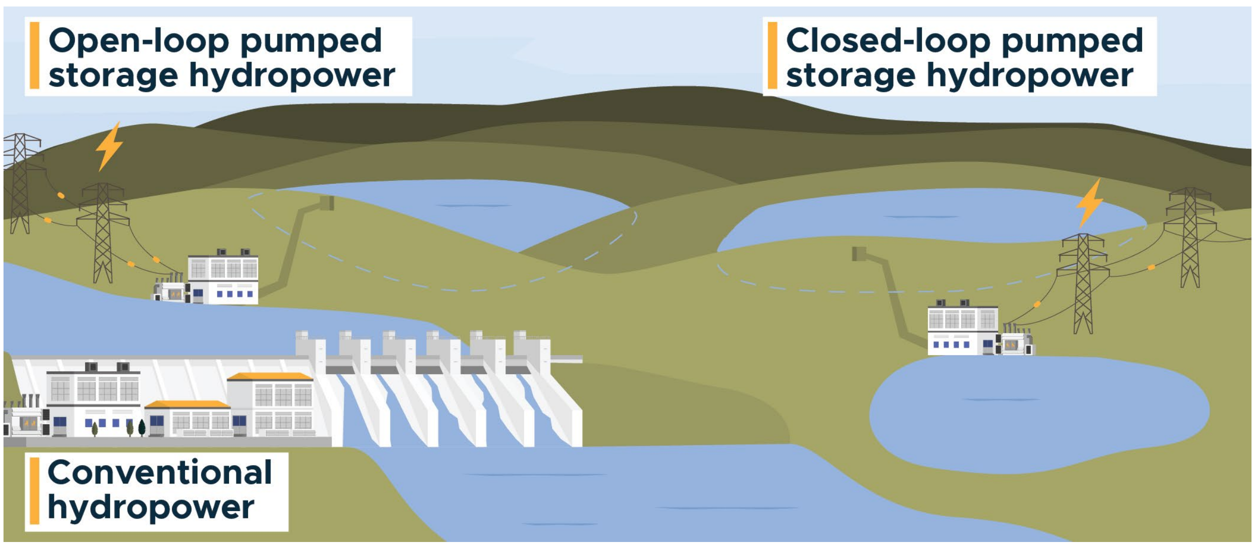

Figure 1-1 PSH is a long-duration energy storage technology that uses energy to pump water from a lower reservoir to an upper reservoir where it can be stored and later released to the lower reservoir when energy is needed. This figure illustrates differences between types of hydropower facilities with different configurations including open-loop PSH—PSH that is continuously connected to a naturally flowing water feature (top left), closed-loop PSH—PSH that is not continuously connected to a naturally flowing water feature (top right), and conventional hydropower—hydropower that uses dams or impoundments in a river to generate electricity (bottom left). Please note that these are generalized illustrations to provide a conceptual understanding of these hydropower technologies. Sizes, footprint, and specific design of these different types of hydropower facilities are highly variable based on factors such as landscape configuration, power and ancillary service needs, and water availability. Design and configuration approaches, such as siting closed-loop PSH in abandoned mines or quarries or creating a PSH facility by adding an upper reservoir onto an existing reservoir, may also reduce construction impacts and the need for new ground disturbing activities.

Although PSH represents only 2% of hydropower projects in the United States, it provides 21% of total generation capacity (Figure 1-2) and 96% of energy storage capacity (Uría-Martínez and Johnson 2023). Currently, all 43 operational PSH facilities in the United States are open-loop and were primarily built in the 1960s and 70s to store energy produced by nuclear power plants. However, the number of closed-loop PSH may change rapidly in the coming years. According to data from 11 June 2024, 77% (77 of the 100)

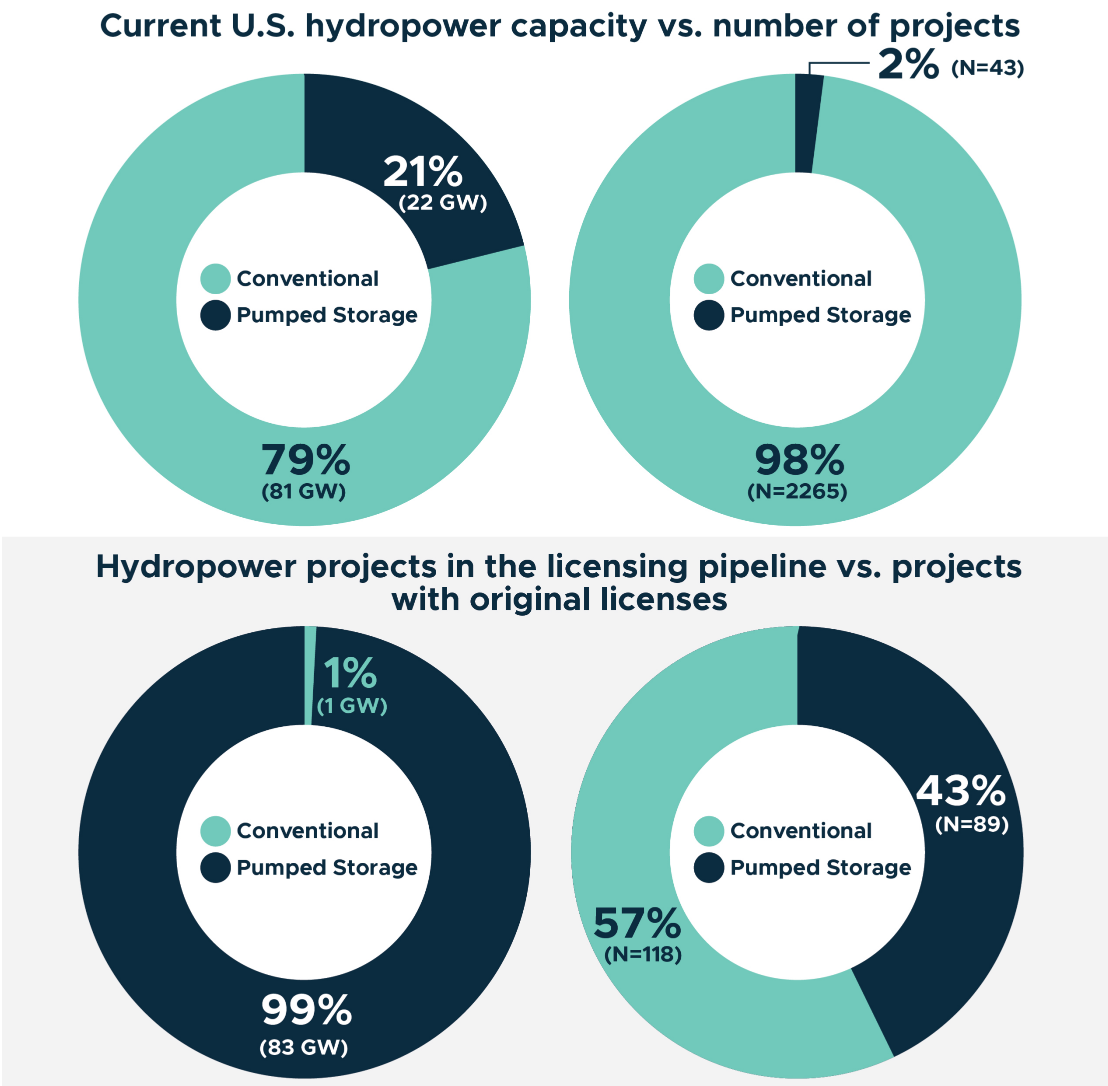

Figure 1-2 Data from 2022 shows that PSH makes up an outsized portion of installed capacity for the current US hydropower fleet (Johnson et al. 2023). PSH contributes 21% of total installed capacity (top left) despite representing only 2% of the hydropower projects currently online in the US (top right). The future US hydropower fleet may rely more on PSH for supplying storage, electricity, and many of the other grid services hydropower can provide. Based on projects in the pipeline for an original FERC hydropower license, that is, the first FERC license a hydropower facility ever receives, nearly all generation (bottom left) and 43% of original licenses are PSH facilities (including open- and closed-loop; FERC 2023).

of active PSH preliminary permits from the Federal Energy Regulatory Commission (FERC) are issued to proposed closed-loop PSH. Many proposals for FERC licenses for closed-loop PSH facilities are determined infeasible early in the regulatory process (i.e., prior to filing the final license application) and are abandoned prior to issuance of the National Environmental Policy Act (NEPA) document (i.e., Environmental Assessments, Environmental Impact Statements; Uría-Martínez and Johnson 2023) thus there is little documentation of potential project impacts and mitigations for closed-loop PSH facilities. In fact, PSH projects can be so short-lived in the early stages of the licensing process that the number of these facilities can vary widely over the course of the year. Even so, 43% of projects in the permitting and licensing pipeline for original licenses are for closed-loop PSH facilities.

While there are currently no closed-loop PSH facilities in the United States, closed-loop PSH has been reported to have some advantages over open-loop PSH and other energy storage technologies. Compared

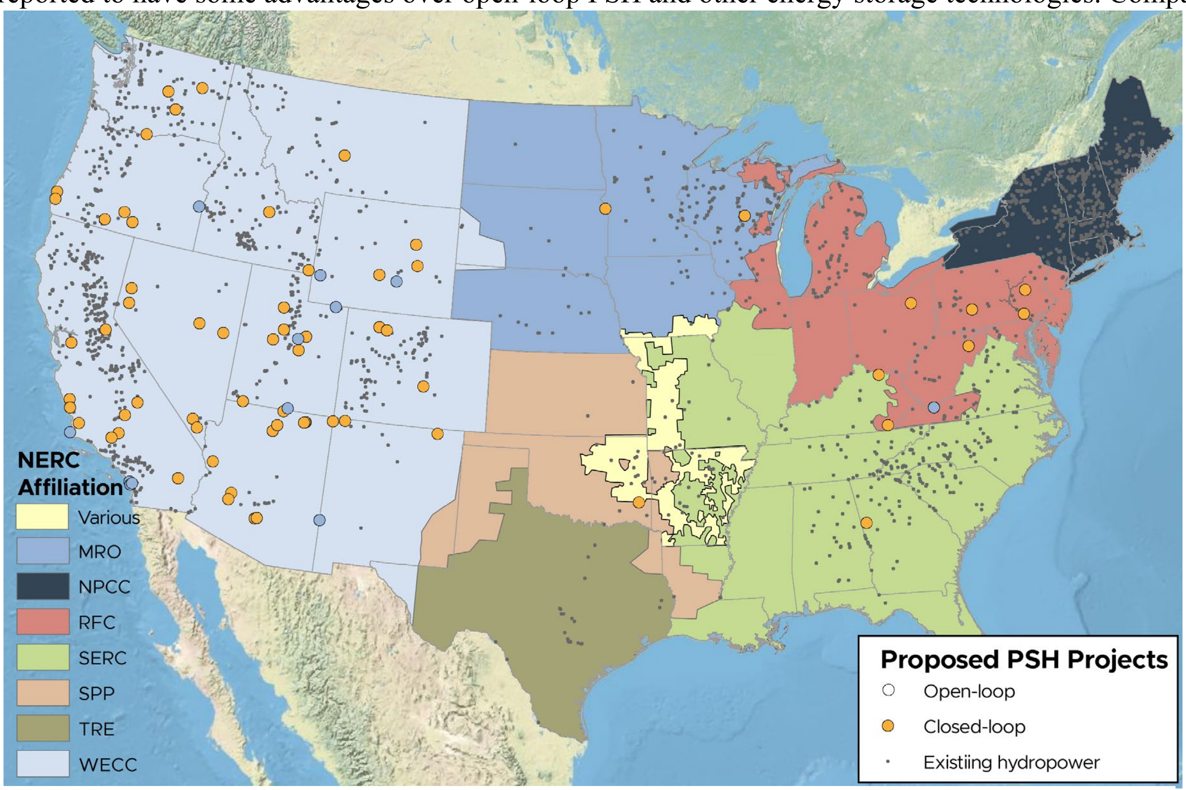

Figure 1-3 PSH can help regional authorities responsible for ensuring electric reliability, such as North American Electric Reliability Corporation (NERC) Reliability Entities increase electrical grid stability through provisioning grid ancillary services and providing long-duration energy storage. This map shows proposed closed- (gold circles) and open-loop (light blue circles) PSH plants in each NERC Regional Entity area—areas where a Regional Entity has responsibilities and authorities to enforce NERC and regional electrical reliability standards. State boundaries and locations of existing hydropower facilities are shown for reference (gray dots; Johnson et al. 2023). NERC Regional Entity areas abbreviations are as follows: Various—area with a mix of NERC memberships, MRO—Midwest Reliability Organization, NPCC—Northeast Power Coordinating Council, RFC—ReliabilityFirst Corporation, SERC—SERC Reliability Corporation, SPP—Southwest Power Pool, TRE—Texas Reliability Entity, WECC—Western Electricity Coordinating Council (ORNL; Last modified: 9 December 2022; Accessed on: 19 November 2024).

to open-loop PSH, closed-loop PSH generally has lower number and severity of aquatic resource impacts (Saulsbury 2020). For example, closed-loop PSH is not likely to have fish entrainment issues whereas open-loop facilities may have to address fish entrainment potentially through studies and/or mitigation. Compared to other energy storage technologies, closed-loop PSH has been reported to have the lowest life cycle greenhouse gas (GHG) emissions when compared to several chemical batteries and compressed air energy storage technologies (Simon et al. 2023). Although the Simon et al. (2023) study does not consider reservoir emissions, closed-loop PSH is thought to have lower reservoir GHG emissions than conventional hydropower (IHASWG 2021) or other hydropower types like conventional hydropower or open-loop PSH that receives sediment inputs from a river or other naturally flowing water feature (Wang et al. 2024). Because no closed-loop PSH facilities have been built in the United States, any empirical data to support these hypotheses would have to come from outside countries.

The United States hydropower fleet has approximately 22 gigawatts of PSH which provides 96% of utility-scale storage in the United States (Uría-Martinez and Johnson 2023; Figure 1.2). However, large increases in storage are still needed to support the rapid deployment of renewable generating resources (IEA 2023). The number of new PSH projects, especially closed-loop PSH projects, currently in the FERC pipeline for original hydropower licenses (i.e., first license issued to a project) suggest that PSH projects will increase in total installed capacity of the overall hydropower fleet (Figure 1-3). While many of these projects will not obtain a license, of the hydropower projects currently in the FERC licensing pipeline, proposed PSH projects account for 43% of the projects and 99% of the total generation capacity (Johnson and Uría-Martínez 2023).

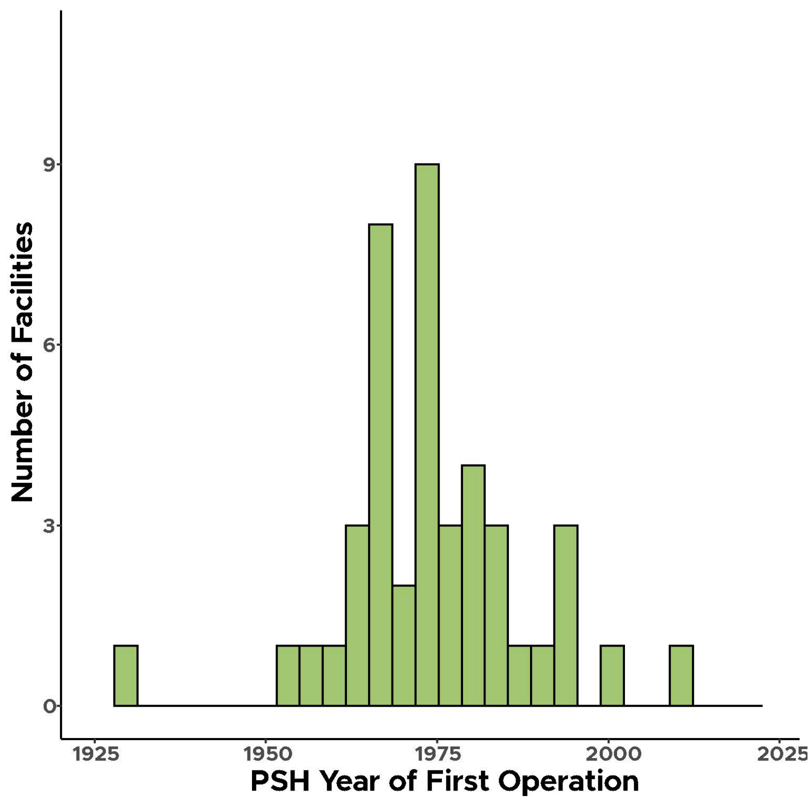

Figure 1-4 Many PSH facilities were commissioned in the 1960s through 1980s with only two facilities beginning operation since 2000. Environmental policies and focus of natural resource impacts raised during PSH licensing studies have evolved since the bulk of PSH was constructed in the 1970s and 1980s (Johnson et al. 2023).

As directed by the America's Water Infrastructure Act of 2018, FERC implemented a 2-year expedited license review process in 2019 for qualifying closed-loop PSH projects based on the assumption that these projects would have lower environmental impacts. In addition, three recent FERC staff decisions regarding closed-loop PSH projects using groundwater confirm that such projects might be outside of FERC's licensing purview if they do not meet any of the other jurisdictional criteria listed in Federal Power Act §23(b). With these FERC actions, it is important that project developers, regulators, resource agencies, and other parties involved in and affected by hydropower development and the FERC permitting and licensing process understand the potential environmental impacts of these projects, as well as measures to avoid, minimize, and mitigate those impacts.

Few PSH facilities have been built in the past 40-years so reports on impacts and mitigations for new PSH development, especially closed-loop PSH, are sparse (Figure 1-4). The FERC hydropower licensing process requires assessing and mitigating environmental impacts under the National Environmental Policy Act (NEPA). Few NEPA documents have been created for new development of PSH facilities, especially closed-loop PSH storage facilities, that can be used by developers, agencies, and others involved in the FERC licensing process for guiding study and mitigation discussions and conducting NEPA assessments. In general, the impacts of closed-loop PSH are thought to be relatively lower than those of open-loop PSH, although there may be some projects where this may not be the case, such as when both the upper and lower reservoir for the closed-loop facility must be constructed or when water abstraction for initial fill or refill water can impact water supplies for societal, agricultural, habitat, or other purposes (Saulsbury 2020). In fact, the amount of water required to fill closed-loop PSH reservoirs may be enough to qualify the owner as a major water user, which can complicate obtaining necessary water rights.

In developing this report, we used a combination of review and data mining of FERC regulatory information from United States hydropower facilities, expert interviews, and review of draft and final environmental review documents for closed-loop PSH projects in other countries to identify impacts, mitigations, and lessons learned that may be useful to apply to United States closed-loop PSH siting, permitting, and development.

The remaining chapters in this report are as follows:

- Chapter 2: Summary of impacts and mitigations from NEPA documents of proposed projects. This chapter generally describes potential environmental impacts and potential mitigations based on aggregated information compiled from six FERC draft and final NEPA documents.
- Chapter 3: Perspectives on environmental impacts and mitigations for closed-loop PSH. This chapter describes potential impacts and proposed mitigations reported in interviews of experts in closed-loop PSH.
- Chapter 4: International closed-loop PSH case studies. This chapter describes environmental impacts and proposed mitigations of closed-loop PSH based on information from environmental documents prepared for five case study sites outside of the United States.
- Chapter 5: Summary. This chapter discusses needs for future investigation and expert-identified lessons learned from the regulatory process associated with closed-loop PSH

2.0 Summary of Impacts and Mitigations from NEPA Documents of Proposed Closed-Loop PSH Projects

This chapter summarizes potential impacts and proposed mitigations from draft and final NEPA documents from proposed closed-loop PSH projects in the United States. In this chapter, we summarize potential impacts and proposed mitigations reported in Environmental Assessments (EA) and draft and final NEPA documents from six closed-loop PSH projects that are not going through the licensing process. These include three active, pre-construction licensed projects: Eagle Mountain (FERC 2012), Swan Lake North (FERC 2019b), and Gordon Butte (FERC 2016), and three inactive projects that had a draft or final NEPA document produced: Summit (FERC 1991), Lorella (FERC 1994), and Mineville (FERC 2019a; Table 2.1; Figure 2.1). At the time this report was being written, the NEPA document for the Goldendale (P-14861) project was available but was not included because it was still involved in the licensing process. Likewise, we did not include information from the 1996 NEPA document for the Blue Diamond project under FERC docket number P-10756 because this project had been taken up by a new developer and was involved in the FERC licensing process under FERC docket number P-14804 while writing this report. Data collection for the report was complete before the licensing proceeding was terminated by FERC on April 18, 2024.

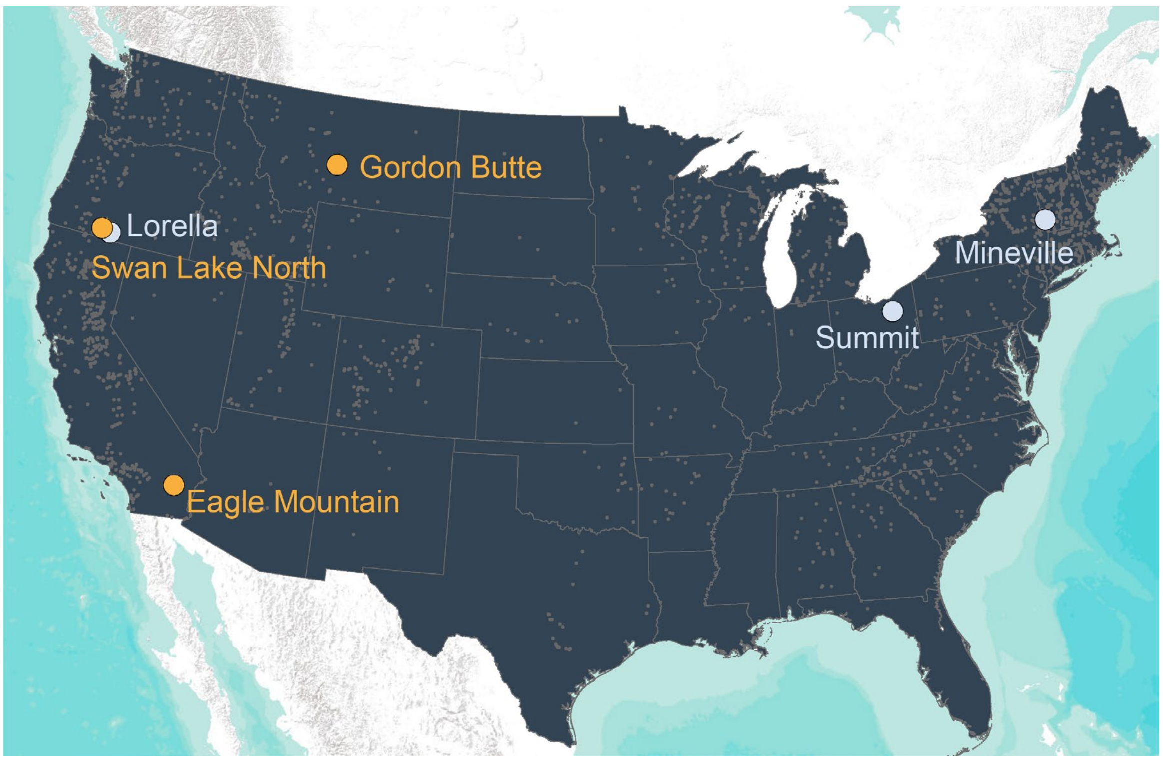

Figure 2-1 Potential impact and proposed mitigations discussed in this chapter were summarized from draft and final NEPA documents created for the six closed-loop PSH projects shown above, none of which were actively going through the licensing process at the time the report was written. Projects in gold have active FERC licenses whereas projects in light blue have been abandoned. Dark grey dots show locations of all existing hydropower, including conventional hydropower, based on data from Johnson et al. (2023).

Table 2-1 Characteristics of the six closed-loop PSH sites summarized in this chapter. In the cases of the Lorella Dam and Mineville Energy Storage projects, Termination Date refers to the date the license application was withdrawn. The type of NEPA document summarized in this report is in the NEPA date column below the date and included Final Environmental Impact Statement (FEIS), Draft Environmental Impact Statement (DEIS), and Environmental Assessment (EA) documents.

FERC #	Project Name	State	Project Active?	Project MW	NEPA date	License Issue Date	Termination Date
P-9423	Summit Pumped Storage Hydroelectric Project	OH	No	1500	1/1991 FEIS	4/12/1991	4/12/2001
P-11181	Lorella Dam	OR	No	1000	4/1994 DEIS	NA	10/12/1998
P-11858	Mineville Energy Storage Project	NY	No	240	6/2019 DEIS	NA	12/11/2020
P-12635	Eagle Mountain Pumped Storage Project	CA	Yes	1300	1/2012 FEIS	7/21/2014	Active license
P-13318	Swan Lake North Pumped Storage Project	OR	Yes	393	1/2019 FEIS	4/30/2019	Active license
P-13642	Gordon Butte	MT	Yes	400	9/2016 EA	12/14/2016	Active license

2.2 Methods for Creating Case Study Datasets

The summary of impacts and mitigations described in this chapter were extracted from NEPA documents for the case study PSH projects listed in Table 2-1 and put in a dataset (Appendix C) that could be statistically summarized. The discussion of impacts and mitigations in NEPA documents for FERC hydropower licenses are typically organized by resource category and includes:1. Geologic and soil resources, 2. Water resources, 3. Fisheries and aquatic ecology resources, 4. Terrestrial resources, 5. Threatened and endangered species, 6. Recreation and land use, 7. Aesthetic resources, 8. Cultural resources, 9. Socioeconomics, 10. Environmental justice, 11. Air quality and noise. However, exact nomenclature of these categories may change slightly between NEPA documents for different projects.

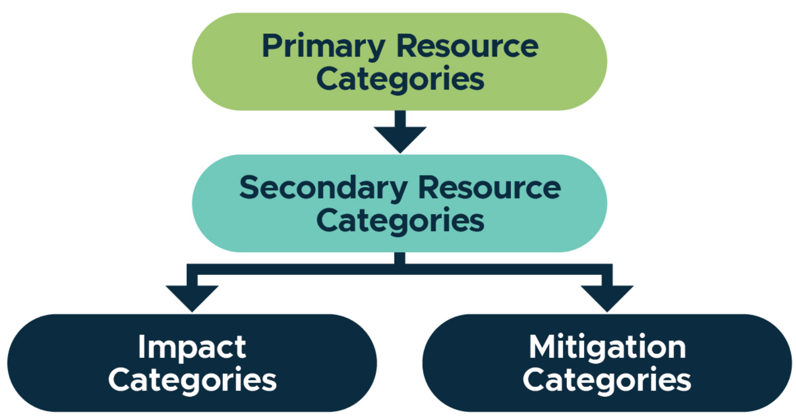

Figure 2-2 Data structure for data from NEPA documents as summarized in this report.

To summarize impacts and mitigations for this chapter, we identified individual impacts and mitigations from the NEPA documents of the projects described above and created a hierarchical data set of impacts and mitigations (Supplemental Data; Figure 2.2; Figure 2.3). We then copied and pasted each impact and mitigation into separate columns in our dataset. Secondary impact and mitigation categories were created based on the impacts and mitigations extracted from the NEPA documents rather than defining categories *a priori*. This method resulted in 18 Secondary Resource Categories, 28 Impact Categories, and 23 Mitigation Categories (Figure 2-3). While some detail is lost with this method, it allowed for aggregation of impacts and their mitigations to gain a greater understanding of common impacts and mitigations across projects.

Project phases were assigned based on when the impacts and mitigations occurred. For example, if the impact was entirely created and mitigated during construction, phase was recorded as “Construction”. An example of a construction impact would be increased traffic from construction vehicles where the impact is also mitigated during construction through construction traffic control methods. Likewise, impacts that are realized and mitigated during the operations and maintenance phase, such as bird electrocution from powerline collisions, was recorded as “Operations and Maintenance”. Impacts beginning during the construction phase that would be ongoing throughout the life of the project, were recorded as “All”. For example, if the impact is that filling and refilling project reservoirs may impact surface water quantity, the impact and mitigation begin to take place during the construction phase and will continue during the operations and maintenance phase, it was marked “All” in the project phases category.

We reported the frequency of impact and mitigation categories across all six projects for each primary resource category as the count of each impact and mitigation category. For example, the Geologic and Soil Resources “subsidence, seismic, or other geological risk” impact frequency was determined as the count of all instances of this impact category in the Geologic and Soil Resources primary resource category across all six projects.

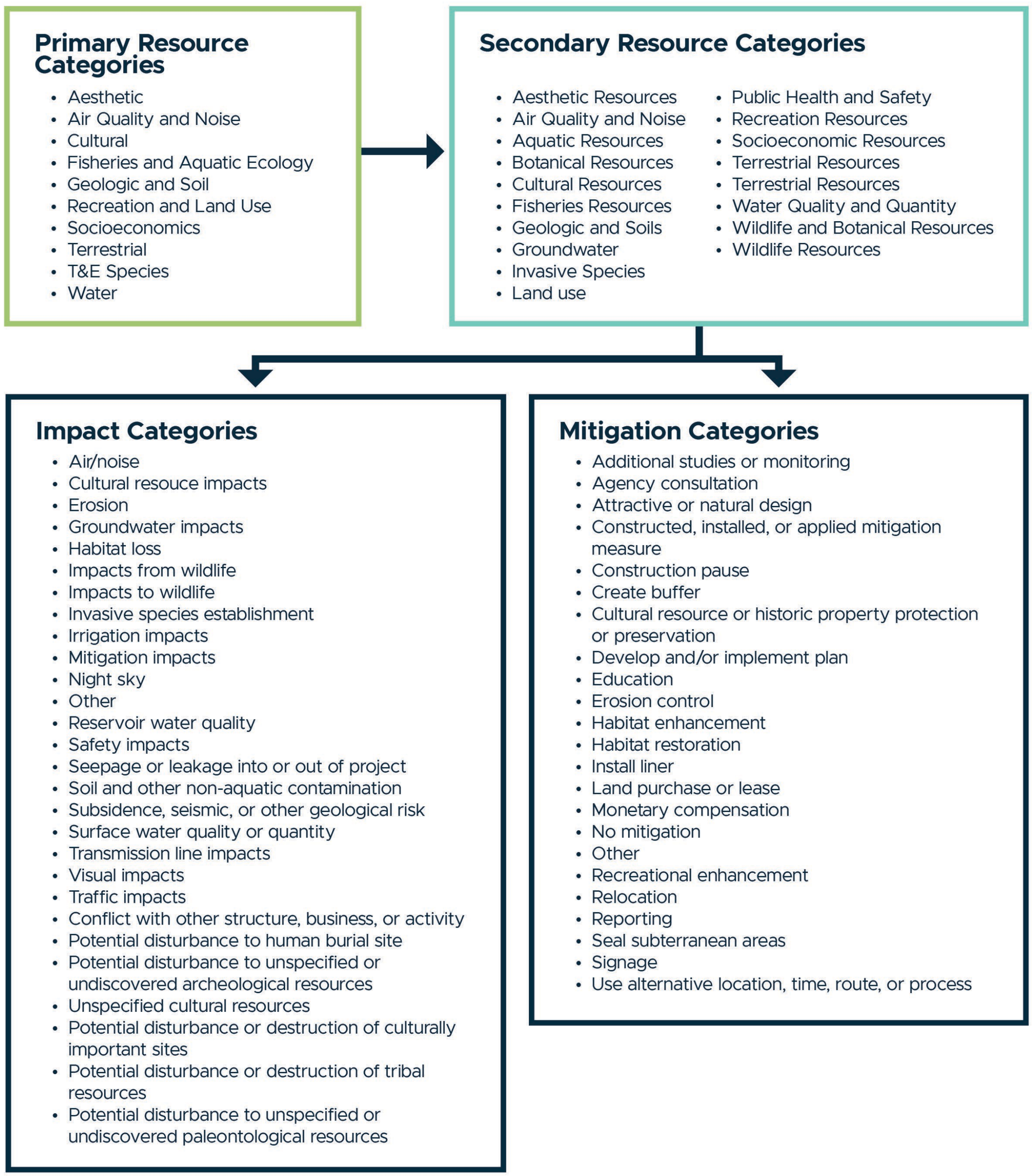

Figure 2-3 Categories of data from NEPA documents as summarized in this report.

2.3 Geologic and Soil Resources

2.3.1 Impacts

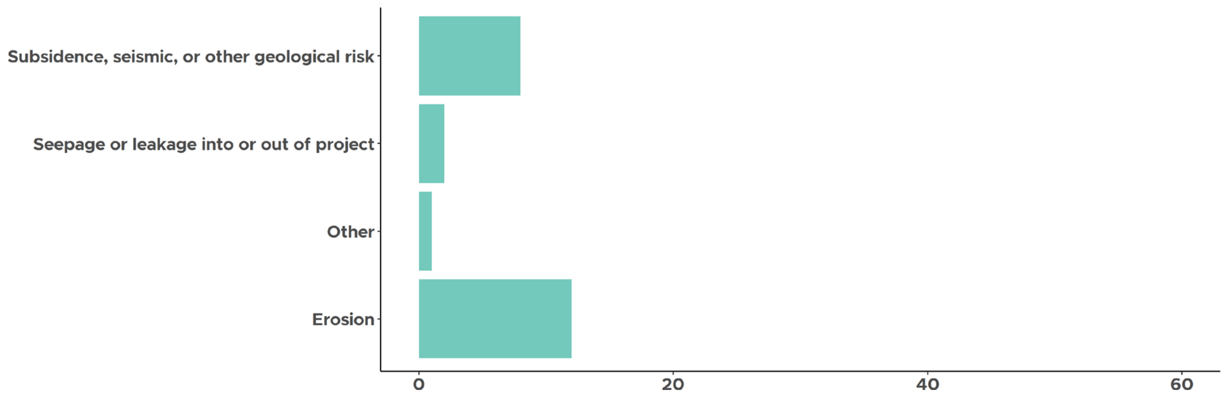

Figure 2-4 Frequency of potential geology and soil resource impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential geology and soils impacts are summarized in Figure 2-4. All six projects listed impacts to geology and soils that could occur during all project phases. The impacts reported could be broken down into four general types: erosion, seepage or leakage into or out of the project, subsidence, and increased seismic risks. Most erosion impacts described were associated with the construction phase and attributed to wind and water from runoff, although there were also erosion impacts identified along culverts and other water control structures that would continue for the life of the project. Erosion was also associated with the frequent and rapid drawdowns of water in the reservoirs during the operations phase. The frequency of occurrence and speed of drawdowns in PSH reservoirs were associated with increased seismic risks including gradual land movement and small earthquakes. Seepage or leakage into or out of the project was identified as a potential impact for nearly all projects surveyed and was a contributing factor to increased risk of land subsidence. Geology and soils impacts are likely to be highly site-specific and assessments will need to include factors such as geologic characteristics and project design.

2.3.2 Mitigations

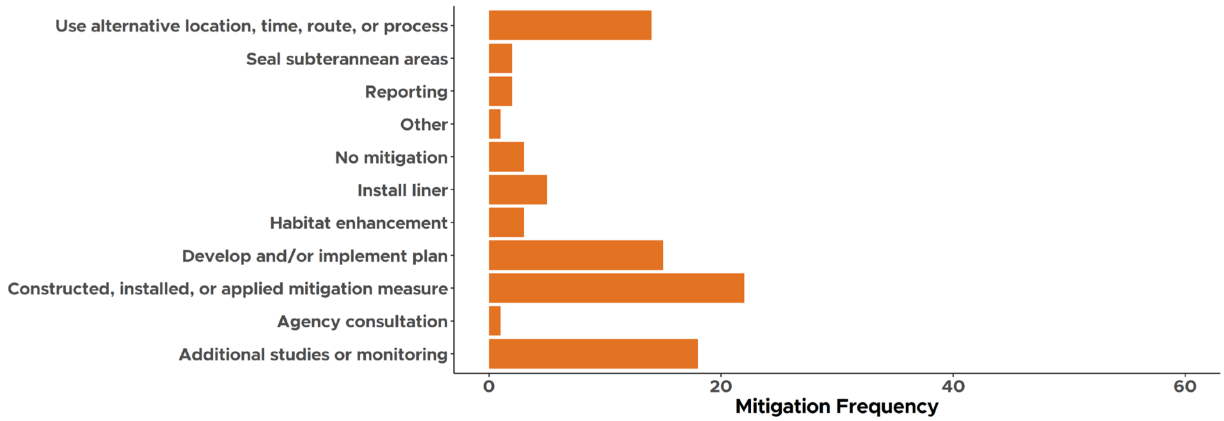

Figure 2-5 Frequency of proposed water resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for geology and soil impacts are summarized in Figure 2-5. Erosion control measures to mitigate potential impacts to geologic and soil resources included planting fast-growing vegetation and adding rip rap or chemical tacks to stabilize soils. Creation of an erosion plan and related erosion prevention measures were also proposed, including timing construction activities during times of year that would minimize erosion, vegetative cover preservation outside of reservoir areas, avoiding sharp slope breaks, and stormwater management practices that prevent erosion. Seepage and leakage into or out of the project was primarily mitigated through installation of impermeable liners in the reservoirs and sealing mines and other subterranean openings. Additional seismic and geotechnical studies were also proposed to gain a better understanding of geological impacts and risks.

2.4 Water Resources

2.4.1 Impacts

Detailed examples of potential water resource impacts and proposed mitigations are provided in Table 2-2. Proposed water resource impacts are summarized in Figure 2-6. Surface water quality or quantity and impacts to groundwater quality and quantity were the most common impacts reported across the projects reviewed. Surface water quantity impacts included minimum flows for nearby waterways when that waterway was used for initial fill or refill water or when groundwater was pumped for initial fill or refill water. Concerns about surface water quantity were often identified pertaining to precipitation runoff being collected by project reservoirs rather than in natural watersheds of streams and rivers. Conversely, concerns about too much runoff water into project reservoirs was also frequently identified as a potential impact to dam safety where dams could be overtopped or otherwise structurally undermined or when these reservoirs needed to conduct emergency releases of water that would potentially impact water quality of nearby surface waters. Other surface water quality impacts included increased concentrations of dissolved solids in project reservoirs due to evaporation and biofouling.

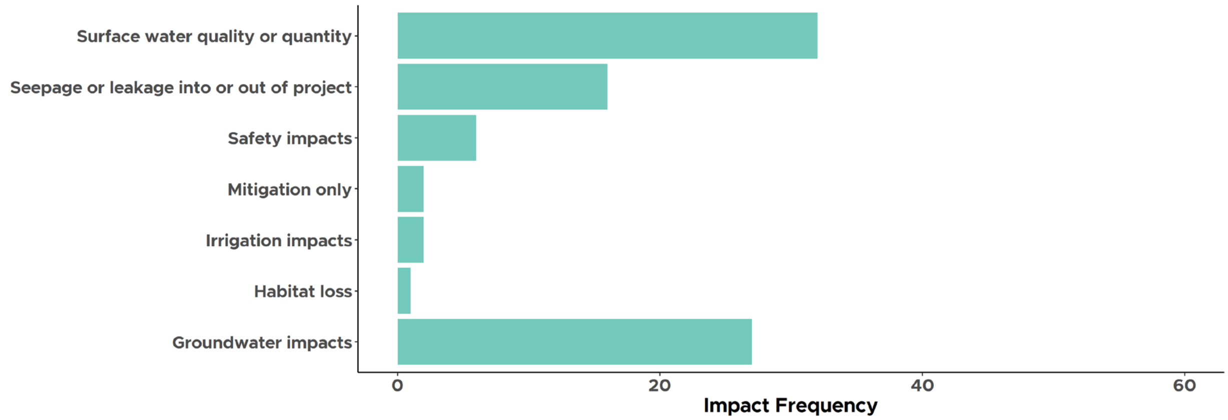

Figure 2-6 Frequency of potential water resource impacts from six closed-loop PSH case study sites presented in Appendix C.

Groundwater quality was also identified as a potential impact due to project seepage or leakage either into or out of the project. Abandoned mines are frequently proposed as project sites, and they may contain residues from previous mining activities including oils, greases, heavy metals, and toxic wastes. There is also the possibility for seepage of reservoir or evaporation pond water that contains increased concentrations of minerals or other solutes that become concentrated as water evaporates. Industrial lubricants and other contaminants required for project operation or electricity generation also have the potential to seep into the groundwater and reduce groundwater quality.

While irrigation impacts may pertain to irrigation water quantity or quality that could potentially be impacted by project construction or operation, irrigation impacts were only mentioned in the draft NEPA document for the Lorella project. These impacts were related to the need to keep water in or out of the irrigation canals at certain times of year. One potential irrigation impact was due to the potential for an endangered fish to become entrained into the irrigation canals and the canals needed to be dewatered to prevent entrainment. There were also potential irrigation impacts because project construction activities required dewatering of the irrigation canals.

Habitat loss impacts included channel modification required for reservoir flood control as well as loss of wetland habitat due to project construction.

2.4.2 Mitigations

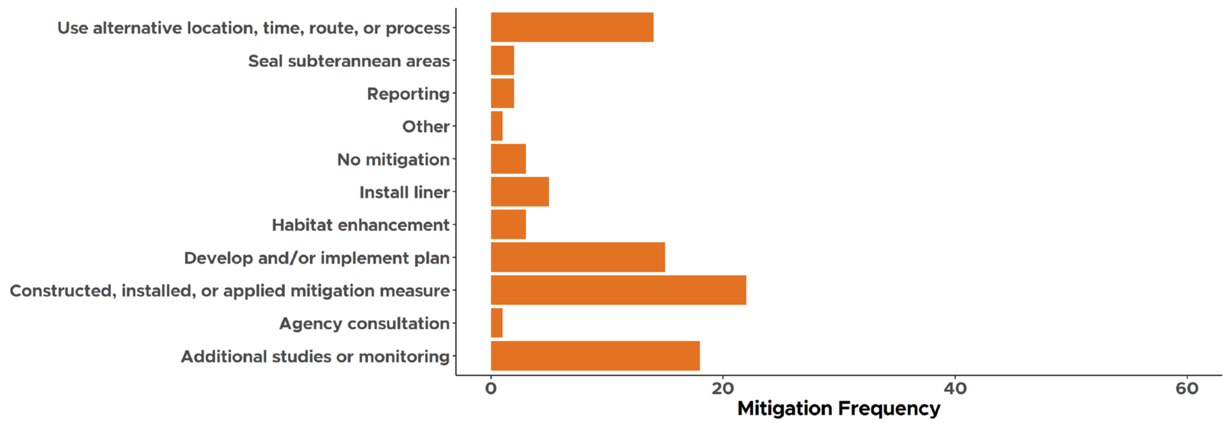

Figure 2-7 . Frequency of proposed water resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for water resource impacts are summarized in Figure 2-7. Surface water quality and quantity issues were often mitigated through constructing or installing a feature, facility, or piece of equipment. Surface water quantity issues may be mitigated through construction of a diversion channel or flood control structures that could provide additional control of stormwater runoff. Minimum flow requirements for or maximum pumping limits from nearby waterways were also applied as a surface water quantity mitigation measure for when groundwater pumping was occurring or being directly abstracted from a waterbody for reservoir fill or refill. There were also timing restrictions for withdrawing water from rivers and streams so water could only be taken in spring months when there are naturally high flows. Surface water quality issues typically referred to reservoir water quality and involved construction of evaporation ponds or water treatment facilities such as reverse osmosis facilities for improving reservoir water quality. Use of these water treatment facilities also helped to mitigate for potential impacts to waterbodies outside the project boundaries that could become contaminated through accidental or intentional emergency release of water from the project reservoirs. Development of a water quality standard for total dissolved solids in consultation with state water quality authorities was also a proposed mitigation measure for surface water quality.

Water quality and quantity monitoring plans were a frequent mitigation measure proposed for project impacts. The focus of monitoring plans varied by project, and it was not uncommon for a project to propose more than one plan for mitigation of water quality and quantity. For example, a project may propose plans for monitoring reservoir water quantity and/or quality and nearby stream water quality and/or quantity to ensure project pumping, operations, or seepage are not impacting outside waterbodies.

Prevention of seepage or leakage into or out of the project was a necessary measure for protecting quality of project reservoir water and nearby surface water and groundwater. Installation of a liner in project reservoirs, water conveyance tunnels, and sometimes in the project powerhouse to prevent seepage or leakage either into or out of the project was proposed as a mitigation measure in all NEPA documents we reviewed. Likewise, sealing mines to prevent infiltration of outside water or loss of water from the project was also frequently proposed to prevent leakage or seepage into or out of the project.

Proposed mitigations for groundwater impacts often included additional studies or monitoring to ensure that water being pumped for project fill and refill or groundwater near the project was not affected by initial reservoir fill, refill, or normal project operations. These studies also are essential to ensuring that groundwater that is being impacted is not having unintended consequences for other surface or groundwater users. One project NEPA document discussed using deep water aquifers for project fill and refill because shallow aquifers would potentially impact nearby resident's well water supplies. Pumping tests and installing monitoring wells was proposed as a mitigation to make sure that the project would not impact the other nearby groundwater users.

Table 2-2 Representative potential water resource impacts and proposed mitigations from NEPA documents created for the abandoned Lorella Dam project (P-11181). The Lorella Dam project was a 1000-MW closed-loop PSH in Oregon. The NEPA document was issued in April 1994 and the license application was withdrawn on 12 October, 1998.

Water resource impact type	**Impact**	**Mitigation**
Aquatic resources	Irrigation ditch interconnection to conveyance system providing refill water for facility may entrain and harm Lost River and shortnose suckers	Schedule irrigation ditch interconnection to conveyance system providing facility refill water during seasons that prevent harm to Lost River and shortnose suckers
Water quality and quantity	Reservoir water quality	Develop specific total dissolved solids criteria that would trigger installation of water treatment system.
	Drainage patterns altered as part of wetland mitigation plan	Increased infiltration in wetland mitigation area
	Decreased surface water runoff from lands used for construction of upper and lower reservoirs	Increased runoff from wetlands mitigation area will result in negligible net change in total project area runoff
Groundwater	Potential for reduced groundwater quality or quantity	Implement additional groundwater studies or monitoring program during construction and filling
	Groundwater withdrawals from shallow and deep aquifers for initial filling could impact other users of shallow aquifers	Make-up water for ongoing project operation will only be drawn from deep aquifers
	Leakage from project into our out of project structures	Underground powerhouse and all water conveyance tunnels would be fully lined to contain leakage into or out of project structures
	Off-site impacts to nearby irrigation and domestic-use wells if shallow aquifers are used	Use deep aquifer system rather than shallower aquifers to prevent impacts to other users

2.5 Fisheries Resources and Aquatic Ecology

2.5.1 Impact

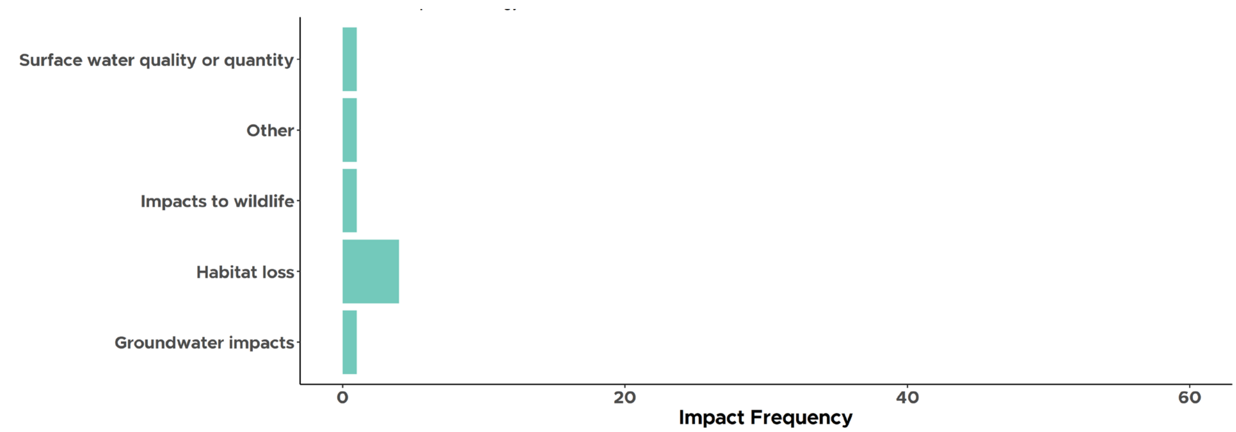

Figure 2-8 Frequency of potential fisheries and aquatic resource impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential fisheries and aquatic resource impacts are summarized in Figure 2-8. There are very few aquatic ecology impacts listed in the NEPA documents reviewed, but the impacts listed could occur during all phases of projects. Of the six projects, only three listed aquatic ecology impacts. Of those three projects reporting impacts, only the Eagle Mountain project is licensed and currently active. Two of the three projects not reporting impacts, Swan Lake North and Gordon Butte, are also licensed and currently active. The aquatic ecology impacts discussed for Eagle Mountain are non-specific, listed only as potential biological impacts. Other aquatic ecology impacts listed at the Summit and Lorella projects included potential impacts to an endangered fish that could potentially get caught in an irrigation canal and potential impacts to fish habitat.

2.5.2 Mitigations

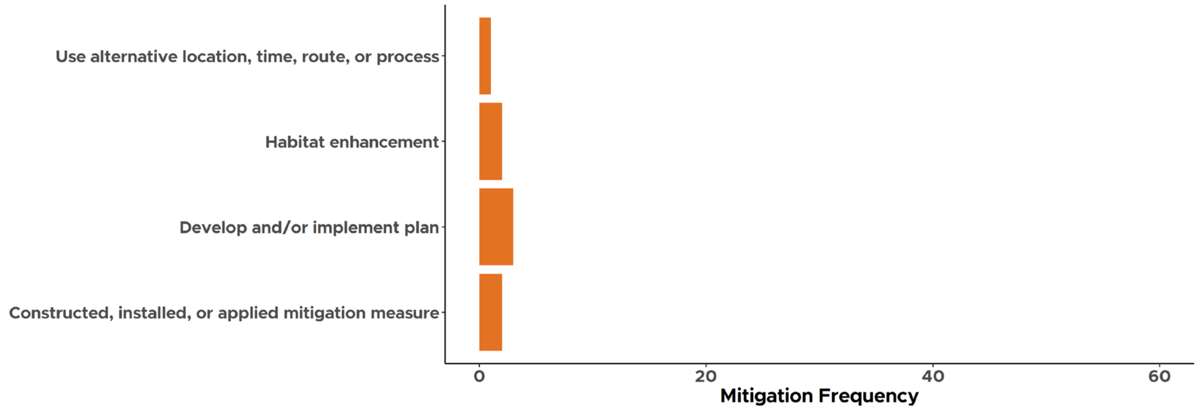

Figure 2-9 Frequency of proposed fisheries and aquatic ecology resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for fisheries and aquatic resource impacts are summarized in Figure 2-9. Some of the measures proposed were enhancements rather than mitigations. In other words, there was not a specific impact that a measure was intended to mitigate; rather, a measure was proposed to enhance aquatic ecology. For example, the Lorella project NEPA document proposed enhancing western pond turtle habitat along the Lost River even though impacts to western pond turtles were not identified. Potential impacts to the endangered fish at the Lorella project were mitigated by ensuring water was in the irrigation canals if fish were in the canals during times of year they are not typically entrained into canals. Other measures worked to create new pond habitat for warmwater fish that did not previously exist. Proposed mitigations for potential aquatic ecology impacts at the Eagle Mountain site were centered on creating an aquatic monitoring and compliance program, but since no specific impacts were identified for this site, targeted mitigation measures were not proposed.

2.6 Terrestrial Resources

2.6.1 Impacts

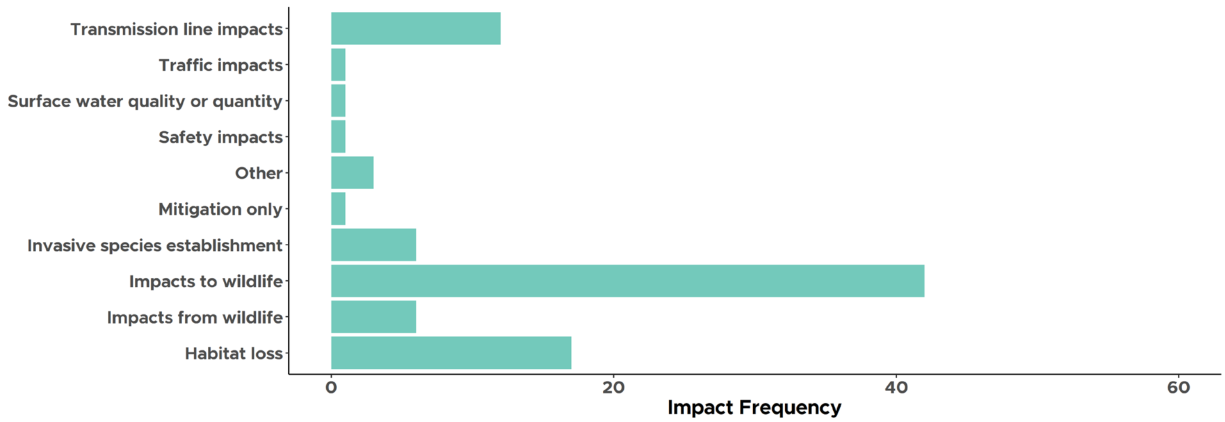

Figure 2-10 Frequency of potential terrestrial resource impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential terrestrial resource impacts are summarized in Figure 2-10. Impacts to and from wildlife were frequently identified in the projects reviewed. These impacts included impacts to wildlife such bat habitat disruption and disturbance from trees being removed and construction equipment being operated. Also, abandoned mines that would be repurposed for reservoirs could create an ecological trap for bats because mine openings may be available when reservoir levels are low but could cause bats to drown once the reservoir is filled or refilled. Some projects also had the potential to result in impacts from wildlife as transmission structures potentially increased bird predation on desert tortoises and other wildlife by providing an improved vantage point for hunting.

Operation of construction vehicles and related construction traffic was identified as a hazard for native wildlife, especially during nesting, mating, or migration season. Reservoirs were also identified as creating an attractive nuisance for wildlife because the water sources may entice wildlife and present a drowning hazard due to steep drop-offs. It was also suggested that birds could be attracted to brine ponds used in reservoir water quality maintenance, and the poor water quality of these ponds could also present a health hazard to birds.

Habitat loss was mostly related to loss of bird and ungulate habitat including critical habitat and movement corridors, although impacts to wetlands and sensitive plants, culturally important plants, and other botanical resources were also identified. Impacts from transmission lines also primarily impacted wildlife and included loss of bird and other raptor nesting habitat from construction of transmission lines, bat, raptor, and other bird collisions with the transmission lines and electrocutions, and transmission lines and towers providing perching structures for predatory birds that may prey on endangered species such as desert tortoise. Vegetation impacts from transmission line construction were also identified.

Invasive species establishment was identified at three of the projects. These establishments could be caused by destruction of native plants that may be recolonized by noxious weeds or other non-native, invasive species. Plants that could potentially be impacted included plants of cultural importance and other native species.

Table 2-3 Potential terrestrial resource impacts and proposed mitigations for the proposed Swan Lake North Pumped Storage Project. Swan Lake North is a 393-MW with an active FERC license. The final NEPA document was issued January 2019 and the license was issued 30 April, 2019.

Plan name	Mitigation measure specifications
Revegetation and Noxious Weed Management	Revegetation seed mixes and plant species will include wild celery and other plants important in tribal customs pending seed or plant availability; Create plan to manage vegetation during project operation
Wildlife Habitat Restoration and Enhancement	Update and finalize previously filed plan to include lost and long-term habitat disturbance
Conservation Land Management Plan	Identifies parcels to be acquired; Criteria to select parcels; Habitat improvements for each parcel
Avian Protection Plan	Spring and summer preconstruction surveys; Prohibit blasting and helicopter use near active raptor nests from 1 January to 15 August; Consult with resource agencies before conducting high-decibel activities; Prohibit ground disturbance and vegetation clearing in reservoir areas between 1 April and 15 July to protect nesting songbirds; Design transmission structures to minimize bird collision and electrocution; Procedures to document and report bird fatalities and injuries
Ungulate Protection Plan	Reservoir fencing to prevent drowning; Decommission access roads unnecessary for long-term project operation and maintenance to reduce habitat disturbance; Trenches designed to minimize wildlife entrapment; Create wildlife crossings under penstock; Prohibit winter construction along transmission corridor to minimize disturbance to wildlife; Manage parts of transmission line right of way for wildlife benefits; Big game water sources near both upper and lower reservoirs
Fire Prevention Plan	Measures and protocols that licensee must follow to prevent wildfires during construction and operation; Removal of slash by means other than burning within 1-year of project construction.

A variety of other impacts were infrequently identified across projects surveyed for this report. These impacts included reservoir levels potentially impacting terrestrial resources, potential increased fire risk caused by project construction and operation, and traffic impacts due to construction of new roads required to access the project. Impacts caused by the project providing water subsidies that would promote establishment of new vegetation in the project area was also identified as well as unspecified potential biological impacts.

2.6.2 Mitigations

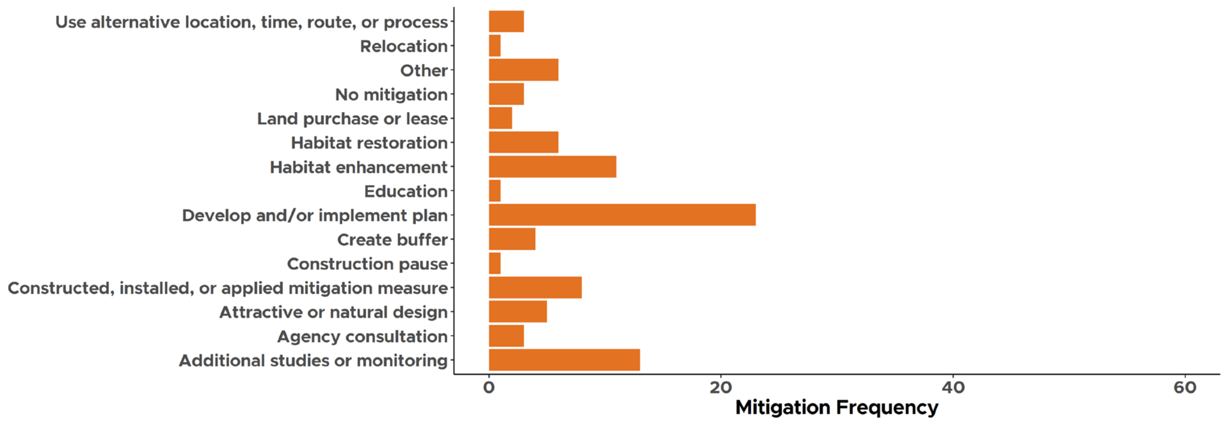

Figure 2-11 Frequency of proposed terrestrial resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for terrestrial resource impacts are summarized in Figure 2-11. Proposed mitigations for impacts involved reducing or avoiding disturbance to wildlife or their habitats, especially during critical life history periods such as migrations, nesting, or reproduction through managing construction schedules or avoiding nearby sites. Fence-row vegetation was planted to provide additional habitat for deer and rabbits. Removal of livestock from a wetland mitigation area was proposed to increase forage for ungulates impacted by the project. Proposed mitigations for raptor and other bird collision and electrocution with transmission lines was through using transmission line designs that would minimize these hazards. Relocation of burrowing owls and ground nesting birds were proposed as mitigations at some sites.

Specific examples of plans from the Swan Lake North project are detailed in Table 2-3. Drafting of plans was also frequently listed as proposed mitigations including 1) Avian Protection and Transmission Line Design Plans that would monitor and evaluate impacts such as construction noise, nighttime lighting, habitat destruction and preservation methods, nesting and critical habitat protections, and electrocution and collision reduction methods; 2) Wildlife Habitat Enhancement and Restoration and Ungulate Protection Plans that would monitor and evaluate impacts such as fencing reservoirs to prevent drownings, habitat disturbance and protection measures including application of dust reduction methods to reduce dust on ungraded or new roads, decommissioning construction roads and other areas not necessary for long-term project operations and maintenance to reduce disturbance to wildlife and their habitats, and managing parts of the transmission line right-of-way for wildlife benefits; 3) Revegetation, Noxious Weed Control, and Invasive Species Plans that would include site-specific measures for revegetation and controlling and preventing noxious weed and invasive plant infestations; 4) Brine Pond Management Plans to minimize attractiveness to and exclude migratory birds; 5) Conservation Lands Management Plan that identifies parcels to be acquired for conservation lands, criteria used to select the parcels, and habitat improvements to be implemented, and 6) Fire Prevention Plan that describes measures and protocols to prevent wildfires. These proposed plans often required consultation with tribal, federal, or state resource agencies.

2.7 Threatened and Endangered Species

Potential impacts to and proposed mitigations for threatened and endangered species occurring near a project development site can be complicated when there are many species involved. Figure 2-13 uses an example from the Eagle Mountain project to illustrate this complexity by connecting the impact for each species to the proposed mitigation measure.

2.7.1 Impacts

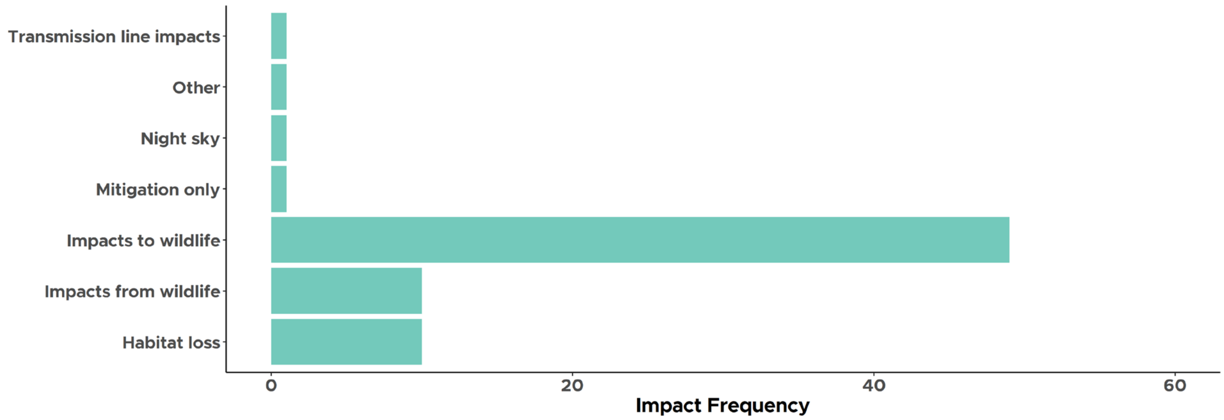

Figure 2-12 Frequency of potential threatened and endangered species impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential threatened and endangered species impacts are summarized in Figure 2-12. Impacts identified for threatened and endangered species are similar to those identified for terrestrial resources including impacts to wildlife such as transmission lines presenting a potential electrocution or collision hazard, reservoirs being an attractive nuisance, habitat loss, and night sky impacts from light pollution. Potential impacts from wildlife were also noted such as predation of desert tortoises from predatory birds perching on transmission poles was also identified as a potential impact.

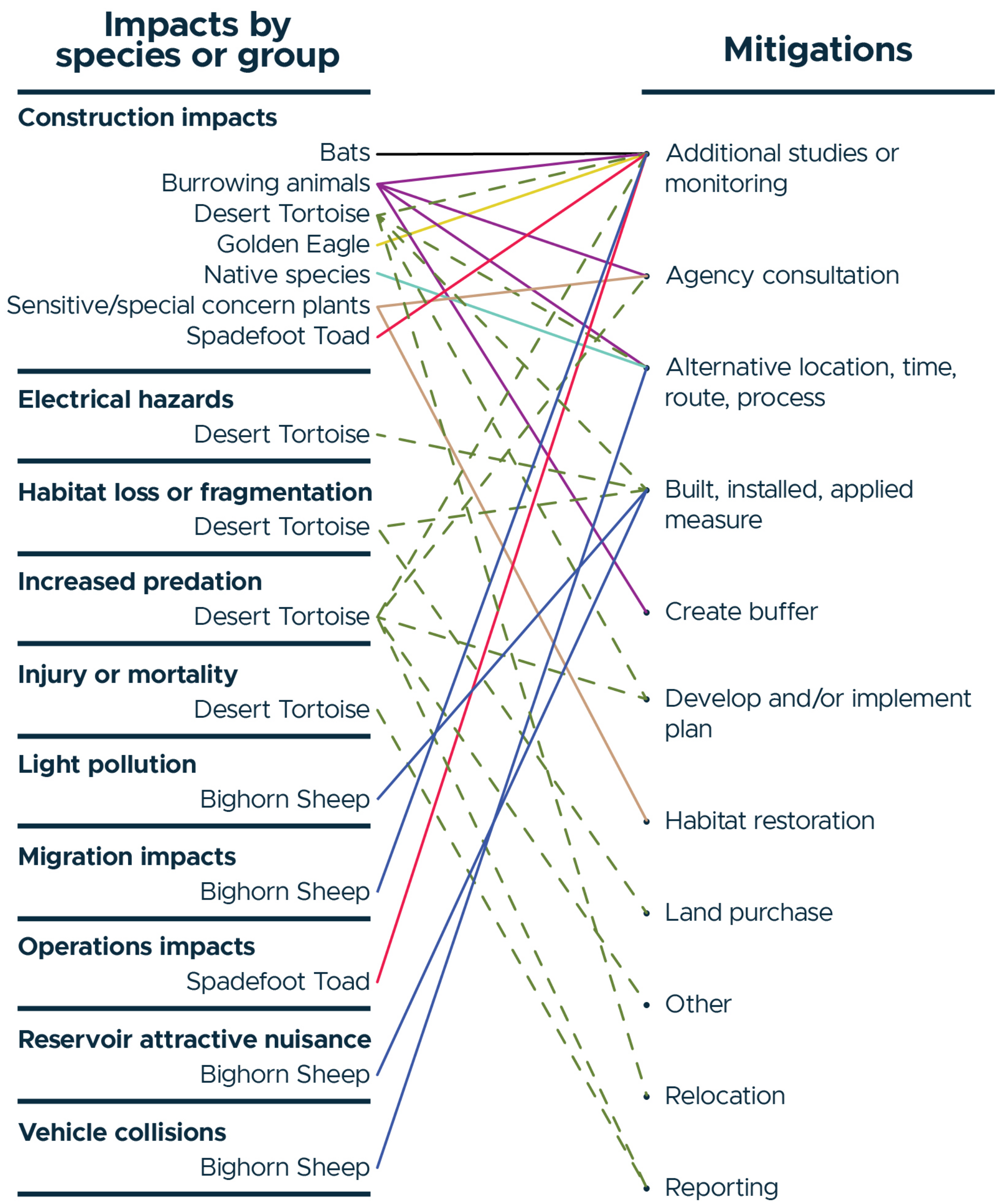

Figure 2-13 Threatened and endangered species impacts for the Eagle Mountain project by species or group (left column) and mitigations (FERC 2012). Lines match an impact for a species or group with the proposed mitigation. Lines species or groups as follows: bats—solid black, burrowing animals (includes burrowing owl and mammals)—solid purple, desert tortoise—dashed dark green, golden eagle—soild gold, native species—solid aqua blue, sensitive/special concern plants—solid tan, spadefoot toad—solid red, bighorn sheep—solid dark blue.

2.7.3 Mitigations

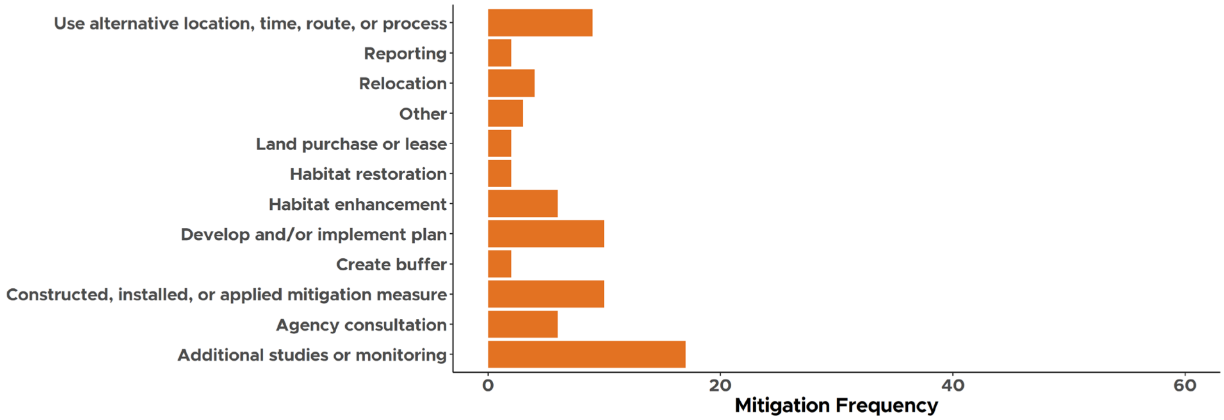

Figure 2-14 Frequency of proposed threatened and endangered species mitigations from six closed-loop.

Proposed mitigations for threatened and endangered species impacts are summarized in Figure 2-13. Mitigations for impacts to threatened and endangered species were, again, like those proposed for terrestrial impacts. Aside from proposing monitoring of species of concern, proposed measures included scheduling to avoid or physically avoiding construction or other disruptive activities during critical life history periods like nesting or migration and relocation of sensitive species. A Predator Monitoring and Control Plan was also proposed at one site to address potential increases in predation of desert tortoises by birds perching on transmission lines and canines such as coyotes. Ongoing monitoring or appointment of a biological monitor for a project were other measures proposed to address impacts to threatened and endangered species.

2.8 Recreation and Land Use

There were not strong patterns in recreation and land use impacts (Figure 2-14) and mitigations (Figure 2-15) across projects. In fact, the most frequent impact category was “Mitigation Only” meaning that there was some sort of recreational enhancement proposed to provide benefits to the community that were not specific to any one impact.

2.8.1 Impacts

Potential recreation and land use impacts are summarized in Figure 2-14. Project nighttime lighting affecting dark skies for back country campers was identified as a potential project impact, but there were very few potential recreational impacts because land with recreational opportunities was generally avoided in project siting. There were also potential road closures for construction that may impact recreational access identified as an impact.

There were several potential land use impacts identified including impacts to irrigation due to loss of irrigation payments to irrigation districts because irrigated land was taken out of production for project footprint, disruption of irrigation activities, irrigated land taken out of production even if temporarily for construction activities and impacts to the irrigation canals themselves from reduced water availability due to reservoir capture of water. Generalized impacts to agriculture were also identified.

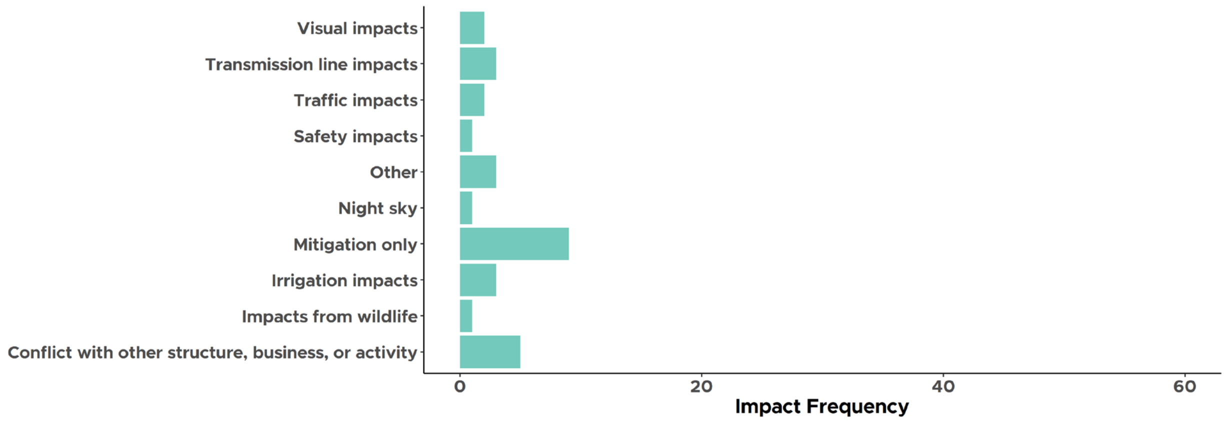

Figure 2-15 Number of potential recreation and land use impacts from six closed-loop PSH case study sites presented in Appendix C.

Several safety impacts were identified for the projects reviewed. These included increased traffic to and near project sites, closing roads on or near the project site during construction, unsafe recreational conditions near the project due to fluctuating reservoir levels, and impacts to nearby residents from noise, dust, and other construction activities. Cattle grazing in the transmission corridor could potentially increase erosion. Other impacts were also identified including inundation of mineral reserves by flooding a mine for one of the reservoirs, construction staging and material storage areas would have substantial footprints, and the transmission line would have impacts on resources because of the relatively large amounts of land it would cross.

2.8.2 Mitigations

Proposed mitigations for recreation and land use impacts are summarized in Figure 2-15. There were many enhancements proposed for recreation despite very few impacts but providing new or improved recreational opportunities is commonly proposed to offset other environmental impacts that cannot be mitigated. Some of these recreational enhancements included funding off-site recreational developments to enhance wildlife viewing opportunities, addition of recreational signage to new or existing trails or recreation areas, land purchases for recreational development, and construction of interpretive facilities.

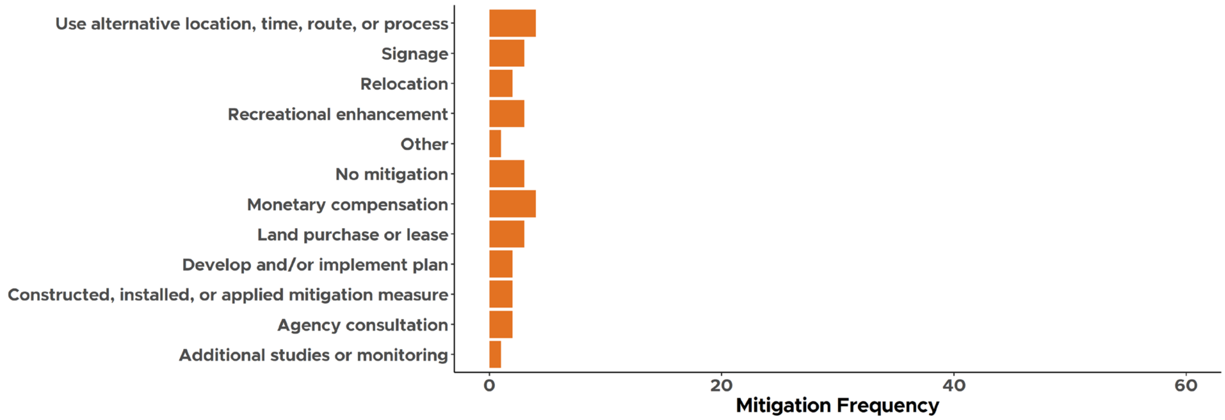

Figure 2-16 Number of proposed recreation and land use mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigation for potential impacts to recreational access included posted notices that would direct potential visitors to use alternate routes due to construction activities. In at least one case, visual impacts of the project during the daytime from a recreational area were determined to be negligible because they were indistinguishable from previous mining activities. Mitigation for dark sky impacts would include selecting lighting products that would minimize visibility from long distances and agency consultation and additional studies or monitoring to ensure dark sky mitigation measures were sufficient.

Impacts to agricultural activities including irrigation were proposed to be mitigated through locating livestock watering troughs and salt licks away from the transmission corridor, timing of construction of new canal facilities to avoid conflicts with irrigation activities, and purchase of land, irrigation systems, and making payments to irrigation districts to compensate for loss of income caused by taking land out of irrigated production.

Safety impacts would also be mitigated through the addition of traffic advisory signs warning of increased traffic on roadways to and near the project site and compensation of nearby property owners for disruption. Footprints of construction staging and material storage areas would be minimized to the extent possible. The transmission line route ultimately constructed would seek to minimize resource impacts and no mitigation was proposed for impacts to mineral reserves being flooded because there was no plan to recover the reserves.

2.9 Aesthetic Resources

2.9.1 Impacts

Potential aesthetic resource impacts are summarized in Figure 2-16. Impacts to aesthetic resources included visual impacts of the project, which typically included concerns about the project structures such as project reservoirs, buildings, roads, and transmission lines not matching the visual character of the surrounding landscape or causing visual disturbance. Light pollution was also mentioned as a potential impact.

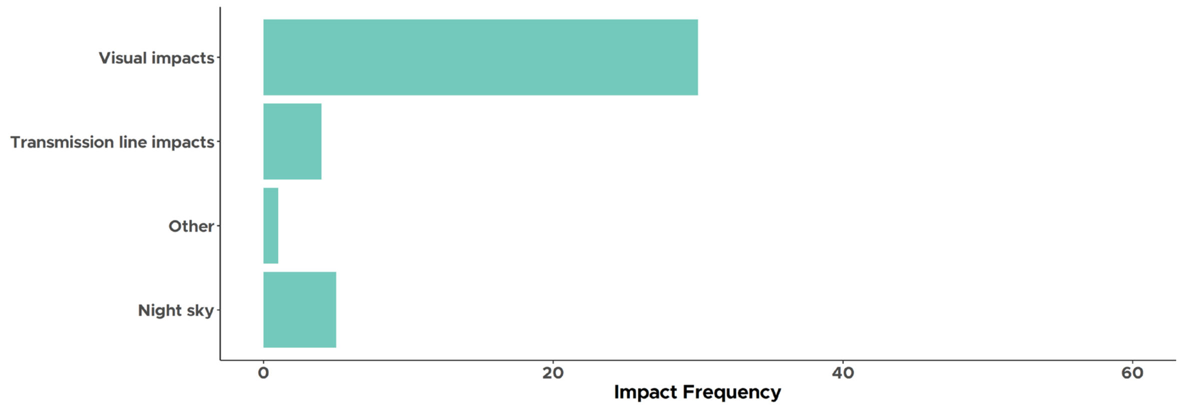

Figure 2-17 Frequency of potential aesthetic resource impacts from six closed-loop PSH case study sites presented in Appendix C.

2.9.2 Mitigations

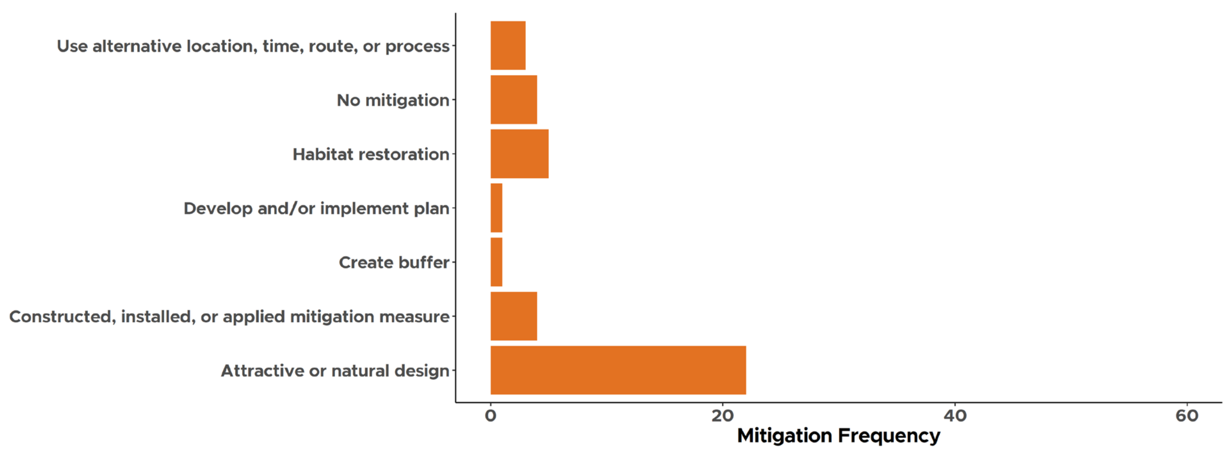

Figure 2-18 Frequency of proposed aesthetic resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for aesthetic resource impacts are summarized in Figure 2-17. Mitigations for visual and aesthetic resource impacts included using attractive or natural design features and colors and native materials so the project is not so obvious on the landscape. Using vegetation and fencing to shield the project features from views of the surrounding landscape was also proposed as a mitigation. Minimizing the amount of construction and ground-disturbance needed for roads, staging areas, and crane pads and placing ones that are necessary outside of publicly accessible vantage points and visually sensitive areas was also proposed to mitigate for visual project impacts. Mitigating for impacts to night skies included lighting product selection and design alternatives to minimize the amount of lighting needed. This could include directional lighting, light hoods, and designing light features so they only turn on as needed for safety.

2.10 Cultural Resources

Table 2-4 provides examples from across the NEPA documents reviewed of potential cultural resource impacts and their mitigations also noting impacts that were determined to not be mitigable. Below, we summarize potential impacts to cultural resources (Figure 2-18) and proposed mitigations (Figure 2-19) from NEPA documents reviewed in Appendix C. Mitigations captured are those proposed in the NEPA documents, and it is important to note that there may not have been agreement on how or whether certain impacts could be mitigated.

2.10.1 Impacts

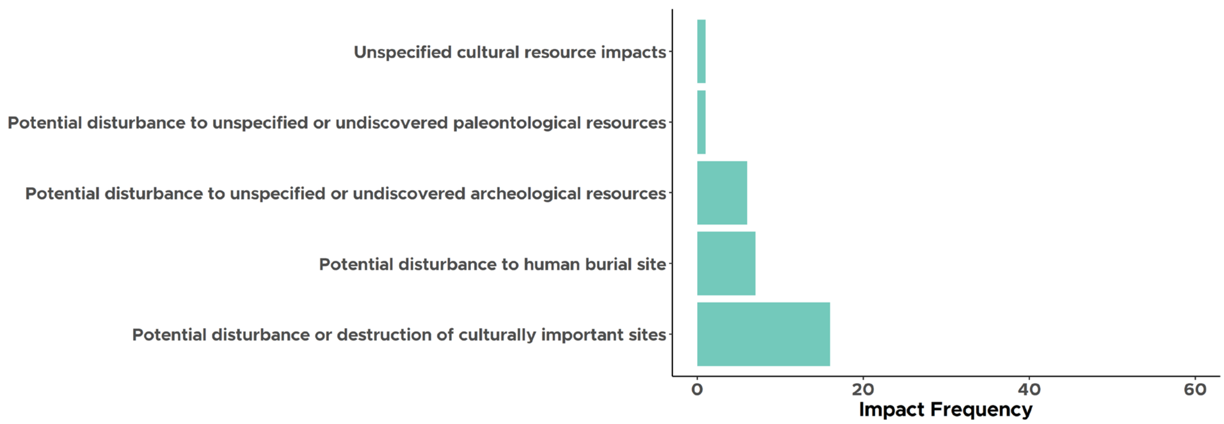

Figure 2-19 Frequency of potential cultural resource impacts from six closed-loop PSH case study sites presented in Appendix C.

Impacts to cultural resources were commonly identified in the proposed projects, although projects with more recent NEPA documents reviewed for this report seem to report fewer cultural resource impacts although whether the decrease in numbers of impacts is due to developers are avoiding selection of sites with a larger number of cultural resource impacts or some other reason is not known. However, natural resources have important cultural significance in many cases, so cultural resources can also sometimes include water, aquatic or terrestrial animals, plants, geological features, and more that may not necessarily be captured in the cultural resources impact category.

Cultural resource impacts tied to human developments described in NEPA documents ranged in age from pre-European contact indigenous settlements to early post-European settlement sites. Several projects identified potential impacts to known or likely archeological sites, including human burial sites and sacred sites, within the project boundaries. Several NEPA documents described the potential for disturbing archeological sites that had not been previously known or identified and sites that were unspecified for a variety of reasons including protection of the cultural resource. However, the significance and gravity of impacts to these special sites and to tribal communities can be difficult or impossible to generalize, capture, or mitigate.

Potential disturbance to paleontological resources and unspecified cultural resources were also described in some cases that may be left without additional details of location or characteristics to protect the integrity of the resource.

2.10.2 Mitigations

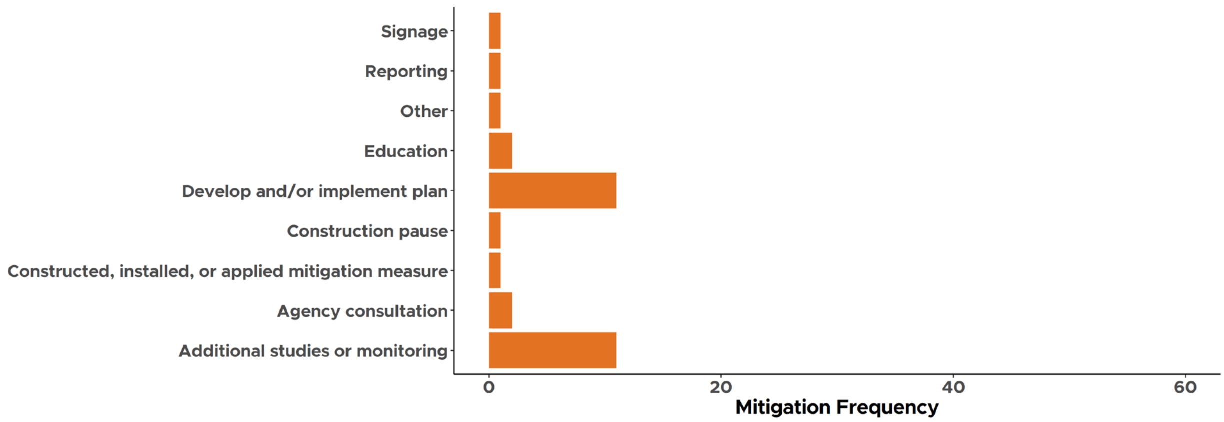

Figure 2-20 Frequency of proposed cultural resource mitigations from six closed-loop PSH case study sites presented in Appendix C.

Many cultural resources impacts cannot be mitigated for reasons such as the place being inextricable from the resource precluding relocation as an acceptable mitigation, project development leading to destruction of an irreplaceable resource, and other reasons. Avoiding the impact is often the most desired outcome. Many projects proposed development and implementation of cultural resource plans involving consultation with tribal nations, SHPOs, tribal, state, federal natural resource agencies, and local communities. There was also an emphasis on educating project construction workers on the potential cultural significance of discovering a previously undiscovered or unknown human burial, archaeological, or paleontological site so they would follow proper protocols if an undiscovered or unknown site is discovered. Proposed protocols if a previously undiscovered or unknown site was identified included work stoppage, fencing off the identified site, and consulting with tribal, state, or federal cultural resource officers. Mitigations were also proposed that would include avoiding construction activities if a nearby culturally important site is used for ceremonies or other traditional purposes.

Additional studies and monitoring were often proposed to identify sensitive or special areas prior to accidental disturbance or destruction including hiring one or more cultural resource monitors to oversee all ground-disturbing activity at the project site. Identification of known sites was also listed as a proposed mitigation for several projects and those known sites were often protected by fencing and flagging to ensure they were not disturbed during construction activities. Construction site restoration sometimes included reseeding disturbed areas with native plants of cultural importance. Interpretive signage was frequently proposed near a facility or in off-site mitigation areas to describe the cultural or historic significance of areas disturbed by the project or within the project boundaries.

Table 2-4 Potential impacts to cultural resources and proposed mitigations across all six projects included in this study to provide more information on specific impacts summarized by each aggregated impact. The "aggregated impact" column provides the name given to a group of related impacts to allow for data summarization and is listed as the "Short Impact" column in Appendix C.

Aggregated Impact	Impact	Mitigation
Potential disturbance or destruction of culturally important site	Impacts to historic properties	Develop and implement Historic Properties Management Plan with State Historic Preservation Officer (SHPO)
	Cultural resources including traditional cultural properties, unanticipated discoveries of artifacts or human remains	Develop education plan with local tribes to introduce project workers to cultural resource laws, regulations, protocols, and requirements; Develop plan for curation of any recovered archeological materials
	Loss of plants of cultural significance to local tribes	Revegetate disturbed areas with culturally significant plants to offset loss of reservoir land
	Project would adversely impact views from culturally significant sites used by local tribes for traditional cultural practices	Not able to be mitigated
	Project would add to cumulative impacts of energy infrastructure on traditional cultural properties	Not able to be mitigated
Potential disturbance to human burial site	Potential impacts to previously unidentified human remains	Mark boundaries of known burial sites and instruct construction workers to avoid site damage; Presence of cultural resource monitors during construction activities; Monitor sensitive areas during construction; Develop Historic Properties Management Plan in with agencies, SHPO, and local tribes in case historic properties or human remains are identified; Implement plan for discovery of previously unknown cultural resources or human remains
Potential disturbance to unspecified/undiscovered archeological resources	Potential impacts to previously undiscovered cultural resources uncovered during ground-breaking and other construction activities	Monitor ground-breaking and other construction in case of undiscovered archeological resources

2.11 Socioeconomics

2.11.1 Impacts

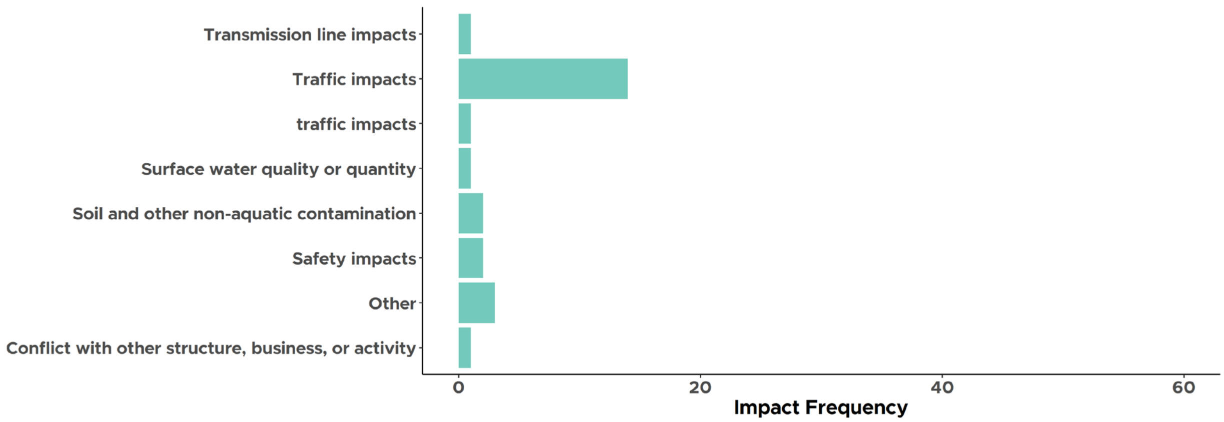

Figure 2-21 Frequency of potential socioeconomic impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential socioeconomic impacts are summarized in Figure 2-20 Frequency of proposed cultural resource mitigations from six closed-loop PSH case study sites presented in Appendix C. NEPA documents reviewed for this report identified a variety of different types of traffic impacts categorized as socioeconomic impacts. These impacts included increases in traffic on roads to and near the project site, and increased congestion on roadways during already congested times such as when children are being transported. Traffic increases described included both vehicles for construction workers and heavy machinery and trucks required for construction. Increased traffic of heavy construction vehicles such as dump trucks increases congestion but also presents safety hazards to other vehicles on the road. For instance, one site reviewed would require more than 100 dump truck trips per year to dispose of brine from the project brine pond. Other traffic safety issues described were creation of fog near roadways in cases where reservoir water temperatures could be ice-free and above ambient temperatures during winter.

General safety issues were also identified in project impacts including increases in thefts at construction sites that could burden local law enforcement as well as direct human safety issues such as drowning and electrocution hazards from project reservoirs and electrical transmission infrastructure. Additional human safety risks such as the potential for electromagnetic frequency effects and potential for release of contaminants were also identified as impacts.

Some impacts identified had no mitigations proposed, such as potential housing shortages for non-local workers and additional costs of snow removal to state and county to allow access to construction site. Potential housing shortages have been described as especially problematic in some cases because nearby towns would not have large increases in long-term residents due to the project so building additional housing, schools, or other businesses and community infrastructure may permanently change the town and the potential for abandoned houses, buildings, and businesses.

2.11.2 Mitigations

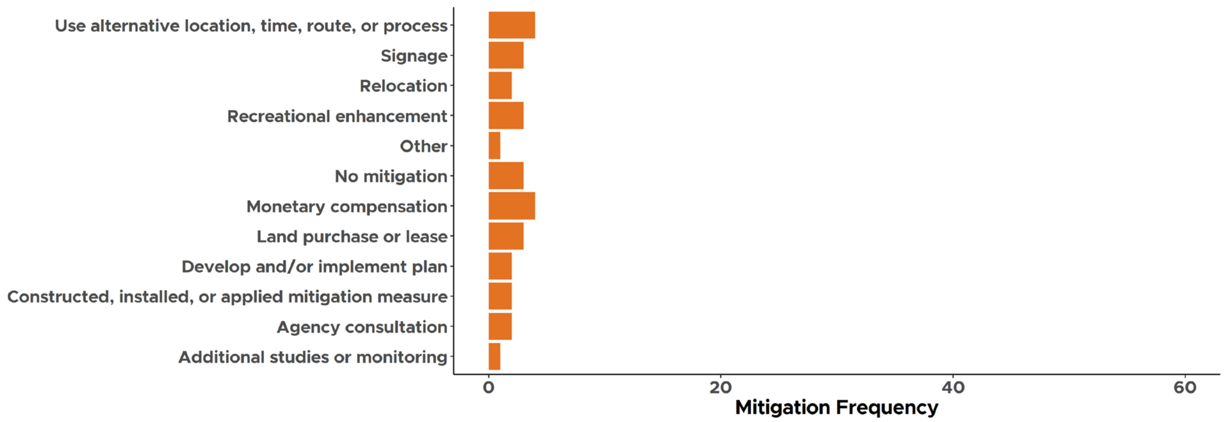

Figure 2-22 Frequency of proposed mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for socioeconomic impacts are summarized in Figure 2-21 Frequency of potential socioeconomic impacts from six closed-loop PSH case study sites presented in Appendix C.. Proposed mitigations for traffic impacts included monitoring traffic conditions and implementing shuttle bus service or carpooling to construction site to reduce traffic, developing and implementing a traffic management plan, and staggering work shifts to ensure crew buses and personnel vehicles are off roads prior to morning and school bus traffic. Safety hazards from increased truck and construction vehicle traffic would be mitigated through restricting delivery times to times when school buses would not regularly be on the road and using less frequent truck brine disposal—every ten years versus every year—or disposing of brine by train instead. Microclimate impacts such as the potential for fog to develop near reservoir would be mitigated through signs warning motorists of the potential for fog.

Mitigating impacts on local law enforcement from thefts at the project area was proposed to be accomplished through on-site private security at the construction site. Drowning and electrocution risks would be managed through fencing around the project area. Electromagnetic frequency impacts would be minimized through spacing design of electrical conductors and transmission lines. Accidental release of contaminants would be addressed in a Spill Prevention, Control, and Containment Plan that would outline mitigations.

2.12 Environmental Justice

Swan Lake North had the only NEPA document surveyed for this report that assessed environmental justice impacts and mitigations. Environmental justice impacts were assessed using information about income, poverty, and unemployment to determine if low-income individuals were overdistributed in the project area and disproportionately impacted by project construction and operation. For Swan Lake North, it was determined that Indian Tribes, especially the Klamath Tribes—a sovereign nation that consults with the United States government on a government-to-government level—could be disproportionately impacted by the project. However, the impacts to the environmental justice communities are discussed in other categories and included increased traffic (discussed in Socioeconomics) and noise and air pollution (discussed in Air Quality and Noise). Moreover, the

Klamath Tribes would likely lose cultural resources and wealth including traditional cultural properties, such as sacred sites, that hold long-term, traditional significance—impacts that cannot be mitigated. Many Indian tribes are

There are an estimated >1,000 jobs associated with construction of the Swan Lake North facility, and 170 of them would likely go to Klamath County residents, including 11 long-term jobs for Klamath County residents. Social programs in Klamath County are projected to benefit from the Swan Lake North project through increases in tax revenue that could benefit low-income county residents and Environmental Justice communities, although FERC found these impacts to be unquantifiable because many social programs also receive funds from state and federal sources. Best management practices for construction related air and noise pollution would be used to limit impacts on both local communities including members of the Klamath Tribes.

Based on their analysis of the total socioeconomic impacts, FERC determined that the Swan Lake North site was not selected based on the economic status of the Klamath Tribes and nearby rural residents in Klamath County and did not discriminate against the Tribes or the community because of their economic status.

2.13 Air Quality and Noise

2.13.1 Impacts

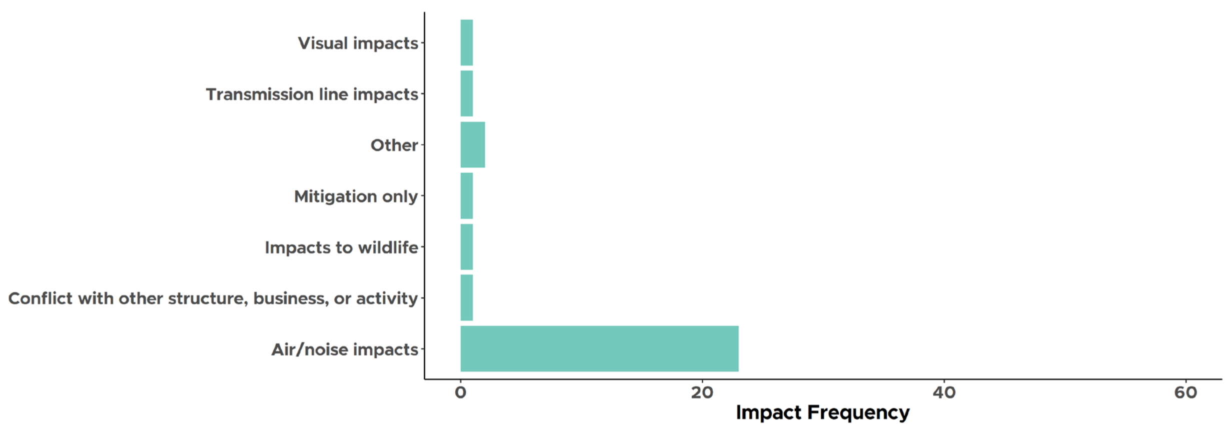

Figure 2-23 Frequency of potential air quality and noise impacts from six closed-loop PSH case study sites presented in Appendix C.

Potential air quality and noise impacts are summarized in Figure 2-22. Most air quality and noise impacts can be attributed to project construction and specifically included increased dust during all project phases (i.e., construction through operation) and increased noise during all phases that disturbs nearby residents and wildlife. Increased dust from project construction caused by digging and construction vehicles driving on dirt and gravel roads was a commonly listed impact among NEPA documents. Earth-disturbing construction activity would be restricted to essential activities only on windy days and amounts of contemporaneously disturbed areas would be restricted to reduce dust impacts. Exhaust emissions from construction vehicles were also a concern, as were emissions from coal-fired power plants that would generate the electricity used to power the pumps used to move water to the upper reservoir. Aside from decreasing air quality, coal-fired power plant emissions were cited in the NEPA document to "contribute to exacerbating regional acid rain and global warming".

Specific examples of potential impacts and proposed mitigations for air quality and noise impacts from the Gordon Butte project are provided in Table 2-5. Noise from construction and operation phases were also frequently cited in NEPA documents listed as being potentially disruptive to people and wildlife. Noise from transmission lines, especially during wet weather, and blasting and boring associated with underground power tunnel construction were listed as impacts. Also, noise from construction vehicles and vehicles associated with conducting operations and maintenance activities were cited as impacts. One proposed project would use trucks to empty a brine pond that was critical to project operations, and emptying this pond would require ~3000 truckloads of salt to be removed every 10-years for the life of the project, contributing to noise pollution, vehicle emissions, and impacting public safety.

Table 2-5 Air quality and noise and socioeconomic impacts at the Gordon Butte project, a 400-MW project in Montana with an active FERC license that had an EA issue date of September 2016 and a license issue date of 14 December 2016 were similar in that they all pertained to construction impacts (FERC 2016).

Resource Category	Potential Impact	Proposed Mitigation
Air Quality and Noise	Construction noise	Based on final project design, revise preliminary Construction Noise Mitigation Plan to include site-specific measures to limit construction noise
	Construction dust	Based on final project design, revise preliminary Dust Plan to include site-specific dust control best management practices to maintain good air quality during construction
Socioeconomics	Increased construction and workforce activity including traffic and unsafe parking on-site may strain local infrastructure	Minimize local infrastructure and service impacts by developing a construction workforce management plan; develop traffic management plan, provide bus service for project personnel, provide on-site security
	Construction traffic creating traffic congestion or safety hazards while children are being transported	Stagger work shifts (i.e., day shifts between 7:00 AM and 5:30 PM and night shifts between 8PM and 6:30 AM) to ensure crew buses and vehicles are off the roads prior to am and pm school bus traffic

2.13.2 Mitigations

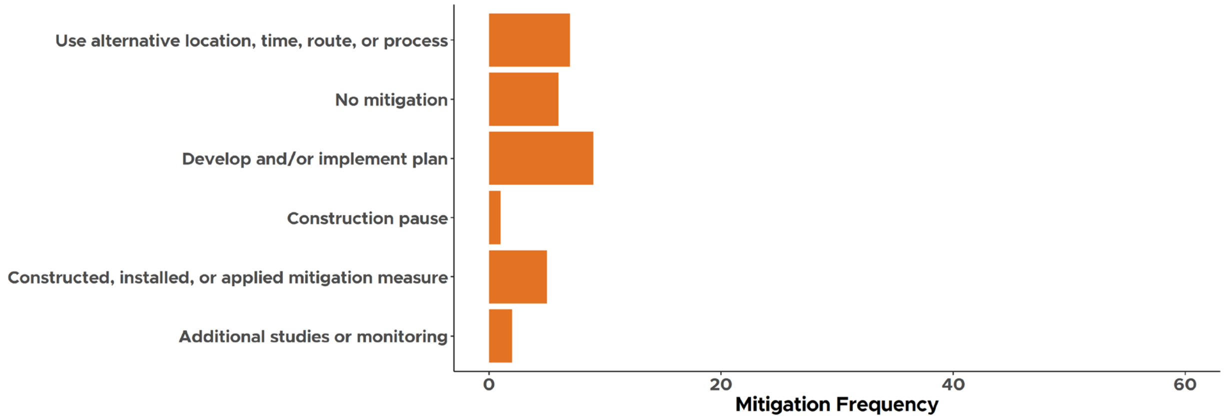

Figure 2-24 Frequency of proposed air quality and noise mitigations from six closed-loop PSH case study sites presented in Appendix C.

Proposed mitigations for air quality and noise impacts are summarized in Figure 2-23. Mitigations for these impacts ranged from revising a previously filed dust plan to include "site-specific dust control best management practices to maintain good air quality during construction" to using "chemicals or water to control fugitive dust on the access roads and other areas subject to heavy traffic during construction" (Figure 2-23). Dust mitigation also involved planting vegetation, typically native vegetation, in disturbed areas to reduce erosion. Air quality permits would also need to be obtained to operate electrical generators. Emissions from construction vehicles would be mitigated through proper tuning of construction machinery and retrofitting with emission control device.

Documents we reviewed proposed mitigating construction noise through outfitting construction equipment with noise mufflers and intake silencers. Compliance with local noise ordinances was also proposed as a mitigation for one project. Some noise impacts had no associated mitigation measures, such as noise from the salt trucks removing brine and the noise associated with transmission lines during wet weather.

Impacts of emissions on the local community were identified in the "Other" secondary impact category. The impact listed was increased emissions from coal-fired power plants needed for pumping, which would exacerbate global warming and regional acid rain issues. There were no mitigations identified for this impact— the NEPA document (for Summit) stated that no mitigation was necessary because emissions from the coal plants would contribute to regional acid rain and global warming issues until state or federal regulations were created to specifically address these issues regardless of whether the closed-loop PSH plant was constructed.

3.0 Perspectives on Environmental Impacts and Mitigations for Closed-Loop Pumped Storage Hydropower from Interviews

3.1 Introduction

In this chapter, we present perspectives on environmental impacts of closed-loop PSH from members of the hydropower community to supplement what we learned from NEPA documents. Only a few proposed closed-loop PSH projects have draft or final NEPA documents. This limits the scope of environmental impacts that can be documented and provides little information about the impacts of projects that either have not undergone environmental review within the licensing process or are abandoned by the developer prior to the environmental review stage. Additionally, these interviews were structured to provide more context about impacts reported in the NEPA documents we reviewed. That said, we recognize people from different sectors (e.g., developers, regulators, environmental non-governmental organizations [eNGOs]) may have very different perspectives on why and how environmental impacts are documented and assessed.

3.2 Methods

We conducted semi-structured interviews with nine members of the hydropower community (Table 3-1), who we recruited through snowball sampling. The 60-minute interviews were conducted via Microsoft Teams and recorded with consent from interviewees. All interviewees had direct experience with PSH licensing, although some did not have experience with closed-loop PSH licensing specifically; however, all interviewees were familiar with closed-loop PSH technologies and, at a minimum, had tangential involvement with closed-loop PSH proceedings. Environmental NGOs had differences in perspectives among them and included environmental issues such as general conservation, river protection, and recreation with a range of spatial areas of organizational interest ranging from local to global.

Table 3-1 Number of interviews conducted by sector.

Sector	# Interviews
Industry Consultant	1
Project Developer	4
Federal Hydropower Operator	1
Environmental NGO	4
Federal Natural Resource Agency	1

We were unable to secure interviews with tribal, state agency, or FERC representatives. We sent multiple interview requests to tribal and state agency representatives, but we were unable to interview anyone from these groups. FERC staff declined to participate in the interviews. Our small sample size and absence of certain perspectives limited our ability to conduct meaningful quantitative analysis, so the interview findings are only qualitatively discussed.

During the interviews, we asked interviewees about the environmental impacts of closed-loop PSH both related to specific projects and more generally. Interview questions addressed the following topics:

- Environmental issues (not) addressed in environmental review, permitting, or licensing;

- Project sites or characteristics that contribute greater or lower environmental impacts;
- Expected impacts to specific aquatic or terrestrial resource categories; and
- Protection, mitigation, and enhancement measures to address expected impacts.

To the extent possible, we organized interviewee responses to interview questions (see Appendix B for full Interview Guide) using the same NEPA resource categories as presented in the previous two chapters.

3.3 Results

Interviewees highlighted most natural resource impacts from closed-loop PSH identified in the NEPA documents, but in some cases, different sectors of the hydropower community placed emphasis on different types of impacts. Across all sectors, interviewees discussed the importance of working to identify and minimize or eliminate cultural resource impacts and impacts to aesthetic resources. Similarly, interviewees from across sectors discussed the environmental opportunities and challenges with repurposing brownfield sites, such as abandoned mines, for constructing new closed-loop PSH.

In general, interviewees from across sectors gave similar types of responses to our questions, identifying similar types of impacts and mitigations. Challenges with identifying impacts was highlighted in several interviews because no closed-loop PSH has been built in the United States, and resource agencies tasked with conducting environmental assessments for hydropower licensing may not be familiar with the terrestrial and land use impacts of closed-loop PSH.

> *In the case of closed-loop pump storage, you're not going to be a controlling feature at all in the watershed, so you can have challenges with resource agencies that just don't know quite how to deal with your type of project (Project developer).*

We present the results of the interviews about specific resource areas below. While we attempted to organize impact types using NEPA categories, the conversational nature of interviews made these distinctions less straightforward. As a result, two or more resource impact categories may be presented together.

3.3.1 Geologic and Soil Resources

Impacts and mitigations to geologic and soil resources described by interviewees were like those we reported from NEPA documents. Impacts described included increased erosion, increased subsidence and seismic activity, and potential for contaminant releases from mines that can impact ground and surface water and species. A federal hydropower operator pointed out that while there are unavoidable impacts to geology and soils from constructing a PSH plant, battery storage technologies also have impacts to geology and soils although those impacts may be felt elsewhere.

> *What are the impacts of other alternatives? We've done some of the math on this. If you're talking about lithium ion, how much and what volume of critical minerals are you talking about … you're having an environmental impact, but it may be happening to [people in a different area] (Federal hydropower operator).*

Mitigations for impacts to geologic and soil resources described in interviews included implementing best management practices for soil erosion and creating a sediment and erosion control plan. There was also mention of the need for additional studies to better understand the geologic and soil resource impacts including rock and soil surveys and slope stability and seismic activity studies.

3.3.2 Aquatic Resources: Water Resources and Fisheries and Aquatic Ecology

Because closed-loop PSH is not continuously connected to a naturally flowing water feature, it does not have many of the aquatic resource impacts typically associated with in-channel, conventional hydropower. For example, closed-loop PSH does not cause issues with fish passage because it does not block a stream. Fish entrainment issues are also not a concern because proposed closed-loop PSH facilities do not have fish in their reservoirs. Aquatic resource impacts described in interviews could be categorized as impacts to fisheries and aquatic ecology, impacts to water quantity, and impacts to water quality.

Fisheries and aquatic ecology: Interviewees were largely in agreement that closed-loop PSH is likely to have reduced impacts to flowing aquatic systems. One eNGO interview participant summarized the potential for reduced aquatic impacts:

> *When you have an open-loop project that's connected to a free-flowing river, there is the potential for greater impacts with fluctuations in the river, changes in water quality, water availability. And theoretically [in] a closed-loop system, you still have to fill it from somewhere and refresh it, but a closed-loop system could be less environmentally impactful given the right conditions (eNGO).*

Another eNGO interviewee also described how closed-loop PSH presented an opportunity for reduced impact energy storage and generation:

> *Appropriately sited closed-loop pumped storage tends to pose less environmental risk than open-loop. Open-loop often relies on in-river dams either existing or constructed for a particular project to create an upper and lower reservoir. Dams impede fish migration, alter water quality parameters, [and] inhibit natural river processes (eNGO).*

Mitigations to potential impacts to fisheries and aquatic resources involved the timing, quantity, and frequency of initial reservoir fill and refill. Minimizing impacts to these resources would require restrictions on water withdrawals for fill or refill during critical life history periods for fish and aquatic organisms, including spawning and when eggs or young fish are most vulnerable to dewatering impacts from habitat and temperature alterations.

Water quantity: The most cited aquatic resource issues by interviewees were surface water and groundwater quantity impacts from the initial filling and subsequent refilling of project reservoirs. One federal natural resource agency respondent stated:

> *On paper, it makes sense. One of the benefits for pumped storage is that it's long term. I'm not familiar with new battery technology. I know batteries have concerns with the rare earth, or the materials needed to make them, and they don't last forever. A pumped storage project would be a 40-year license and would continue going. So that's one of the benefits, and personally it makes sense. ... It's just the location and the availability of water (Federal natural resource agency).*

In cases where surface water was the source of this water, interviewees suggested stream drawdown could impact fish, other aquatic biota, or recreation by dewatering the stream. There was also concern about use of groundwater as the PSH water source because groundwater withdrawals could also impact surface water quantity if there was sufficient connection between the groundwater source and surface waters. Using groundwater as a source for reservoir fill and refill was also identified to potentially impact wetlands, water supplies for private wells including for private residences, municipal water supplies, and agricultural water use. One developer described the importance of identifying a long-term source of water to the sustainability of their project and how it impacts their project site selection:

> *It's your fuel source for the project ... so we scrutinize our use of water probably more than all the stakeholders. We need a sustainable source of water for 100-years plus, which is sort of the lifetime of the asset that our investors are thinking about when we're thinking about taking on a project. So, it needs to be a very sustainable source of water (Project developer).*

This developer went further in describing some of the factors they take into consideration in determining the sustainability of water supply:

> *We're trying to show little if no impact to surface, groundwater, and aquatic ecology. So how do we do that? Each project is a little bit different on surface water quality. The big one is we're building a closed-loop facility, so even during periods of O&M, being able to move water from one reservoir to another, and to do all this without having to do a surface discharge, and then building projects in a way that we're not capturing a large rain, precip, or runoff event, any way where there could be an impact to surface water. ... Making sure that you're not capturing surface water into your system is certainly an issue that we have to deal with on all these closed-loop projects (Project developer).*

Reduced runoff water to surface water due to water captured by the project reservoirs was also identified as a water quantity issue during interviews.

Mitigations for water quantity impacts listed by interviewees included water right buyout or compensation for use of water rights, restrictions on withdrawal rate and timing so that rates were not higher than a body of water could sustain without becoming dewatered. Timing of water withdrawals for initial fill and refill were also discussed as a potential mitigation such that withdrawals would occur during times of year with higher flows. Mitigations for runoff captured by project reservoirs included bypass channels or pipes or spillways from project reservoirs that would send water to local surface waters.

Water Quality: Water quality issues were also commonly cited by interviewees and included biofouling, temperature alterations, and concentration of metals or other contaminants when abandoned mines or other brownfield sites are used as closed-loop PSH sites. Opportunity and concern for repurposing these brownfield sites was described by interviewees across sectors because of the possibility of contaminated water infiltrating uncontaminated surface or groundwater supplies.

> *A couple of [mining] projects I've looked into have existing water quality liabilities or environmental liabilities associated with historic mining features. And the second you build a new water feature, especially a surface water feature, and have the ability to move those liabilities from one underground location into a surface location you create complexity. ... So the projects we've looked at were just a little bit too complex for us to take on from a liability standpoint (Project developer).*

> *There's a lot of thought about repurposing coal mine water in the underground mines, and that's not really viable as the quality of water. Nobody wants that to come out from underground due to the acidic nature of it and other contaminants (Industry consultant).*

It's reclaiming your brownfield site and an abandoned smelter, so there's all kinds of land disturbance [and] there's no direct water intake with the [river]. So, it's closed-loop. There are zero aquatic fisheries impacts, but certain stakeholders have tried to make [aquatic fisheries impacts] cause number one. And scientifically, it's just not possible. But it's such a hot button issue. It's a lightning rod, particularly for the northwest. And most people just don't understand how can it not be an issue. That's because the water is coming from the [river], from the abandoned [type of metal] smelter's 25 CFS water right that is now owned by the public utility district (Industry consultant).

There's been some interest in doing these in old mines, but that could also have a lot of effects in terms of what are we bringing into the groundwater and other interactions (Federal natural resource agency).

Several water quality mitigations were discussed by interviewees including installing liners in reservoirs to prevent seepage of contaminated or poor-quality water, improvement of dissolved oxygen through aerating turbines, destratification of reservoirs through summer reservoir drawdowns below the thermocline, and implementation of stormwater pollution prevention and reservoir water quality monitoring plans. One developer interviewed described reduced emphasis on water quality for initial fill water at their proposed facility and mitigating the lower quality water through water treatment infrastructure once in the facility:

For any closed-loop, the question is going to be where's the water coming from. And if it's coming from one place it may be more of an issue than another. We don't need potable water. We probably don't want to run a pipe to the Pacific Ocean and set up salt water, but we're pretty flexible with the quality of the water. And in theory, if it's got too much of something, if it comes out of the wastewater treatment plant, for example, it's got some contaminants in it. We could, at least in theory, put together a temporary processing facility that treats the water on the way in so that it meets the quality standards for the equipment (Project developer).

Thermal modeling studies were also mentioned by one interview participant to understand thermal impacts and evaluate mitigation options.

3.3.3 Terrestrial Resources and Threatened and Endangered Species

Most of the impacts discussed by interviewees identified impacts to specific taxa or life history events like migration. Specific taxa mentioned by interviewees included deer, bats, salamanders, sage grouse, raptors, insects, bats, native plants, desert tortoises, and "sensitive species" as well as introduction of invasive plants. Impacts to these species included disturbed, inundated, or removed land or habitat, new reservoirs acting as an attractive nuisance to wildlife or prey such as insects that would attract bats and birds, and light pollution impacts on nocturnal species. Fragmentation of migration corridors and habitat was frequently mentioned by interviewees. One interviewee from an eNGO described impacts to terrestrial resources that give them reservations about greenfield closed-loop PSH development.

I continue to have significant reservations about greenfield development, not just the inundation of new lands that may be forested or natural in their setting, but all of the associated project components. Power lines, for example, are significantly impactful to the ecology. They create wildlife connectivity challenges, fragment forested ecosystems, bifurcate and damage our trails and recreation assets. All too often, *energy development projects are proposed or built [in one region], but the energy is consumed [in a different] region. So, there are challenges with putting power lines in place. For example, there are project boundaries for hydropower projects, but ultimately that power is going to have to get to market. So, the proximity of these resources to the consumers. Although I realize it's outside of the scope of what would normally be within environmental assessment (eNGO).*

Mitigations for terrestrial resources included habitat replacement through offsite land acquisition, site selection to avoid sensitive species or habitat, on- or off-site mitigation for impacted species, creation and implementation of wildlife and vegetation management plans, contaminant cleanup and site remediation for brownfield sites, and off-site or adjacent site restoration of native plants and habitat. Studies that would survey animals in an area were discussed to inform impact assessment and mitigation.

3.3.4 Recreation, Land Use, and Aesthetic Resources

Site selection and prioritization (or avoidance) of certain land uses, or avoidance of visual impacts including views of project construction, operation, or light pollution for users of recreation areas for development was a major theme in interviews across sectors. There was also mention of the relative land sparing that closed-loop PSH offers for electricity storage and generation compared to solar and wind.

1,200 megawatts of storage, 9 hours or 12 depending on how it's configured. ... And your impact on the landscape is two 60-acre ponds. If you were going to build that scale of solar in [name of state] , you'd need 50,000 acres of land. And on direct comparison with wind, you'd need almost 8,000 acres of land. So, land use is an important component of this, as well, what is the best value of our resources (Project developer).

Discussions of recreation and land use in interviews mostly centered around how prioritizing brownfield sites for development may provide a mechanism for site improvement. Specifically, closed-loop PSH development could be a way to bring no longer utilized lands back into the fold of economic productivity, contributing to local economies. This point was emphasized by interviewees from across sectors.

We want to make the site better than when we found it, so we searched pretty hard to find sites that weren't on pristine areas (Federal hydropower operator).

The brownfield sites we're pursuing now, the contaminants are well defined and have been well defined for a long period of time where they can be removed or contained in a different type of way as part of our redevelopment that doesn't increase the liability, and in some cases completely removes that liability and disposes it from the site if that makes sense (Project developer).

In general, I think there will be fewer environmental impacts from closed-loop pumped storage compared to open-loop pumped storage, but I think it's hard to answer that question without answering the question of whether or not that closed-loop system is utilizing a site that has already been deteriorated because of some previous land use.... We have to create a marketplace that better incentivizes utilizing those already degraded lands (eNGO).

When it comes to the economic viability, there is a lot of research and work to make use of brownfields and sites that have previously been degraded. Whether it's funding available from the government for adaptive reuse of those locations or community *interest in bringing those areas back onto the local tax roll, I think there's a lot of economic viability for targeting areas that have already been impacted. I'll reference abandoned coal mines again. These are large areas, potential storage for water, often at elevation. Most of these mines are elevated above the river corridor. And I think it's most economically viable to consider developing within those areas and locations where there's community support for them (eNGO).*

Mitigations for this impact category discussed in interviews included recreational enhancements and mitigations, such as rerouting a trail system, adding mountain bike trails and interpretive signage, using lighting that complies with international dark sky compliance measures, attractive or natural materials or design of project buildings, infrastructure, and transmission infrastructure, and new and improved recreational access and opportunities. There was also discussion of mitigating impacts by avoiding sites or by utilizing construction and design techniques that minimize project impacts.

If you're going to be building adjacent to some natural characteristic, potentially that's a problem and much of it can be mitigated by your construction and technique, so maybe you have to go deeper underground, maybe you have to build some berms around if you can't go deeper underground. But it's all super site-specific and as a developer, you look at a site and you make a judgment as to how difficult it's going to be there. So, if you find a site adjacent to Yosemite, you probably don't want to deal with that. Whereas like us, we're in the middle of [an ecosystem], there's nothing around it. People won't see it, even from nearby roads. It really won't be visible. There will be a little building where our equipment's going to be and that's it (Project developer).

Pre-construction site visitor surveys for recreation impacts, visual resource assessments and mapping, including photo simulations of the project during construction and operations phases were identified as studies that can be used to inform impact assessment and mitigation.

3.3.5 Cultural Resources and Environmental Justice

Impacts to cultural resources and environmental justice discussed in interviews included impacts to sites of cultural or historic significance, plants, wildlife, and fish and fisheries of cultural significance. Developers and consultants discussed some of the lessons learned, including a lack of understanding of the nature or significance of certain cultural sites and that some impacts cannot be mitigated.

The [cultural] resources are fundamentally connected with the place. And [to hear] that moving them would be worse than flooding them, speaks to the importance of careful engagement with the tribes because a lot of what someone like myself might think of as an appropriate mitigation measure, it turns out is not appropriate at all (Industry consultant).

Cultural resources are most often environmental resources and vice versa. So [protection, mitigation, and enhancement needs to] take that into account. ... Off-site terrestrial mitigation is great for raptor nesting and habitat, but if it's removing these animals and species from their original sites, that's a cultural resource impact (eNGO).

In many cases, sites of cultural significance are held in confidence by tribal nations and other communities with culturally significant resources and developers engaging with these communities early in the permitting process is the only way to gain an understanding of what sites need to be avoided.

> *A lot of culturally significant or tribally significant areas are not well mapped and not well understood or intentionally kept in confidential files. So understanding where they are and maintaining that confidentiality but avoiding those special places is something that should be done early on (eNGO).*

Understanding what sites should be avoided because of project impacts can also include potential impacts to tribes and other environmental justice stakeholders.

> *So, for impacts to water, we're not just looking at can we enter into a contract that's sustainable over a long period of time. With closed-loop you're in a much better situation to say our project will have zero impacts on time immemorial water rights and making sure that your project doesn't impact those types of resources [is] certainly something that we take on as we approach our projects (Project developer).*

Again, interviewees identified that mitigation of impacts to cultural resources and environmental justice communities may not always be possible. Even in cases where the significance of the historic or culturally significant resource is not associated with the place, moving buildings or structures of historic or cultural importance to a nearby area, for example, may not be appropriate because the once undeveloped views from that resource, which are part of what makes that resource special, will now contain the project or other visual impacts from the project such as nighttime lighting. Interviewees did, however, identify that cultural resource and environmental justice impacts may be avoided (rather than mitigated) through tribal consultation and community engagement in advance of the preliminary permit application filing to provide input during the following points in the project development process: site and management design process, site selection of private and/or already developed land to avoid cultural resource and recreation issues, archaeological preservation and access agreements, and museum creation and/or restoration of off-site historic properties to mitigate for impacts to historic properties.

3.3.6 Socioeconomics

Impacts to local infrastructure were identified, specifically impacts to communities where closed-loop PSH plants would be located. These communities are often small and remote and an influx of workers and their families may stress local resources like hospitals, recreational access, roads, housing, or schools during the multi-year construction process. Impacts to these types of local communities can be significant.

> *Where are all those construction workers going? Where are they going to live? Where are they going to recreate? Where are they going to be hunting and fishing? And this is potentially a six-year construction project. So that's a temporary but potentially significant multiyear issue associated with these with these projects (Federal natural resource agency).*

Mitigations discussed for these issues involved constructing more housing, groceries, hospitals, gas stations, and other infrastructure to accommodate these workers, but because these additions would change the nature of the community even after the construction workers left town, this was not necessarily discussed as an acceptable mitigation. Engagement with the local community was determined to be imperative to determining the appropriate mitigation measures for socioeconomic issues.

3.3.7 Air Quality and Noise

Few air quality and noise impacts were identified in interview discussions but impacts included sound and light disturbances from project construction and operation as well as GHG emissions from construction vehicle exhaust and concrete, pumping (if fossil fuels are used), and potential GHG emissions from reservoirs.

Mitigations identified in interviews included requiring light and sound maxima for construction equipment. Although NEPA documents often list mitigations for vehicle emissions (e.g., use newer construction equipment, reduce idling of construction vehicles, establish shuttle transportation or encourage carpooling), they were not discussed in interviews.

There was no mitigation discussed for reservoir GHG emissions although based interviews and review of NEPA documents, this is not necessarily surprising. Findings from the NEPA documents reviewed suggest that closed-loop PSH reservoirs are lined as a standard practice, making them less likely to serve as a significant source of GHG compared to conventional hydropower reservoirs because they typically would not have a substantial source of decomposing material or other environmental conditions resulting in GHG production and emissions. To our knowledge, there has been no consideration of reservoir GHG in proposed project NEPA documents although there has also been little to no empirical scientific evaluation of GHG production in closed-loop PSH facilities.

3.3.8 Cross-cutting Impacts and Mitigations

Interviewees discussed several cross-cutting environmental impact and mitigation issues during our conversations. Below are some quotes describing some of these cross-cutting impacts and, where applicable, a diversity of perspectives about them.

Unintentional introductions of wildlife into project reservoirs and water quality

> *Keeping water in a closed-loop is going to create its own body of challenges. And then there are externalities that are hard to capture, like a hawk flying over with a trout and that trout drops into this water body. And now you've got trout introduced in this ecology, or aquatic invasives that get brought into this water body. And then managing for the water quality within the closed-loop system is still going to be important because you're going to have waterfowl using those areas (eNGO).*

Tradeoffs between developer needs for project viability and robust and timely identification of environmental impacts and mitigations

> *Even with this project, [permitting] should be so quick and easy to do. There was no opposition, there were no comments to the scoping. It should be like stamp approved. But it's going to take three- or four-years, or however long (Project developer).*

> *An expedited NEPA review makes perfect sense in areas where this project is adding economic viability to a site that's being underutilized with minimal or negligible environmental damage or community damage. When it comes to the environmental review, permitting or licensing decisions for a closed-loop pumped storage project, that would be a greenfield development, a new location. I do not support expedited review (eNGO).*

> *This is a really battered watershed and it's hard for stakeholders, at least some of the environmental NGOs, to support. We realize that energy storage is absolutely needed, [but] it's hard to even support new closed-loop pumped hydro. It's getting at that kind of cumulative effects situation. It might be OK in some places, but in places where you have [existing effects] on the water ... there are tipping points. To achieve the same energy storage and grid resiliency ends, it just seems like there are other options that need to be considered (eNGO).*

Comparing closed-loop PSH project footprint and land use environmental impacts with other generation and storage technologies

> *1200 megawatts of storage, 9 hours or 12 depending on how it's configured. ... And your impact on the landscape is 260 acre ponds. If you were going to build that scale of solar in [name of state], you'd need 50,000 acres of land. And on direct comparison with wind, you'd need almost 8000 acres of land. So land use is an important component of this, as well, what is the best value of our resources (Project developer).*

> *What are the impacts of other alternatives. We've done some of the math on this. If you're talking about lithium ion, we've dug how much and what volume of critical minerals are you talking about ... you're having an environmental impact but it may be happening to all those people over there (Federal hydropower operator).*

> *On paper, it makes sense. One of the benefits for pump storage is that it's long term. I'm not familiar with new battery technology. I know batteries have concerns with the rare earth or the materials needed to make them and they don't last forever. A pump storage project would be a 40-year license and would continue going. So that's one of the benefits, and personally it makes sense. ... It's just that the location and the availability of water (Federal natural resource agency).*

4.0 International Case Studies

4.1 Introduction

Few closed-loop PSH projects exist across the globe, although there is currently great interest in developing closed-loop PSH projects. Shepherding closed-loop PSH projects to construction is elusive in most countries outside the United States (Table 4-1). According to data from the International Hydropower Association (IHA) Pumped Storage Tracking Tool (2024), only 13 countries have operational closed-loop PSH plants including Belgium, China, Croatia, Germany, India, Ireland, Israel, Italy, Japan, Romania, Switzerland, Ukraine, and United Kingdom (Table 2). China has begun construction on 30 closed-loop PSH projects whereas numbers of closed-loop PSH projects under construction in other countries are much lower. Australia, France, Indonesia, Israel, Slovakia, Switzerland each have one closed-loop PSH plant under construction and Germany, India, Morocco each have two closed-loop PSH plants under construction. The United States has the most pre-construction closed-loop PSH projects of any country although has no under construction or operational projects. Please note that numbers from the IHA Pumped Storage Tracking Tool (IHA 2024) dataset are lower than numbers of pre-construction projects obtained from FERC.

Table 4-1 Numbers of pre-construction, under construction, and operational closed-loop PSH by countries across the world from the IHA Pumped Storage Tracking Tool. Data accessed 2 January 2024.

Continent/PSH type	Pre-construction	Construction	Operational	Row total
Africa	**5**	**2**	**6**	**13**
Closed-loop	3	2		5
Open-loop	2		6	8
Asia	**63**	**36**	**122**	**221**
Closed-loop	61	34	15	110
Open-loop	2		105	107
Storage		2	2	4
Australia	**10**	**1**	**7**	**18**
Closed-loop	9	1		10
Open-loop	1		5	6
Storage			2	2
Europe	**36**	**9**	**226**	**271**
Closed-loop	24	5	23	52
Open-loop	12	4	178	194

Storage			25	25
North America	**95**		**41**	**136**
Closed-loop	62			62
Open-loop	33		40	73
Storage			1	1
South America	**1**		**4**	**5**
Closed-loop	1			1
Open-loop			4	4
Column total	**210**	**48**	**406**	**664**

In this chapter, we provide additional context on the environmental impacts of closed-loop PSH by examining closed-loop PSH facilities in other countries. We identified potential international case studies of closed-loop PSH through multiple sources, including online searches of academic literature, news

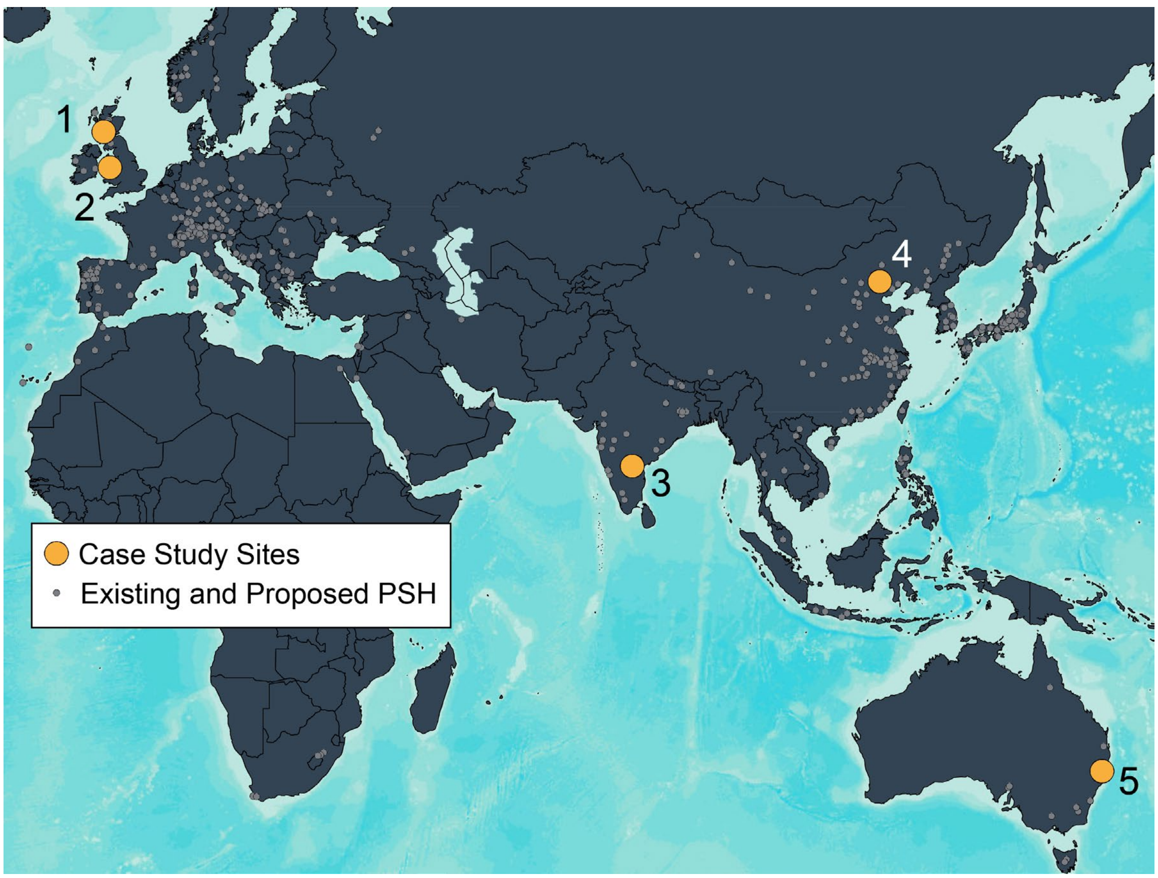

Figure 4-1 Map showing locations of international closed-loop PSH project case studies reviewed in this chapter including 1) Cruachan, 2) Glyn Rhonwy, 3) Pinnapuram, 4) Luanping, 5) Oven Mountain.

media, and Google; review of existing databases, such as the IHA's Pumped Storage Tracking Tool; and personal communications with hydropower community members. These sources provided a preliminary list of more than 100 PSH facilities or projects from 26 countries; however, many of these did not meet our definition of closed-loop PSH, or they did not contain enough publicly available information to construct a narrative summary of impacts.

For example, many facilities identified as closed-loop connect two reservoirs from conventional hydropower facilities created by dams in a river. Facilities configured in this way do not meet our definition of closed-loop, that is, hydropower facilities that are not continuously connected to a naturally flowing waterbody.

To determine whether the international sites met our definition of closed-loop PSH and had publicly available documentation of impacts and mitigations, we conducted targeted keyword searches via Google, news media, and regulatory agency websites using the project name and/or location. Documents of interest included journal articles, project summaries, feasibility studies or reports, scoping reports, and environmental assessments or reports. Among the projects identified, 23 met our definition of closed-loop (Table 4-2). Seven projects provided enough documentation for us to write a narrative summary of impacts, including one which did not have an English translation and was reviewed in Chinese. We selected five projects for this case study chapter, including one operational project undergoing expansion (Cruachan Power Station in Argyll and Bute, Scotland, UK); two projects under construction (Luanping PSH Station in Luanping, China and Pinnapuram Integrated Renewable Energy Project in Andhra Pradesh, India); and two-preconstruction projects (Glyn Rhonwy Pumped Storage Scheme in Llanberis, North Wales, UK, and Oven Mountain Pumped Hydro Energy Storage Project in New South Wales, Australia). These projects have an average capacity of 708-MW and are further summarized in Table 4-1.

Table 4-2 Summary of project characteristics for international closed-loop pumped-storage projects. Based on publicly available documentation, we identified 23 projects that met our definition of closed-loop pumped storage hydropower. In some cases, satellite was used to make the determination.

Project	Location	Status	Capacity (MW)	Brief Description
*Oven Mountain Pumped Hydro Energy Storage Project	Australia	Pre-Construction	600	New construction of both reservoirs
Energy Storage Bernegger (Pfaffenboden/Molln)	Austria	Pre-Construction	300	Gravel pit as lower reservoir
Canyon Creek Pumped Hydro Energy Storage Project	Canada	Pre-Construction	75	New construction of both reservoirs near decommissioned coal mine
Marmora PSP	Canada	Pre-Construction	400	Open-pit iron ore mine as lower reservoir; Integration with solar
Ida-Virumaa Hydroelectric Power Plant	Estonia	Pre-Construction	225	Oil shale mine as lower reservoir; Upper reservoir built on tailings structure
Ippagudem PSP	India	Pre-Construction	3960	New construction of both reservoirs

Shahpur PSP (Rajasthan)	India	Pre-Construction	2520	New construction of both reservoirs; Integration with wind and solar
Veeraballi Off-Stream Closed-loop Pumped Storage Project	India	Pre-Construction	1800	New construction of both reservoirs
Silvermines Hydro	Ireland	Pre-Construction	360	Existing artificial lake from mine pit as lower reservoir
*Glyn Rhonwy Pumped Storage Scheme	UK	Pre-Construction	100	Quarries as both reservoirs
Kidston Pumped Storage Hydro Project (K2-Hydro)	Australia	Construction	250	Gold mine pits as both reservoirs
*Luanping PSH Station	China	Construction	1200	Magnetite mining pit as lower reservoir
*Pinnapuram Integrated Renewable Energy Project	India	Construction	1200	New construction of both reservoirs; Integration with wind and solar
Kokhav Hayarden Pumped Storage Hydropower Project	Israel	Construction	344	New construction of both reservoirs
Manara PSP	Israel	Construction	156	New construction of both reservoirs
*Cruachan Power Station Expansion Project	UK	Construction	440	Loch Awe as lower reservoir
Turlough Hill Power Station	Ireland	Operational	292	Naturally occurring lake as bottom reservoir
Mount Gilboa PSP	Israel	Operational	300	New construction of both reservoirs
Anapo	Italy	Operational	500	New construction of both reservoirs
Campo Moro	Italy	Operational	37	New construction of both reservoirs
Chiotas-Piastra Plant (Entracque Plant)	Italy	Operational	1200	New construction of both reservoirs; shared lower reservoir with co-located plant
Edolo Hydroelectric Plant	Italy	Operational	978	New construction of three reservoirs; two upper reservoirs
Rovina-Piastra Plant (Entracque Plant)	Italy	Operational	134	New construction of both reservoirs; shared lower reservoir with co-located plant

** Included in report*

Each international case study includes a project overview describing its location, reservoirs, and basic operational structure, as well as a summary of impacts and mitigations related to geologic and soil resources, water resources, aquatic resources, terrestrial resources, species of concern, recreation and land use, aesthetic resources, cultural resources, socioeconomics, and air quality and noise. Not all international documentation followed these resource categories, so we recategorized them where possible and appropriate.

4.2 Methods

Case studies were selected based on geography to the extent possible and completeness of publicly available documents. Because of incongruities among case study projects and documents, we did not present quantitative assessments of case study impacts and mitigations as we did for United States projects in Appendix C.

4.3 Cruachan Power Station Expansion Project

Note: Information for this case study was obtained from the project website and its Environmental Impact Assessment (EIS) (citation).

The Cruachan Expansion Project (Cruachan 2, license applicant: Drax Cruachan Expansion Limited) is a proposed 600-MW expansion of the existing 440 MW Cruachan Power Station (Cruachan 1, opened 1965) along the banks of Loch Awe in Argyll and Bute, Scotland. The proposed project will be located in the Scottish Highlands adjacent to Cruachan 1 and use the same reservoirs, Cruachan Reservoir as the upper and Loch Awe as the lower. The project will operate independently of Cruachan 1 and require construction of new intake structures, underground shafts and tunnels, an underground powerhouse, substation extension, ventilation shaft, tailrace tunnel, inlet/outlet structure, as well as work buildings and access tunnels. While this project is categorized as closed-loop PSH and technically meets our report definition of closed-loop PSH, it uses a natural lake as a lower reservoir, creating potential aquatic resource impacts to aquatic biota similarly to an open-loop facility including fish entrainment and impingement. This project would not meet the FERC definition of a closed-loop project eligible for the expedited 2-year licensing process because that definition excludes projects that use lakes as a reservoir.

Figure 4-2. Map showing location of the Cruachan Power Station Expansion Project. Non-labeled orange dots represent locations of other facilities discussed in this chapter.

Cruachan Reservoir (live storage: 8.5 x 10^6-m^3) is located within a natural coire on the southwest facing slope of Ben Cruachan and has connectivity to the ocean through the River Awe. The reservoir is impounded by a concrete mixed gravity and buttress dam across the natural outlet to the Allt Cruachan Burn, and there is path around the reservoir for public access the summit of Ben Cruachan. Loch Awe, which is impounded by Loch Awe Barrage, and the longest freshwater loch in Scotland (41-km) as well as the third largest (38-km^2). The current abstraction from Loch Awe will not change as a result of the proposed project, and neither groundwater abstractions nor dewatering are planned. Land for the proposed project site includes a range of habitats, including grasslands, wetlands, and woodland. Part of this area includes two internationally designated sites, the Glen Etive and Glen Fyne Special Protection Area and part of the Loch Etive Woods Special Area of Conservation, as well as the Coille Leitire Site of Special Scientific Interest on an ancient woodland.

4.3.1 Cruachan Impacts and Mitigations

4.3.1.1 Geologic and Soil Resources

Potential project impacts to geologic and soil resources are expected during the construction phase, including potential disturbance to peat deposits, groundwater and soil contamination from tunnelling, and contamination due to storage of fuel or oil used during construction. Proposed mitigations include project management plans (e.g., Construction Environment Management Plan, Peat Management Plan), which emphasize a project design that avoids construction on areas with peat.

4.3.1.2 Water Resources

Water resource impacts were predicted across the construction and operation phases of the project. During construction, impacts include increased runoff and pollution potential from a temporary road diversion; increased sedimentation to waterbodies; potential mobilization of rock and spoil material into the lower reservoir from wind and rain related runoff; and temporary increases in flood risk due to increased surface water runoff from working areas.

During operation, impacts include potential alterations to the hydrological regime of both reservoirs; alterations to the hydro-morphology of the upper reservoir; volume displacement, water levels effects, and flood risk due to new structures; increases in surface water runoff due to new in permanent impermeable surfaces; increased chemical and physical pollution to surface water; additional scour and morphological damage to the bed and banks of the lower reservoir; and increased foul water effluent from operational buildings.

Proposed mitigations for construction impacts include development and implementation of Construction Environment Management Plan, including a temporary canopy structure to limit sediment and runoff from project works. Operational impacts to hydrological regime, hydro-morphology, and runoff are cited as negligible due to minor changes in hydrological discharge, abstraction, and volume displacement in reservoirs. Scouring impacts cited as negligible given limits on the outfall velocity (0.3-m/s) by installation of fish screens. Mitigations for other operational impacts, including potential pollution, will be addressed through the Construction Environment Plan and safe water handling.

4.3.1.3 Aquatic Resources

The main aquatic habitat within the site is the reservoirs, which comprise 17% of the project site. During surveys no species were detected in the upper reservoir despite assumed presence of limited populations of arctic charr and brook lamprey. Four freshwater species were detected in the lower reservoir, including European minnow, European perch, European eel, and brown trout. An Ecological Clerk of Works will oversee construction, including practices within the Construction Environment Management Plan such as pre-commencement surveys and Species Protection Plans, where appropriate. Despite these mitigations, there are potential, though highly localized, residual impacts for Atlantic salmon and sea trout, which are present in the adjacent river catchment, as is the European eel. These residual impacts will be addressed through a Fish Monitoring and Mitigation plan.

4.3.1.4 Terrestrial Resources

Limited terrestrial resource impacts were predicted across the construction and development phases of the project. Construction impacts to habitat and species (mammals, birds, fish) will be managed and mitigated through the same management plans cited in aquatic resources impacts, as well as through a Habitat Restoration and Landscape Mitigation Plan for work areas. After construction mitigation, there are predicted residual impacts to Northern Wet Heaths and otters due to habitat removal during construction. Operational impacts include disturbance to the same species, as well as peat habitat. The Habitat Restoration and Landscape Mitigation Plan will include peat habitat restoration and tree planting, which may enhance biodiversity. In addition, an operational lighting plan will be used to mitigate wildlife impacts.

4.3.1.5 Species of Concern

Protected species impacts were predicted across the construction and development phases of the project. The following protected species were identified within the project site through surveys: otters, badger, red squirrel, pine marten, bats, golden and white-tailed eagle, 50 other species of breeding birds, European minnow, European perch, European eel, and brown trout. Other species of concern include Artic charr and brook lamprey, which are assumed through desk research to be present, as well as Atlantic salmon and sea trout, which are present in the adjacent river catchment. Migratory salmon and sea trout are allowed passage through a fish lift, but spawning habitat was deemed unsuitable or suboptimal. The management plans and mitigation measures outlined in the aquatic and terrestrial resource impacts will be used to limit impacts on protected species.

4.3.1.6 Recreation and Land Use

There are tourist destinations adjacent to the project site but none within it. Recreation and land use impacts are only predicted for the construction phase of the project, including a minor increase in local traffic. A Construction Traffic Management Plan and temporary pedestrian crossing signal will mitigate this impact. Otherwise, existing mitigations make impacts to local tourism and recreation unlikely.

4.3.1.7 Aesthetic Resources

Aesthetic resource impacts are predicted for the construction and operation phases of the project. Temporary impacts to the Rocky Coastland and Rugged Mountain landscape are predicted due to construction of the lower reservoir waterside structure and upper intake structure. Landscape impacts for the lower reservoir will extend up to 7.5-km from the proposed structure and be largely contained within the mountains for the upper intake. In addition, project construction and operation may visually impact three local properties, two roads, and two recreational routes within 1km of the site. Landscape and visual impacts are expected to be significantly reduced after 10-years of operation due to planting and vegetation regrowth and establishment.

4.3.1.8 Cultural Resources

Cultural resource impacts are predicted for the construction and operation phases of the project. Construction will significantly but temporarily impact the Cruachan Dam, which is listed as a heritage asset, but this cannot be mitigated due to the project’s connection to the existing power station.

Construction may also necessitate removal of four post-medieval agricultural features, but no mitigation is planned given their minor significance. During operation, there is a predicted minor impact to the character of the Cruachan Dam given the visibility of the upper intake. Partial mitigation may be achieved through intake design considerations.

4.3.1.9 Socioeconomics

Minor beneficial socioeconomic impacts are predicted during project construction and operation. During construction, a temporary increase in local employment is predicted. During operation, an increase in indirect employment through the supply chain and wider economy is predicted.

4.3.1.10 Air Quality and Noise

Air quality and noise impacts are predicted during construction for local residents and construction workers resulting from vehicle movements, blasting, and dust. Noise and vibration impacts will be partially mitigated through the Construction Environment Management Plan and Construction Traffic Management Plan, which include work phasing and restricted work times, durations, and vehicle movements. Air quality impacts will be mitigated through the same measures listed above, as well as the Dust Management Plan and protective clothing for construction workers. There are no predicted air quality and noise impacts during project operation.

4.4 Luanping (滦平) Pumped Storage Hydropower Station

Note: Information for this case study was obtained from the project website and its EIS.

Luanping Pumped Storage Hydropower Station is located in Luanping County, Chengde City, Hebei Province, China, approximately 247km northeast from the capital city Beijing. The proposed installed capacity of Luanping project is 1200MW, and the rated water head is 470-m.

The main project includes an upper reservoir, a lower reservoir, an underground powerhouse, a water filling/recharge system, and a control room. Project construction started in December 2022, and the estimated project construction is 69-months. The upper reservoir is located in the west valley of Pingding Mountain and will require new construction. The designed reservoir capacity is 17.92 million m^3 with a corresponding water level at 940-m. The lower reservoir is located in the west of the Shanghabaqin village and will use an existing magnetite mining pit. The designed capacity for lower reservoir is 28.67 x 10^6-m^3 with the water storage level at 460-m.

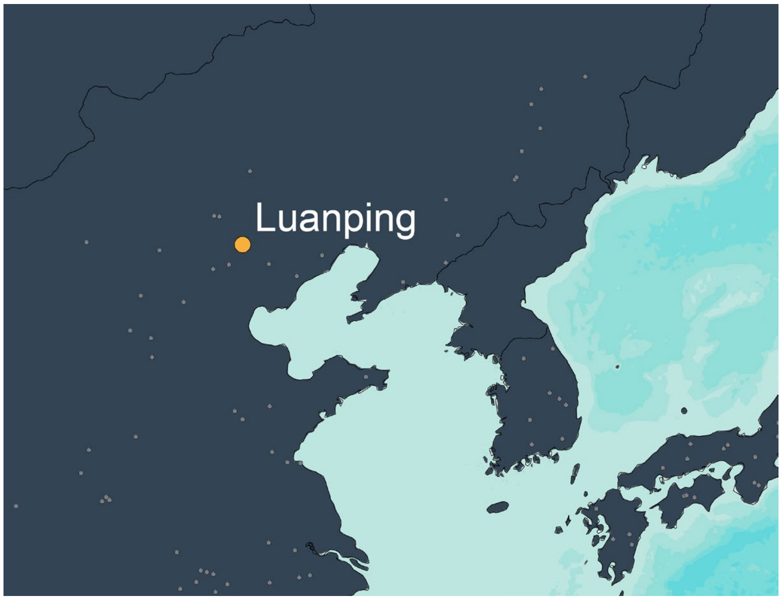

Figure 4-3. Map showing location of the Luanping Pumped Storage Hydropower Station.

Luanping project takes water from the nearby surface water source Yixun River. The water filling and recharge system mainly includes a rubber dam and a water transfer tunnel, which are used for both initial water filling and periodic recharge. The tunnel is about 2.3-km long and connects the lower reservoir and Yixun River. The rubber dam will be located on the Yixun River, west side of the lower reservoir. The height of the rubber dam is 3.3-m, and the total length of the dam is 85-m. For the initial fill, about 45.5 x 10^6-m^3 water will be abstracted to permit full operation. During project operation, the annual water replenishment from the Yixun River will be approximately 1.06 x 10^6-m^3.

4.4.1 Luanping Impacts and Mitigations

4.4.1.1 Geologic and Soil Resources

During the construction phase, the project may have a negative impact on the structure, fertility, and physical properties of the soil in the evaluation area due to surface rolling, excavation, and land occupation. While in the operation phase, the soil in the project area has a moderate risk of salinization due to the shallow groundwater level and high evaporation rates. Mitigation measures include water quality management in the reservoir area during operation to avoid water pollution that may lead to soil pollution (e.g., acidification, alkalization, and salinization); preventing pollutants from entering the soil by waste management practices (e.g., collection and treatment of wastewater, garbage, waste oil); and leakage prevention measures in the reservoir area.

Overall, project construction and operation is unlikely to adversely affect local geology; however, there are possible changes to the reservoir bank topography and stability after the water filling. Measures such as sufficient support, concrete blocking, concrete backfill, and lining during the construction process could help mitigate the impacts.

4.4.1.2 Water Resources

Initial filling and operation of the project will cause surface water quantity reduction and reduce flows up to about 45-km downstream of the surface water collection point located on Yixun River. Mitigation actions include prioritizing the ecological flow before water intake during the initial filling and operation; installation of ecological flow online monitoring facilities; and stopping water intake when the natural flow at the water collection point is less than the calculated minimum ecological flow.

Wastewater from construction activities (e.g., sand and gravel processing, concrete production, machinery repair) and domestic sources will be treated and reused without external discharge, so wastewater will not likely affect the surface water quality of surrounding natural water systems. Mitigation measures for wastewater include reusing treated water for construction, dust reduction, and on-site greening. During operation, a small amount of wastewater for maintenance, ground washing and domestic uses will be treated and reused without external discharge, which will not likely affect the surface water quality of surrounding natural water systems.

The biological oxygen demand, chemical oxygen demand, nutrients (nitrogen, phosphorous), total suspended solids, and heavy metals in the reservoirs will likely increase during the initial filling stage and improve later due to water circulation between the upper and lower reservoirs and freshwater recharge. Mitigation actions include reservoir bottom cleaning before water storage and water and soil conservation measures around the reservoirs.

During construction, excavation may temporarily lower the groundwater level in the surrounding area. Measures such as sufficient support, concrete blocking, concrete backfill, and lining could help mitigate the impacts during the construction process. During operation, the upper reservoir has a potential risk of leakage since the water storage elevation is greater than the groundwater level elevation of the surrounding area. Based on hydrological analysis, the groundwater level in the area will likely increase after the water filling phase, which will reduce the leakage risk of the upper reservoir. Overall, the impact on groundwater level change is not significant. Mitigation actions include leakage prevention measures in the reservoir area. Domestic water for the construction crew and the developer is taken from an on-site groundwater well. Due to the very small amount, negligible adverse effect is expected on the groundwater quantity.

Impacts to groundwater quality are expected to be negligible during the construction and operation phases. The wastewater collection, treatment, and reuse system will be strictly managed to achieve comprehensive water use without external discharge, which could ensure little impact the groundwater quality.

4.4.1.3 Aquatic Resources

There are no significant impacts expected for aquatic habitats and species during the construction and the operation phase of the project. During construction, initial filling, and the operation, surface water extraction will account for the ecological flow river and ensure a constant flow during dry periods. The impact on fish and other species during the construction period will be limited to increases in the concentration of total suspended solids, as well as noise generated during the construction of the water intake pipeline, which may disturb fish. Pre-construction surveys indicate the project area is mainly dominated by small, benthic fish, and the impact of both construction and operation periods is limited.

4.4.1.4 Terrestrial Resources

The construction and the submersion of the reservoir area will cause vegetation damage and loss of 32% woodland, 11% grassland, 5% farmland, and 1% shrubland habitat; however, this is mostly limited to the upper reservoir area, since the lower reservoir is an existing mining pit. The construction will also fragment the terrestrial landscape, reduce the vegetation biomass by 7%, decrease net primary productivity in the project area, and negatively impact the resilience and integrity of the local terrestrial ecosystem.

Project construction will cause habitat loss for amphibians and reptiles. Noises and lights during construction have a negative impact on bird breeding and may force local bird species to migrate and in turn reduce the bird populations. Construction may also increase the risk of bird collisions. Pre-construction surveys identified potential impacts to bird species in the project area, including two species of nationally protected birds including long-eared owl and red-footed falcon and three species of locally protected birds, including blue-billed magpie, magpie and gray magpie.

Mitigation actions for soil and water conservation include covering excavated slopes during construction, soil preservation for vegetation restoration, and post-construction vegetation restoration. During operation, negligible effects are expected for terrestrial ecosystems.

4.4.1.5 Cultural Resources

Within 100-m of the project area there are three state level heritage assets. The construction may affect the heritage assets due to vibration and dust. Mitigation actions before the construction stage include a pre-construction survey, development of a heritage protection emergency plan, and development of a detailed blasting plan based on the lithology around the heritage assets. Mitigation actions during construction include the establishment of a fence to isolate the construction site and heritage assets and siting material yards, dumps, and other temporary construction sites away from assets. Impacts to the landscape and scenery view during project operation will be mitigated, including through routine inspection and monitoring of the heritage and slope stability of the reservoirs.

4.4.1.6 Socioeconomics

Monetary compensation will be provided to 108 local farmers who will have a total of 9-ha of farmland expropriated for project construction. Because this land is characterized as basic farmland, the same amount of land will need to be recategorized as basic farmland to supplement the occupied area based on the food security regulations in China. The project affects 6.19-km of 10kv transmission line for Baotong Mining Co., Ltd, which owns the magnetite pit in lower reservoir area; one-time compensation will be paid to the mining company. During operation, the annual income of the project is expected to be 1.57 billion yuan (RMB), and the annual value-added tax payment is about 100-200 million yuan (RMB). About 130 jobs will be created. The electricity from the project will be distributed to the Beijing, Tianjin, and Hebei power grids.

4.4.1.7 Air Quality and Noise

Negligible air quality impacts are expected during project construction and operation. Mitigation actions during the construction phase to reduce dust emissions from excavation, blasting, and transportation include installing dust removal equipment for sand processing and the concrete production system; covered or sealed transport of cement, fly ash and slag; and road cleaning and watering to reduce dust.

During construction, temporary noise and vibration impacts are expected for construction workers and adjacent settlements; a noise management plan will help to mitigate the impacts. Specific measures include selection of low-noise equipment; use of vibration damping bases and sound insulation covers for equipment; deceleration and no-noise areas; personal protection for construction workers; and 1.2-km of mobile sound barriers for nearby settlements. During operation, negligible noise and vibration impacts are expected given the underground and distant location of the generator units.

4.5 Pinnapuram Integrated Renewable Energy Project

Note: Information for this case study was obtained from the project website, project summary, and Feasibility Report (citation).

The Standalone Pumped Storage Component of Pinnapuram Integrated Renewable Energy Project (license applicant: Greenko Energies) is a 1200-MW project being developed near the Pinnapuram village (2km) in the Kurnool district of Andhra Pradesh, India. The hybrid project will be integrated with 1000-MW solar and 550-MW wind generation; power from each component would use a central pooling station connected to the existing substation at Orvakallu. Construction for the pumped storage component will require 714-ha, which includes part of the Gani Reserve Forest. The area within 10km of project works is characterized by moderately sloping terrain with land use and cover including forest (12.5%), scrub (18.7%), agriculture (49.0%), settlement (0.5%), mining (0.8%), barren rock (14.3%), and water (4.2%). Depending on site suitability, technical feasibility, and local energy requirements or demand, the project identified the possibility for future expansion to 3000-MW solar, 2000-MW wind, and 2400-MW pumped storage.

Figure 4-4. Map showing location of the Pinnapuram Integrated Renewable Energy Project.

The project includes two new reservoirs (119.3-m head) northwest of the existing Gorakallu Reservoir (12.4-thousand million cubic feet), which is allocated in part for irrigation. The lower reservoir (319-ha, 4-km long, 1.5-km wide) will be located approximately 37-km from Kurnool district and largely shielded by isolated small ridges. The upper reservoir (280-ha, 7-km long) will be located about 65-km from Kurnool and adjacent to Pinnapuram village. Both reservoirs will have a live storage capacity of 1.2-thousand million cubic feet and be enclosed by rockfill embankments at an average height of 12- to 14-m and maximum height of 33m for the lower reservoir and 35-m for the upper reservoir. Initial fill of the upper reservoir will require water to be pumped from the Gorakallu Reservoir, and annual evaporation losses (7.85 x 10^6-m^3) will also be sourced from Gorakallu. Additional project works will include intake and outlet structures, penstock, aboveground powerhouse, tail race channel, access roads, contractor facilities, and temporary worker camps.

4.5.1 Pinnapuram Impacts and Mitigations

Note: The feasibility report for this project did not identify operational impacts of the project.

4.5.1.1 Geologic and Soil Resources

Construction impacts to geologic and soil resources may include erosion and land slips or slides due to slope cutting.

4.5.1.2 Water Resources

Potential impacts to water resources from construction include pollution and drainage disruption in small tributaries. Construction activities such as rock crushing and blasting may impact water quality and turbidity through release of suspended solids in effluent. Worker camps and additional construction works may contribute pollution from improper discharge or disposal of wastewater, sewage, fuel, and lubricants. Road construction may also disrupt the natural drainage regime. Proposed mitigations for these impacts will be addressed in monitoring and management plans, such as the Air and Water Management Plan, Solid Waste Management Plan, and Muck Dumping Plan. Specific mitigation measures may include effluent treatment as well as construction of septic tanks, soak pits, and retaining walls at dumping sites.

4.5.1.3 Aquatic Resources

There are no aquatic resource impacts predicted for project construction nor operation.

4.5.1.4 Terrestrial Resources

Terrestrial resource impacts from project construction may include loss of forest land and vegetation as well as disturbance of native wildlife. Forest land and vegetation will be lost from project works, including the construction materials and fuelwood required for the temporary worker camps. Wildlife disturbance will result from construction noise and increased opportunity for human interference within and around the worker camps. Specific mitigation measures to address land and vegetation impacts include biodiversity monitoring, rehabilitation of critical species, preservation and restoration of disturbed areas, compensatory afforestation, grass replanting, soil conservation, and greenbelt development.

Specific mitigation measures to address wildlife disturbance include surveillance. The mitigation measures and others will be outline in specific monitoring and management plans, including the Environmental Monitoring Plan, Biodiversity Conservation and Wildlife Management Plan, Compensatory Afforestation Plan, Landscape Restoration and Green Belt Development Plan. In addition, the project will elect a Biodiversity Management Committee to oversee construction works.

4.5.1.5 Species of Concern

Desk and field surveys of plants and animals within 10-km of the project area identified 133 flowering plant species, 21 mammal species, 47 bird species, 13 butterfly species, and four reptile species. Two mammals are listed as Endangered, including the Wild Dog (*Cuon alpinus*) and Black Buck (*Antilope cervicapra*). Two bird species are listed as Endangered, including the Black-shouldered Kite (*Elanus axillaris*) and Indian Peafowl (*Pavo cristatus*), and the Black-necked stork (*Ephippiorhynchus asiaticus*) is reported as Near Threatened. As mentioned above, the primary impacts to protected species may include loss of forest habitat and disturbance via construction noise and human interaction. The Biodiversity Conservation and Wildlife Management Plan, together with the Biodiversity Management

Committee, will prioritize preservation and restoration of natural habitats where possible, rehabilitation of critical species via on-site and off-site conservation, habitat enhancement and afforestation, as well as awareness raising activities for workers in the project area.

4.5.1.6 Recreation and Land Use

Project development is proposed on forest (366-ha), private (120-ha), and government (228-ha) land. Potential impacts to land use include acquisition and/or loss of land, as well as increased access to previously undisturbed land. Loss of forest land will be mitigated using the same measure listed above. Compensation or mitigation measures for loss of private land will be informed by a social impact assessment, which includes a socioeconomic survey.

4.5.1.7 Aesthetic Resources

There are no aesthetic resource impacts predicted for project construction nor operation.

4.5.1.8 Cultural Resources

There are no cultural resource impacts predicted during project construction nor operation because no monuments of national or archeological significance are located in the project area.

4.5.1.9 Socioeconomic

Project construction may contribute socioeconomic impacts to the local area. Potential positive impacts include increased job opportunities (i.e., 1100 jobs designated for locals, 900 for migrants from other areas) and indirect benefits to the local service industry. Potential negative impacts include an increase in sociocultural conflicts associated with the influx of non-local populations, as well as increased disease spread potential given the source and number of workers temporarily housed within the project area. Project developers plan to work with local leaders and organizations to identify and mitigate potential sociocultural conflicts. Health impacts will be addressed through on-site medical services as well as existing measures outlined in project monitoring and management plans.

4.5.1.10 Air Quality and Noise

Project construction may contribute air quality and noise impacts. Project excavation, construction, and transportation may reduce air quality through dust generation and other suspended particulate matter; related air pollution may impact worker and vegetation health. Construction works may also increase noise pollution, resulting in worker hearing loss and wildlife disturbance. Proposed mitigation measures for air quality impacts include limits on dust-generation activities during high wind events, covering vehicles carrying waste, watering roads, and wet-drilling. Proposed mitigation measures for noise impacts include personal protective equipment, monitoring and management of construction movement, blasting controls and surveillance, and planting vegetation near the construction area. These mitigation measures are further detailed in the Air and Water Management Plan.

4.6 Glyn Rhonwy Pumped Storage Scheme

Note: Information for this case study was obtained from the project website and Environmental Statement (citation).

The Glyn Rhonwy Pumped Storage Scheme (license applicant: Snowdonia Pumped Hydro Limited) is a planned 99.9-MW project located on the slopes of Cefn Du mountain, 1.5km northwest of Llanberis, North Wales near Snowdonia National Park. The project site (97.77-ha) contains the Glyn Rhonwy Industrial Estate, which includes a series of abandoned quarry pits, plantation woodland, grazing land, and a road network. The project site is also located within or near environmentally designated sites; Llyn Padarn is a nearby Site of Special Scientific Interest, and the project is within a Landscape Character Area (historical landscape) and the Dinorwig Landscape of Outstanding Historical Influence. Clegir Road intersects the quarries and offers public access to the site. Access to specific areas, such as the quarries, are restricted by locked gates and fencing; however, there is evidence of unauthorized access for leisure activities.

Figure 4-5. Map showing location of the Glyn Rhonwy Pumped Storage Scheme.

Two existing slate quarries which have collected water will serve as the reservoirs for this project. Chwarel Fawr (Quarry 1) will comprise the upper reservoir, and Glyn Rhonwy (Quarry 6) will comprise the lower reservoir. The slopes adjacent to the quarries include grazing land covered with slate waste and other remnants of industrial work on the site. To prepare the quarries for the project, reservoir excavation, stabilization, and dam construction are proposed, including a 510-m long dam (25-m above ground level) for the upper reservoir and a 215-m long dam (15-m above ground level) for the lower reservoir. To provide equivalent storage capacity in each of the reservoirs (1.3 x 10^6-m^3), the lower reservoir will require excavation beyond dam construction. Spoil material that cannot be repurposed during construction and will be deposited among the existing slate mounds of the upper reservoir.

Both project reservoirs will include an overflow spillway to natural watercourses with the upper reservoir discharging into Nant y Betws and the lower reservoir discharging into Llyn Padarn. During construction, existing water from the reservoirs will be discharged into those watercourses after management to minimize suspended solid transport. The Llyn Padarn spillway and adjacent pump station will be used to abstract water for initial filling and periodic top-up. After construction, the spillways will permit intermittent, operational discharges and drawdown in case of pump system failure.

4.6.1 Glyn Rhonwy Impacts and Mitigations

4.6.1.1 Geologic and Soil Resources

Project impacts to geology and soil resources are not expected during construction or operation. While construction will yield slate waste, it will be reused for dam construction at both reservoirs and slate mound stabilization at the upper reservoir. In addition, project excavation may reveal contaminated land or unexploded ammunitions from past use of adjacent land as a munitions store; the Ordnance Management Strategy will outline measures to address associated impacts and risks.

4.6.1.2 Water Resources

Preconstruction surveys and desk research determined groundwater does not provide an important contribution to local water resources, and existing private water supplies will not be impacted. That said, both minor and moderate adverse impacts are predicted for water resources during project construction and operation. Construction poses a potential risk of pollution via sediment (e.g., aluminum) runoff and/or accidental construction or maintenance releases into surface water drainage systems and quarries; these materials may also mobilize via runoff and impact surface and groundwater quality. The impacts are predicted to be minor except for the project water source, where a temporary moderate impact is predicted due to the need for construction within the waterbody and its location downstream. The temporary abstraction (3300-m3/day) for initial fill and top-up is not predicted to have any significant impact on water levels or quality.

The primary impacts during operation include management of excess water. A permanent moderate adverse impact from spillway construction for the upper reservoir may contribute to a loss in lakebed habitat and the potential culverting of the watercourse. A minor adverse impact on water quality is predicted for the same stream due to discharges and its lower dilution potential. In addition, sealing of the lower reservoir may block existing drainage pathways and cause flooding.

Proposed mitigations for construction include development and implementation of plans and programs for water management, pollution prevention, and water quality monitoring. Precautionary measures and construction design and management will seek to prevent direct discharge and ensure treatment before discharging if monitoring determines changes in water quality. For operation, proposed mitigations include maintenance of water levels and dewatering, as well as an outfall diffuser to disperse flows and avoid lakebed scour. In addition, preference for controlled discharge of excess water will be given to the spillway from the lower reservoir, where impacts will be smaller.

4.6.1.3 Aquatic Resources

Minor adverse impacts are predicted for aquatic resources during project construction and operation. Construction will result in permanent but small loss of lakebed habitat within the project water source. Vibration from construction will also have a minor impact on Artic Charr. During operation, impacts are predicted for a Special Area of Conservation and the project water source, including alterations to the flow regime, water temperature, and nutrient load. In addition, there is potential risk of invasive species introduction to the Special Area of Conservation and maintenance-related pollution to the project water source.

An Ecological Clerk of Works will oversee construction and mitigation measures including pre-construction surveys, a Habitat Management Plan, and invasive species and water quality monitoring. If contamination is detected, water will be treated before being discharged into watercourses. In addition, engineering solutions, such as screening the spillway infrastructure and locating the outlet above the thermocline, will be employed to avoid adverse impacts to fish, including Arctic Charr.

4.6.1.4 Terrestrial Resources

Terrestrial resource impacts are predicted for the construction and operation phases of the project. During construction, permanent minor impacts are predicted from habitat loss and creation. Adverse impacts from habitat loss include Local Wildlife Sites, as well as heath, broadleaved woodland, coniferous woodland, mixed woodland, acid grassland, standing water, and quarry/spoil habitats. Beneficial impacts include spoil habitat creation. As a result of habitat loss, permanent minor impacts are also predicted for wildlife, including reptiles, bids, and bats (e.g., loss of nest sites, roost modification, fragmentation). The proposed project will also have a significant, permanent moderate impact on bats from loss of tree roosts. Predicted impacts during operation include loss of quarry habitats. An Ecological Clerk of Works will oversee construction and mitigation measures including pre-construction surveys, a Habitat Management Plan, and bat habitat enhancement.

4.6.1.5 Species of Concern

Protected or notable species identified through desk research and surveys in the project area include plants, invertebrates, fish, amphibians, reptiles, birds, bats, and other mammals. Two protected species of birds were recorded, including the peregrine falcon and cough, as well as an additional four Red List and nine Amber List Birds of Conservation Concern. Other critical species include the lesser horseshoe bats, which designate the site as a Special Area of Concern, as well as badgers, otters, water voles, European eel, and Arctic charr. The project predicts no impacts on plants, reptiles, birds, polecat, and badgers. Habitat within the project area was deemed unlikely to support populations of otters, water voles, European eel, and Arctic charr. Construction and maintenance activities have the potential to impact bats. Specific management and mitigation measures for bats include monitoring and reporting, tunnel inspection and bat exclusion, habitat enhancement (e.g., bat boxes, wooden batons), noise and vibration management, and lighting design to limit disturbance. Mitigation measures for other species include pollution prevention, fencing off critical habitats, as well as measures outlined in the resource categories listed above.

4.6.1.6 Recreation and Land Use

Recreation and land use impacts are predicted only for the construction phase of the project. This includes a temporary adverse impact on local highway traffic, which may affect tourism and recreation access near the project site. Proposed mitigations for the predicted impacts are outlined in the Construction Traffic Management plan, which will schedule and control construction movements and maintain pedestrian access within and around the project site.

4.6.1.7 Aesthetic Resources

Aesthetic resource impacts are predicted for the construction and operation phases of the project. Construction will have a limited adverse impact on the landscape character around Llanberis and Snowdonia National Park, as well as on views from several local mountains and scenic areas. During operation, visual impacts from the dam on the upper reservoir are predicted for recreationists. Proposed mitigations for construction and operation impacts include reinstatement of landforms and vegetation, screening by vegetation, use of local construction materials, and other design considerations.

4.6.1.8 Cultural Resources

Cultural resource impacts are predicted for project construction but not operation. Construction may cause significant adverse impacts to 24 heritage assets, with most assets related to the slate extraction industry. Proposed mitigations for partial or whole asset losses include landscape surveying, building recording, archaeological excavation and recording, and archaeological monitoring. In addition, potential discovery of unrecorded archaeological assets within the existing spoil heaps mean further archaeological investigation and mitigation measures will be employed as needed.

4.6.1.9 Socioeconomics

Socioeconomic impacts from the project are predicted during construction and operation. Temporary positive direct and indirect impacts are expected during construction resulting from employment opportunities and increased investment in local services. A temporary decrease in tourist numbers due to construction may contribute a temporary minor negative impact to the local economy. To help maintain tourist activity, public access and safety will be ensured through traffic diversions and other pedestrian routes. During project operation, 20-35 jobs will be created with net benefits predicted for the local and regional economy.

4.6.1.10 Air Quality and Noise

Exposure to air quality and noise impacts are predicted during construction for local residents, construction workers, and ecology from vehicle movements, drilling, blasting, and dust. Noise, vibration, and dust emissions may result in temporary significant effects for local properties. Noise and vibration impacts will be minimized through a Noise Management Plan and the creation of a community liaison group to identify and address localized effects, where possible. Air quality impacts will be mitigated through the Air Quality Management Plan and Dust Management Plan, which outline best practices for project site planning and management to prevent dust generation, including wheel wash facilities, road sweepers, and speed restrictions. There are no predicted air quality and noise impacts during project operation.

4.7 Oven Mountain Pumped Hydro Energy Storage Project

Note: Information for this case study was obtained from the project website and Scoping Report (citation). The EIS was made available after this chapter was drafted.

The Oven Mountain Pumped Hydro Energy Storage Project (license applicant: OMPS Pty Ltd) is a proposed 600-MW project located on private land between Armidale (60-km northwest) and Kempsey (75-km southeast) in New South Wales, Australia. The project area (2392-ha) is bordered by the Macleay River to the west, Carrai National Park to the east, and Oxley Wild Rivers National Park to the south. The Gondwana Rainforests of Australia are adjacent to the Macleay River and makeup part of Oxley Wild Rivers National Park. The project area is located within the New England tablelands and is characterized by steep and undulating terrain with vegetation cover ranging from heavy to cleared.

Figure 4-6. Map showing location of the Oven Mountain Pumped Hydro Energy Storage Project.

The project proposes construction of two new reservoirs on Fingerboard Crossing Creek, an ephemeral tributary of the Macleay River. The upper reservoir would be located on the upper reaches of the creek in a steep valley with either a roller compressed concrete dam or a concrete faced rockfill dam. The reservoir would inundate up to 23-ha. Beyond reservoir and dam construction, project works would include a new underground power station, water and access tunnels, surge tank, intake and outlet structures, new transmission lines, substation augmentation or construction, access roads, and an on-site quarry.

Both project reservoirs would include spillways to discharge excess water from seepage, groundwater, rainfall, and/or flood events into the creek bed. Excess water would be diffused prior to discharge, and creek modifications may be required depending on the scour suitability of the underlying geology. The lower reservoir would be connected to the Macleay River and a pump station at or near the creek to facilitate initial fill (up to 6000-ML) and periodic top-up; initial filling would occur during high flow events to ensure minimal impact on flow and downstream water uses.

4.7.1 Oven Mountain Impacts and Mitigations

Note: The scoping report for this project does not meaningfully address avoidance, mitigation, and/or offset measures; they will be outlined in the forthcoming project NEPA document.

4.7.2 Geologic and Soil Resources

Impacts to geologic and soil resources are predicted during project construction and operation. Construction impacts include soil erosion and sediment transport particularly from works at higher elevations, chemical contamination, from construction and stored fuels or other hazardous materials, improper waste disposal, and disturbance of acid sulfate soils or acid forming bedrock from tunneling. During operation, there is low potential for soil erosion as well as sediment and turbid water runoff. Impacts from construction and operation would be managed and mitigated through erosion and sediment controls, including soil assessment and characterization and erosion and landform evolution modeling. Rehabilitation would be conducted where possible with support from rehabilitation trials.

4.7.3 Water Resources

Impacts to surface and groundwater resources are predicted during the construction and operation phases of the project. During construction, potential surface water impacts include changes in water quality (i.e., erosion, sedimentation) from dam construction and vegetation removal, potential changes to the downstream water quality flow regime due to water extraction, and changes to downstream flood extents from temporary works. During operation, potential surface water impacts include changes to the downstream flow regime, erosion associated with operational discharges into the reservoirs and emergency discharges into the river, geomorphological impacts from reservoir drawdown, and changes to the downstream flood extents.

Groundwater impacts during construction may include loss of natural flows sustaining watercourses, loss of baseflow in permanent streams, lowered regional groundwater levels, loss of water supply to groundwater dependent ecosystems, high groundwater inflows from fractured or faulted geology, and degraded inflow or groundwater quality from construction activities and waste. During operation, potential groundwater impacts include lowered groundwater levels and related changes to surface flow.

To mitigate these potential impacts, the project proposes surface water erosion and sediment controls, as well as groundwater management controls. Specific mitigation measures for groundwater may include pre-grouting fractured or faulted zones, lining of tunnels, maintenance of baseflows in existing watercourses, and treatment of groundwater inflows. Further mitigation measures are to be defined.

4.7.4 Aquatic Resources

Aquatic resource impacts are predicted for project construction and operation. Project construction may negatively impact water quality, endangered ecological communities, aquatic habitat, and threatened species. Construction of roads and other infrastructure may contribute to sediment transport (e.g., antimony, arsenic), sedimentation, erosion, runoff, and removal or inundation of habitat. Construction of reservoirs, dams, and waterway crossings may disrupt surface water hydrology and flow, as well as fish passage and riparian vegetation. Initial and operational filling of the reservoirs could impact aquatic habitat, threatened species, and other species within the source river, including through entrainment. Construction and operation of tunnels may negatively impact groundwater quality and groundwater dependent ecosystems. Additionally, flood events and emergency water releases during operation may affect water quality (e.g., temperature, sedimentation), aquatic habitat, and threatened species.

4.7.4.1 Terrestrial Resources

Terrestrial resource impacts are predicted for the construction phase of the project. Construction of project facilities, reservoirs, and access roads would necessitate vegetation clearing and topography reshaping. This could have direct, short- and long-term impacts on native vegetation, endangered ecological communities, and threatened plant species, and indirect impacts through loss of feeding, refuge, and breeding habitat for native and threatened wildlife. Project construction would also result in hydrology changes that could impact overland flows, drainage lines, and waterways; in turn, this may negatively impact vegetation communities and diversity. In addition, noise, traffic, lights, and dust from construction of reservoirs and tunnels may negatively impact local wildlife populations. Specific operational impacts to terrestrial resources were not cited, except consideration for tourist impacts on the presence of wildlife. Proposed mitigations for project impacts include rehabilitation and revegetation, where soil and topography allow.

4.7.4.2 Species of Concern

Protected species present within the project area include endangered and vulnerable species of mammal, plants, birds, amphibians, reptiles, fish, and invertebrates. Endangered mammals known to be in the area include Spotted-tailed Quoll (*Dasyurus maculatus maculatus*) and Hastings River Mouse (*Pseudomys oralis*); and known vulnerable mammals include Greater Glider (*Petauroides 63enici*), Brush-tailed Rock-wallaby *(Petrogale enicillate*), Koala (*Phascolarctos cinereus*), and New Holland Mouse (*Pseudomys novaehollandiae*). Endangered plants known to be in the area include White-flowered Wax Plant

(*Cynanchum elegans*) and *Grevillea guthrieana*; and known vulnerable plants include *Callistemon pungens*, Narrow-leaved Peppermint (*Eucalyptus nicholii*), and Tall Velvet Sea-berry (*Haloragis exalata*). For birds, the endangered Rufous Scrub-bird (*Atrichornis rufescens*) and vulnerable White-throated Needletail (*Hirundapus caudacutus*) are known to be in the project area. Amphibians and reptiles known to be in the area include the threatened Manning River Helmeted Turtle (*Myuchelys purvisiI*) and the vulnerable Stuttering Frog (Mixophyes balbus). Endangered fish in the area may include Eastern Freshwater Cod (*Maccullochella ikei*) and Southern Purple-spotted Gudgeon (*Mogurnda adspersa*). Additional protected species may occur within the area including 2 mammals, 14 plants, 10 birds, 2 reptiles, and 1 invertebrate. Measures to mitigate any impacts to protected species include avoidance, habitat rehabilitation, and revegetation. Other measures will be outlined in the NEPA document.

4.7.4.3 Recreation and Land Use

Temporary negative impacts to recreation and land use are predicted during construction, including increased local traffic, reduced public access to local trails, and a decrease of tourism; however, long-term benefits from road upgrades may increase local access to transportation routes and social services.

4.7.4.4 Aesthetic Resources

Aesthetic resource impacts are predicted during project construction and operation. Construction activities and operational structures may be visible to nearby recreation sites and result in changes to existing views or landscape settings. In addition, improper landscape rehabilitation after construction may contribute further visual amenity impacts.

4.7.4.5 Cultural Resources

Potential impacts to Aboriginal and historic heritage values were predicted due to project construction. Existing studies and surveys identified 20 Aboriginal sites within 1000-m of the project area, including those with artifact scatter, habitation structures, ritual objects, burial sites, stone arrangements, and restricted sites. While none of the registered sites are located within the construction area, the highest risk for cultural resource impacts stem from road construction, stockpile areas, and upper reservoir construction. Monitoring of registered and unregistered sites will be conducted during construction and operation, and Aboriginal sites identified within the construction zone will require archeological salvage where avoidance is not possible. In addition, the project may impose indirect visual impacts to historic heritage sites adjacent to the project area, but no direct impacts are predicted on site.

4.7.4.6 Socioeconomic

Socioeconomic impacts are predicted for project construction and operation. Construction is predicted to generate 600 full-time equivalent jobs and 1500 indirect jobs; in turn, these jobs are predicted to increase local spending and use of social services. Construction is also expected to contribute temporary negative effects on local access and tourism. Road and communication infrastructure upgrades will provide long-term benefits, and project reservoirs may be utilized for fire-fighting purposes.

4.7.4.7 Air Quality and Noise

Air quality and noise impacts are primarily predicted during project construction. Potential air quality impacts from construction include dust and other particulate matter emissions from construction works and related land or spoil exposure, as well as gaseous pollutants from vehicle emissions. The same impacts are expected during project operation, though to a lesser degree. Noise and vibrations generated from construction are predicted to impact local residences and recreation areas; vibrations may also impact Aboriginal and historic heritage items. Operational noise and vibration would be minimal given the underground location of the powerhouse.

4.8 Summary

The impacts and mitigations from our five international case study sites largely parallel what we found for development and operation of closed-loop PSH projects in the United States. International documentation cites water resource impacts more frequently than other impacts, followed by terrestrial resources and geologic and soil resources. While the broad category of impacts is similar across sites (e.g., flow fluctuation, pollution, erosion, habitat loss or fragmentation, vegetation removal, wildlife disturbance), specific impacts vary by site, especially for projects located on former mine sites or those adjacent to parks. Proposed mitigations and enhancements for international projects were also similar to those in the United States, focusing on monitoring and management plans, modifying/staggering construction schedules, design modifications, and on-site and off-site conservation or restoration.

There were some unique impacts and mitigations identified in our review of international closed-loop PSH projects that were not found in the United States projects discussed. International projects, in general, identified more aquatic resource impacts than in the United States. In at least one project, the Cruachan Power Station in Scotland, the lower reservoir is a natural lake and has similar aquatic resource impacts to an open-loop PSH facility such as fish entrainment and impingement (mitigated with fish screens) and water quality impacts from discharge into the lake that serves as a lower reservoir due to construction runoff. The Luanping project identified that water withdrawals used for the initial reservoir fill would reduce surface water quantity and reduce flows approximately 45 km downstream of the surface water collection point. Some closed-loop PSH projects in the United States did identify the potential for impacts to water quantity from fill water withdrawals, but the scale of impacts for international projects was greater than those identified in proposed United States projects. Mitigating these withdrawals through ecological flow requirements is a commonly used mitigation for surface water quantity impacts at proposed United States projects but not necessarily for international projects. The Pinnapuram project identified unique socioeconomic impacts including sociocultural conflicts that could arise from the influx of non-local populations during project construction which would be mitigated by working with local community leaders to identify and mitigate potential conflicts prior to beginning construction. This project also identified increased disease spread among project construction workers temporarily housed within the project area which would be mitigated through on-site medical services.

5.0 Summary

This chapter synthesizes and discusses key takeaways across chapters from this report to provide a high-level summary of report contents.

5.1 Key Report Findings

The key takeaways presented in this chapter were identified based on:

- Review of NEPA documents
- Interviews with members of the hydropower community engaged in the FERC licensing process for closed-loop PSH
- Review of environmental assessment documents from closed-loop PSH facilities from other countries
- Relevant external resources

1. **There is not a single, standard definition of closed-loop PSH**

In this report, we discuss three definitions of closed-loop PSH including those specified by 1) United States Department of Energy and United States FERC for standard licensing proceedings (default definition used in this report), 2) United States FERC for determining whether a closed-loop PSH project qualifies for the 2-year expedited licensing process, and 3) IHA. The definition of open-loop PSH used by the United States Department of Energy, United States FERC, and the IHA is the same as used in this report; that is, a PSH facility that is continuously connected to a naturally flowing water feature. However, the IHA definition of closed-loop PSH differs from what is used in this report, and both differ from the FERC definition of closed-loop used to qualify a project for the 2-year expedited licensing process. Definitions for closed-loop PSH are as follows:

- United States Department of Energy and FERC: Hydropower facilities that are not continuously connected to a naturally flowing waterbody.
- FERC 2-year expedited licensing process: PSH projects that (1) cause little to no change to existing surface and groundwater flows and uses; (2) are unlikely to adversely affect species listed as a threatened species or endangered species, or designated critical habitat for such species, under the Endangered Species Act of 1973; (3) utilize only reservoirs situated at locations other than natural waterways, lakes, wetlands, and other natural surface water features; and (4) rely only on temporary withdrawals from surface waters or groundwater for the sole purposes of initial fill and periodic recharge needed for project operation.
- IHA: An ‘off-river’ site that produces power from water pumped to an upper reservoir without a significant natural inflow.

  Because there are different definitions of closed-loop PSH, it’s important to define what characteristics are being used to determine if a PSH project is closed-loop.

2. **Very little is known about environmental impacts of closed-loop PSH and this report summarizes most of the available information.**

Closed-loop PSH is relatively rare globally and non-existent in the United States and obtaining information on environmental impacts is difficult. The IHA reports 664 PSH facilities of all types globally at some stage of development ranging from pre-construction to operational. This number includes 240 classified as closed-loop PSH, 392 open-loop PSH, and 32 storage PSH. A minority of the closed-loop PSH plants are operational (N = 38) while most plants are in the pre-construction or construction stage (N = 202; Table 5-1).

Table 5-1 Number of closed-loop PSH facilities globally from the IHA Pumped Storage Tracking Tool dataset (IHA 2024). "All stages" includes open-loop, closed-loop, and storage PSH facilities at pre-construction, construction, and operational phases.

PSH stage/type	Pre-construction	Construction	Operational	Total
Open-loop	50	4	338	392
Closed-loop	160	42	38	240
Storage		2	30	32
All stages/types				664

3. Environmental impacts of all PSH are highly site-specific.

There can be wide variability in impacts among projects even among projects with similar landscape characteristics, land uses, or societal and community needs and governance structures. For example, projects being built in abandoned mines, other brownfield sites, greenfield sites, or on or near tribal lands or resources can have very different impacts. Assessing impacts must be done on a site-by-site basis.

Based on the site-specificity of impacts, a large-scale Programmatic Environmental Impact Statement-type document that generally addresses these impacts is not likely to be useful in regulatory reviews.

4. Closed-loop PSH water sourcing, aquatic resources, and reservoir GHG emissions impacts differ from open-loop PSH.

Impacts unique to closed-loop PSH include impacts to ground or surface water quantity for initial and refill reservoir fill and safety or contamination issues related to using abandoned mine sites as reservoirs, where groundwater contamination from an unlined reservoir is of primary concern. Unlike open-loop PSH, closed-loop PSH does not typically have aquatic resource impacts like fish impingement and entrainment because they are not continuously connected to a naturally flowing body of water. Increased siting flexibility for closed-loop compared to open-loop facilities provides some opportunity to avoid some impacts through site selection.

Potential for reservoir GHG emissions may also be relatively lower in closed-loop PSH compared to open-loop PSH, particularly if closed-loop PSH reservoirs have liners that create a barrier between the water and sediment where GHG is produced (Wang et al. 2024). However, empirical data measuring reservoir GHG emissions from open- and closed-loop PSH are needed to fully test these hypotheses (IHASWG 2021; Wang et al. 2024).

5. Closed-loop PSH mitigations are like those in terrestrial ecosystems but differ from mitigations for existing, conventional hydropower.

There do not appear to be mitigations unique to closed-loop PSH except for mitigations for impacts to ground or surface water quantity caused by initial and refill reservoir fill. In fact, mitigations and impacts for closed-loop PSH are similar to impacts caused by development in terrestrial ecosystems, such as roads and other forms of energy infrastructure, than impacts caused by conventional hydropower in aquatic ecosystems. Mitigations proposed for closed-loop PSH may also resemble those for new stream reach development of conventional hydropower because of similarities in impacts of construction and land disturbance, but comparison of NEPA documents between these types of hydropower projects was beyond the scope of this report.

6. **Impacts to wildlife were the most reported impacts in documents reviewed for this report.**
   - Impacts to wildlife varied among projects, but most projects listed reservoirs creating an attractive
   - nuisance to wildlife including ungulates, bats, and migratory birds, drowning hazards for wildlife that
   - fall into a reservoir, disturbance and safety hazards caused by construction activities, and habitat
   - fragmentation and vehicle collision hazards caused by new roads. For this report, impacts related to
   - transmission lines such as fragmentation and bird collision or electrocution were catalogued
   - separately although those impacts were frequently expected across projects reviewed for this report.
7. **Cultural resource impacts of closed-loop PSH are common and in many cases, cannot be mitigated.**

Potential cultural resource impacts were diverse and included impacts to important sites, plants and other biological resources, as well as the viewshed from traditional cultural properties. Commonly, these impacts are difficult or impossible to mitigate because the significance of the cultural site or resource is inextricable from the site. Destruction or damage to special sites or items during project development may not be avoidable and may therefore lead to licensing delays or project abandonment. For example, at least one of the abandoned licensed projects reviewed for this report had substantial cultural resource impacts.

8. **There are more operational closed-loop PSH facilities in other countries with similar impacts and mitigations to the United States.**

Review of environmental documents developed for projects in other countries suggests that potential impacts and mitigations reported are like those reported in the United States, although environmental documents in the United States typically review a more diverse set of impacts. For example, there is limited reference to the following impacts among international sites: seismic risk, biofouling, reservoir seepage or leakage, fish entrainment, fire risk, and wildlife predation, wildlife drowning, and collision with transmission lines (for bats and birds). That said, international sites also identified some impacts not emphasized in the United States projects, including the use of a PSH reservoir as a water source for firefighting, cultural resource impacts to industrial heritage sites of local importance (e.g., agriculture, mining, hydropower), sociocultural conflicts that could arise from an influx of non-local populations during project construction, and increased disease spread from temporary housing of construction workers at the project site.

9. **Globally, China operates and is constructing the most closed-loop PSH and the United States is proposing the most closed-loop PSH but there are relatively few of these facilities.**

According to data from the IHA Pumped Storage Tracking Tool (2024), nine countries in Europe and four countries in Asia have operational closed-loop PSH (Table 5-2). The age of plants in Europe (mean $\pm$ SD: 50 $\pm$ 20-years; range: 3 – 94--years; N = 23 plants) is older than those in Asia (mean $\pm$ SD: 13 $\pm$ 9-years; range: 2 – 32-years; N = 15 plants).

China has begun construction on 30 closed-loop PSH facilities while other countries have begun construction on one or two plants. The United States has the most pre-construction closed-loop PSH projects of any country (N = 59) although there are no closed-loop PSH plants operational or under construction (IHA 2024).

Table 5-2 Number of pre-construction, under construction, and operational closed-loop PSH plants by continent from IHA Pumped Storage Tracking Tool data (2024).

Continent	Pre-construction	Construction	Operational
Africa	3	2	
Asia	61	34*	15
Australia	9	1	
Europe	24	5	23
North America	62		
South America	1		

10. Interviews identified impacts and provided insights not discussed in NEPA documents.

Interviews with members of the domestic hydropower community provided additional insight and context into the potential impacts and mitigations associated with closed-loop PSH development. Interviewees noted the extent and significance of cultural resource impacts and challenges in identifying these sites, impacts to these cultural sites, and complexities or impossibilities associated with mitigating these impacts. We also gained insights on opportunities and challenges associated with developing brownfield sites, such as abandoned coal mines for closed-loop PSH, comparison of environmental impacts of closed-loop PSH with those of other renewable energy generation and storage projects, and concerns about reservoir GHG emissions associated with developing projects with two reservoirs with frequently fluctuating water levels. There was little difference among sectors of the hydropower community regarding resource impacts, including reservoir emissions.

5.2 Report Knowledge Gaps

Based on information synthesized for this report, including reviews of domestic and international environmental impact assessment documents, expert interviews, and reports and peer-review literature, we have identified the following knowledge gaps and areas where future work is needed to support closed-loop PSH development.

- Closed-loop PSH is unique among hydropower project types because unlike conventional or open-loop PSH, closed-loop PSH can avoid some impacts through site selection. Some of these approaches include:
  - Spatial prioritization: Process that employs spatial optimization algorithms to prioritize sites with certain characteristics (e.g., brownfield, previously impacted) or avoid certain impacts (e.g., endangered species take; degradation or destruction of areas of cultural significance; non-Tribal land/areas where Tribes do not have treaty or reserved rights) may be useful to identify sites with fewer impacts. Such approaches have been applied to other forms of energy development such as offshore wind (Virtanen et al. 2022) and onshore wind and run-of-river hydropower (Popescu et al. 2020).
  - Multi-benefit value stacking: While the energy field has well-accepted the concept of value-stacking, that is, co-locating compatible energy applications such as solar or wind generation and energy storage, incorporating multiple-benefit conservation principles such as intentional resource management for ecological and societal co-benefits, is still relatively new (Shivaram and Biggs 2023). Some solar energy developments provide examples of multi-benefit value stacking including co-location of agricultural crop production, solar-based fertilizer production, or canals with solar developments (Shivaram and Biggs 2023). Similar principles that incorporate energy

  and social or environmental benefits in closed-loop PSH site selection may help to reduce impacts, especially impacts that cannot be mitigated.

  – It is important to note that engagement with local communities and other impacted and/or interested parties and sovereign governments must play a primary role in site selection for any large-scale energy storage project such as closed-loop PSH and may provide important information that influences project feasibility or siting.

- Reservoir emissions were not listed in any of the NEPA documents reviewed for this report but came up in several of the interviews we conducted. Closed-loop projects are likely to have lower GHG emissions than open-loop PSH or conventional hydropower because they are not receiving regular carbon inputs from a connected river or other natural waterbody (Wang et al. 2024) and have lower initial carbon stocks in the reservoirs, particularly in reservoir bottoms lined with a waterproof concrete or membrane. All project NEPA documents reviewed for this report listed installation of some type of reservoir liner as a mitigation measure, which would leave little organic matter available for decomposition that could be a source for GHG. As a result, unlike new conventional hydropower, new closed-loop PSH typically would not have abundant carbon stocks from inundation of uplands, which leads to relatively high GHG emissions. In closed-loop PSH reservoirs, GHG emission potential increases with reservoir age as organic matter accumulates in the reservoirs from autochthonous carbon inputs created by plants and algae that may colonize the reservoir (IHASWG 2021; Wang et al. 2024). However, empirical measurements of closed-loop PSH reservoir GHG production are needed to validate this hypothesis.

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Appendix A – Case Studies of Impacts and Mitigations from FERC Environmental Impact Statements of Closed-Loop Pumped Storage Hydropower Projects in the United States

A.1 Introduction

Nearly all non-federal hydropower projects in the United States are under the jurisdiction of the FERC through its licensing and compliance processes. Although there are many differences between PSH and conventional hydropower projects, the licensing process is the same for both, each requiring environmental impact and mitigation assessments to meet NEPA requirements (Saulsbury 2020). State and federal agency staff that typically review conventional hydropower licensing are also often tasked with identifying potential impacts and mitigations during the PSH licensing process, which can be quite different from impacts and mitigations considered for conventional hydropower. Furthermore, many of the CLPSH facilities in the FERC licensing pipeline may be in states with relatively few conventional hydropower facilities and agency staff may have little prior experience with the FERC licensing process. Even in cases where staff are experienced in FERC hydropower licensing, most of which is likely relicensing or adding power to non-powered dams, impacts and mitigations of CLPSH, which typically differ from those of conventional hydropower or even open-loop PSH, may be unfamiliar.

In this chapter, we describe impacts and mitigations reported in draft and final FERC NEPA documents from six CLPSH projects that are not actively in the licensing process. These include three active licensed projects: Eagle Mountain, Swan Lake North, and Gordon Butte, and three inactive projects that had a draft or final NEPA document produced: Summit, Lorella, and Mineville (Table 2; Figure X). At the time this report was being written, the final NEPA document for the Goldendale project (P-14861) was available, but the project still did not have a FERC license so we did not include it as a case study. Likewise, we have information from the NEPA document produced in 1996 for the Blue Diamond project (FERC P-10756), but because at the time this report was being written, a new developer had taken up the Blue Diamond project and was working to obtain a FERC license (FERC P-14804), we also did not include it in our analysis. A cross-site summary of impacts and mitigations is provided in Chapter 3 of this report.

A.2 Methods for Creating Case Study Datasets

The discussion of impacts and mitigations in NEPA documents issued for FERC licensed projects is typically organized by resource category, although the exact nomenclature of resource categories is not identical among NEPA documents. In structuring information extracted from NEPA documents, we have organized summaries of impacts and mitigations by impact and resource categories (Figure 6). To summarize impacts and mitigations for this chapter, we identified individual impacts and mitigations from the NEPA documents of the projects described above and created a hierarchical data set of impacts and mitigations (Supplemental Data). We then copied and pasted each impact and mitigation into separate columns in our dataset, capturing the exact text from the NEPA document (Figure 5). Secondary impact and mitigation categories were emergent properties of this text; that is, categories were created based on the impacts and mitigations extracted from the NEPA documents rather than defining categories *a priori*. This method resulted in 18 Secondary Resource Categories, 28 Impact Categories, and 23 Mitigation Categories (Figure 6). While some detail is lost with this method, it allows for aggregation of impacts and their mitigations to gain a greater understanding of common impacts and mitigations across projects.

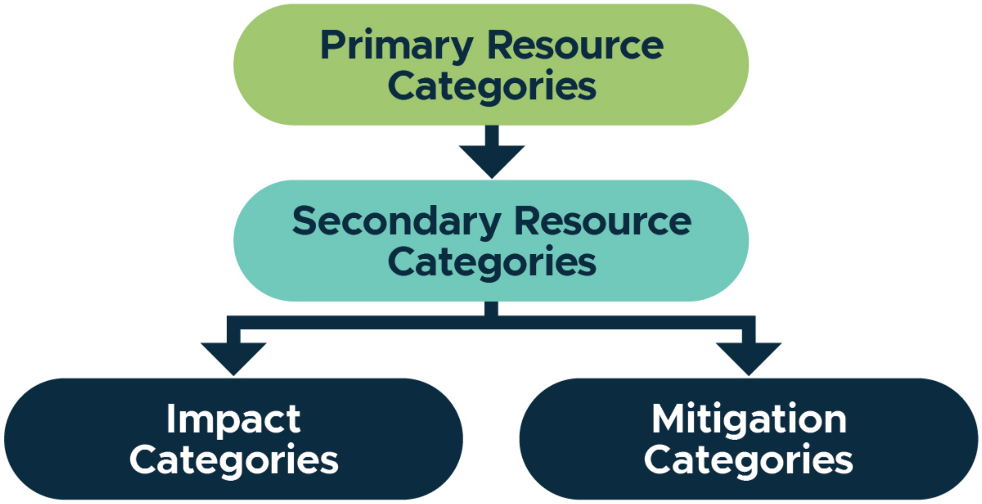

Figure A 1 Data structure for data from NEPA documents as summarized in this report.

Project phases were assigned based on when the impacts and mitigations would occur. For example, if the impact would be entirely created and mitigated during construction, the phase was recorded as "Construction". An example of a construction impact would be increased traffic from construction vehicles where the impact is also mitigated during the construction phase through construction traffic control methods. Likewise, impacts that would occur and be mitigated during the operations and maintenance phase, such as bird electrocution from powerline collisions, were recorded as "Operations and Maintenance". Impacts beginning during the construction phase that would continue throughout the life of the project were recorded as "All". For example, if filling and refilling project reservoirs would affect surface water quantity, the impact and mitigation would begin during the construction phase and would continue during the operations and maintenance phase, so it was marked "All" in the project phases category.

Table A 1 Characteristics of the six, United States CLPSH case study sites.

FERC #	Project Name	State	Project Active?	Project MW	NEPA date	License Issue Date	Termination Date
P-9423	Summit Pumped Storage Hydroelectric Project	OH	No	1500	1/1991	4/12/1991	4/12/2001
P-11181	Lorella Dam	OR	No	1000	4/1994	NA	10/12/1998
P-11858	Mineville Energy Storage Project	NY	No	240	6/2019	NA	12/11/2020
P-12635	Eagle Mountain Pumped Storage Project	CA	Yes	1300	1/2012	7/21/2014	Active license
P-13318	Swan Lake North Pumped Storage Project	OR	Yes	393	1/2019	4/30/2019	Active license
P-13642	Gordon Butte	MT	Yes	400	9/2016	12/14/2016	Active license

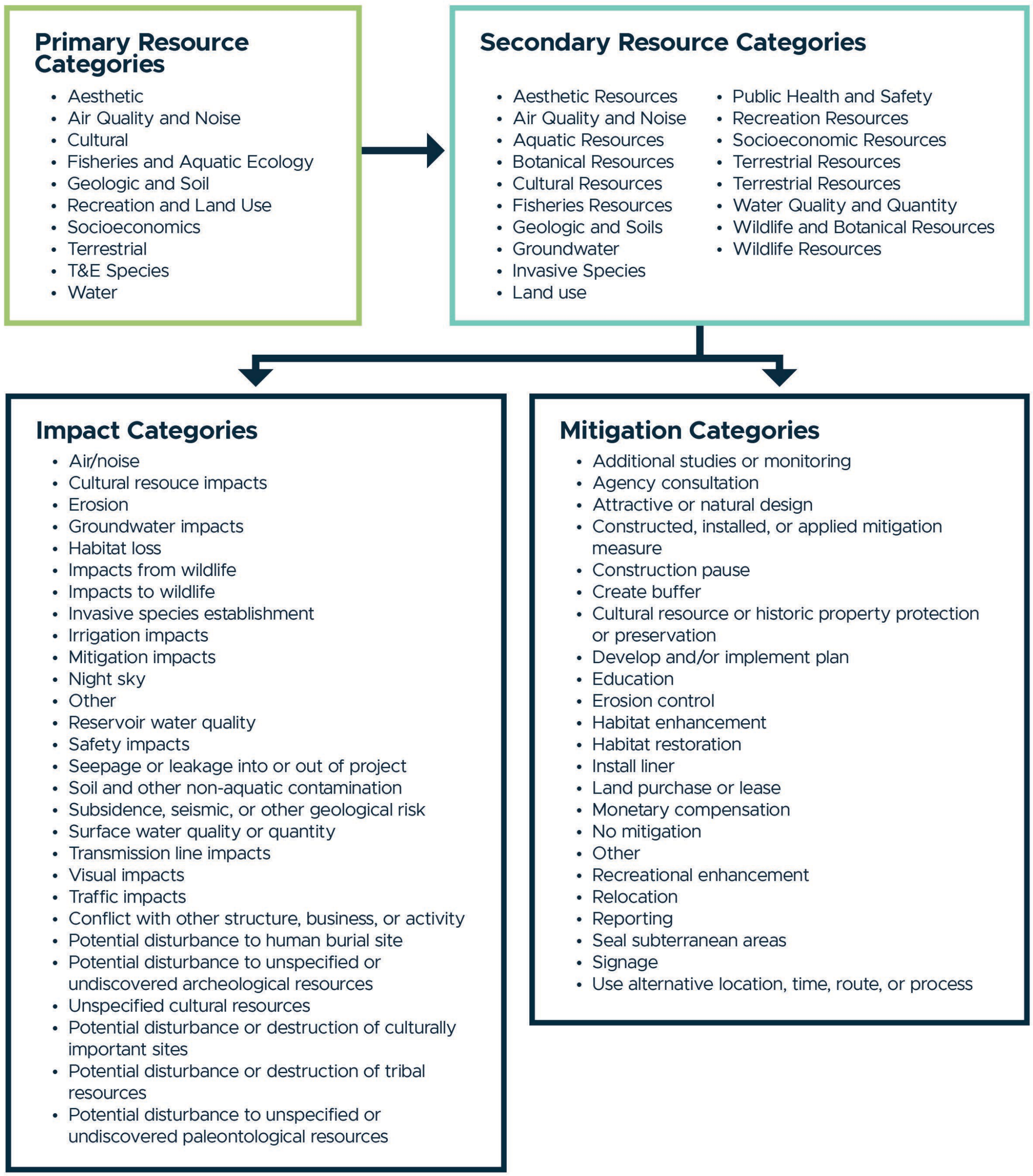

Figure A 2 Categories of data from NEPA documents as summarized in this report.

A.3 Description of Sites Included in NEPA Document Summaries

This section provides brief descriptions and characteristics of each project to provide additional context for understanding the impacts and mitigations summarized in this chapter. All projects are CLPSH projects and are presented in order of ascending FERC docket number. Since FERC docket number is assigned at the time the preliminary permit application is filed, projects with the oldest preliminary permit application filing are listed first. Many factors can influence the timeline of hydropower licenses, so the numerical order of FERC docket numbers does not necessarily coincide with the age of the NEPA or license (Pracheil et al. 2022). While Environmental Justice is an impact category commonly reviewed in NEPA assessments, only the Swan Lake North project explicitly addressed Environmental Justice concerns in their NEPA documents although potential Environmental Justice impacts were commonly assessed in the Socioeconomics; Air Quality and Noise; and Cultural Resources categories in other projects. The Eagle Mountain NEPA stated that Environmental Justice concerns were addressed in Water Resources; Air Quality and Noise; Recreation, Land Use, and Aesthetics; and Socioeconomics.

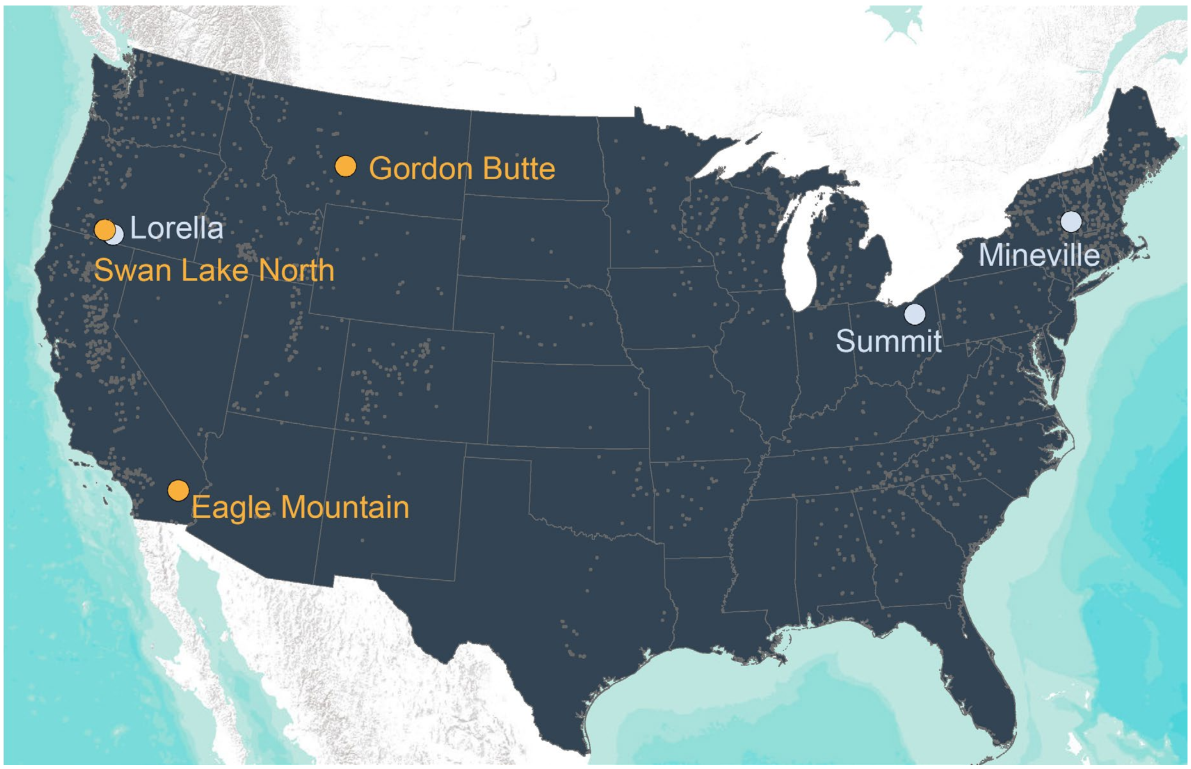

Figure A 3 Locations of case study sites used for summarizing impacts and mitigations from CLPSH. Projects in gold are currently active whereas projects in light blue have been abandoned. Dark gray dots show locations of existing hydropower based on data from Johnson et al. (2023).

A.3.1 Summit P-9423

The Summit Pumped Storage Hydroelectric Project (hereafter, “Summit Project”; license applicant: Summit Energy Storage, Inc.) was proposed as a 1,500-MW CLPSH project located in the city of Norton, Ohio (FERC 1991). The project final NEPA was issued in 1991, the license order was issued April 12, 1991, and the license was terminated by FERC prior to construction on April 12, 2001. The project would have consisted of an excavated, asphalt-lined, upper reservoir and an underground lower reservoir created by limestone mining.

The Summit Project was unique among the projects we reviewed in that the upper reservoir would have been near long-established, low and medium density residential properties (<1-km away). The transmission line right-of-way was even closer to residences, at <30-m (<100-ft) from individual residences at several points.

Land for the proposed upper reservoir was dominated by active agricultural land and undeveloped forest and shrublands. Excavation of the upper reservoir would have led to the loss of approximately 235-m^2 (58-ac) of upland forest habitat and approximately 117-m^2 (29-ac) of wetland and riparian habitat that could serve as habitat for two state-listed plant species: nodding trillium (*Trillium cernuum*) and Baltic rush (*Juncus balticus*). No federally listed threatened or endangered organisms had been documented in the project area.

Figure A 4 A 6 Location of Summit project.

A.3.1.1 Summit Impacts and Mitigations

Geologic and soil resources

Construction erosion, seepage or leakage into or out of the project, and potential subsidence impact on mine stability were identified as impacts at this project. Proposed mitigations for erosion included planting vegetation to stabilize soils and installing sediment basins and silt fences to stop erosion during construction. Mitigation of seepage or leakage would involve installation of a liner to prevent project waters from seeping into or out of the reservoirs. Mitigation of subsidence risk was not identified beyond conducting additional studies to evaluate where underground salt solution cavities were positioned in relation to the project. Subsidence impact on mine stability could not be mitigated without a better understanding of underground geological features at the proposed project site.

Water resources

Potential water resource impacts identified included impacts to surface and groundwater quality and quantity.

Surface water

Biofouling of water in the upper and lower reservoirs was listed as a potential impact although there was not any mitigation listed because the upper and lower reservoirs were described as “a self-contained” system. Water quality issues caused by increased erosion were also listed as a potential impact that could be mitigated through construction of settling ponds and monitoring the construction sites for areas of increased erosion. Initial project fill and refill water would be sourced from a local municipal water supply as well as a nearby lake. At the time the final NEPA was issued, pumping from these sources would only be allowed so long as it would not impact local water supplies and a minimum inflow requirement into the local lake would need to be met to be used for pumping. Increased water temperature in the project diversion channel was listed as a potential impact and planting vegetation was listed as a mitigation measure.

Groundwater
It was identified that there could be potential impacts to private wells which would be mitigated through an applicant-conducted well inventory. If impacts to wells because of pumping were reported, the license applicant would be required to provide alternative water supplies. Although seepage out of the project that could contaminate groundwater was a concern, preventative measures would be taken including installation of an asphalt liner in the upper reservoir, sealing and lining all underground shafts to prevent seepage, isolating all project facilities from any areas with water, and pumping any seepage that still occurred back into the reservoirs.

Fisheries and aquatic resources
While the project was sited off-channel, potential impacts to fish species composition due to habitat loss were identified. Habitat loss could have resulted from run-off being collected by the project rather than following the natural flow path to the South Run. Proposed mitigations included creation of two ponds to provide habitat for warmwater fishes and provide diversion channel slopes gradual enough to provide run, riffle, and pool habitat. Substrate in this channel would be constructed with gravel and cobble. Loss of wetland and riparian habitat were also discussed as a potential project impact and would be mitigated by constructing off-site wetlands and planting willow and cottonwood trees along the diversion channel. There was also concern with oil and grease and potentially other toxic substances discarded in areas of the mine from previous mining activity could contaminate water used for initial washing. This would be mitigated by sealing or properly disposing of these materials prior to washing the interior of the mine.

Terrestrial resources
Terrestrial resource impacts included loss of forest and wetland habitat. These losses would be mitigated through planting vegetation and creating wetlands around the upper reservoir and through educating construction staff that they may not operate construction machinery outside the boundary of the upper reservoir. There was also concern that the reservoir would be an attractive nuisance to unspecified bird species, so the upper reservoir would be monitored for the presence of nuisance birds and control measures would be developed in consultation with resource agencies.

Threatened and endangered species
The only potential threatened and endangered species impacts identified were impacts to sensitive plants including two Ohio state endangered species: nodding trillium (*Trillium cernuum*) and Baltic rush (*Juncus balticus*). To prevent damage or destruction of these plants, any occurrence of these plants in the construction area prior to or during construction would be mitigated through plant relocation.

Recreation and land use
There were no recreation impacts listed although there were proposed recreational on- and off-site enhancements including picnic areas, trails, an interpretive center, and a wildlife area with observation decks. Potential impacts to local residents from project construction were listed as a potential land use impact, which was proposed to be mitigated through providing property owners monetary compensation.

Aesthetic resources
Potential aesthetic resource impacts included the project and transmission lines changing the character of the landscape. These impacts were mitigated through redesign of the upper reservoir to reduce the aesthetic impacts on close residents, landscaping and planting trees and other vegetation to minimize visual intrusion and serve as a visual barrier to infrastructure, attractive or natural design of project works, adjacent recreation area, and transmission line infrastructure.

Cultural resources
Only potential impacts to historic properties were listed as cultural resource impacts for this project. To mitigate these potential impacts, the license applicant would develop a management plan in consultation

with the State Historic Preservation Officer (SHPO) to mitigate impacts of sites that could be placed on the National Register of Historic Places.

Socioeconomics

Socioeconomic impacts centered on potential impacts to traffic safety and from electromagnetic fields (EMF). Proposed mitigations for traffic safety impacts included designing the temporary access roads constructed from the project to the main highway to safety standards of a permanent road to reduce safety risk to motorists, construct signage along nearby roads to warn motorists of potential for fog and ice conditions to reduce visibility because of interactions between warmer waters of upper reservoir and colder air, and using freight trains to move materials and equipment to and from construction site to minimize traffic impacts on roads near the project. To minimize EMF impacts, the applicant proposed to adequately space electrical conductors and transmission lines.

Air quality and noise

Increased dust from construction caused by heavy traffic would be mitigated by using chemicals or water to minimize fugitive dust. Emissions from fossil-fuel powered generation plants needed to pump water to the upper reservoir could exacerbate regional acid rain and climate warming conditions, but no mitigation was proposed for this impact. There was also the potential for project construction activities to create loud noises such as blasting to make the power tunnel. The proposed mitigation for this impact was to use tunnel boring instead of blasting.

A.3.2 Lorella P-11181

The proposed Lorella Pumped Storage Project (license applicant: Energy Storage Partners) was a 1,000 MW project located in Klamath County, Oregon, approximately 32-km (20-mi) from the town of Klamath Falls. The project draft NEPA was issued in 1994, although the applicant requested to withdraw their license application October 12, 1998, prior to the final NEPA being drafted. The proposed project would have consisted of an upper reservoir in a dry valley in the upland area of Bryant Mountain and a lower reservoir on the valley floor at the base of Bryant Mountain. A 6-km (4-mi) transmission line would have been required to connect the project to an existing substation. Both initial fill and refill water for this project would have been sourced through purchasing water rights to an old gas and oil exploration well and two other wells owned by local residents.

Figure A 5 Location of the Lorella project.

Both the upper and lower reservoir for this project would be newly created, above-ground reservoirs that would circulate approximately 2,000,000-m^3 of water between them. The proposed upper reservoir would be formed by two dams: one 54-m (178-ft) high and one 30-m (100-ft) high and hold 1,970,000-m^3 (15,990-ac-ft) of water. Water in the upper reservoir was estimated to vertically fluctuate 37-m (123-ft) on a weekly cycle. The proposed lower reservoir would be formed by one 17-m (57-ft) high dam that would hold 22,999,468-m^3 (18,646-ac-ft) of water. Water in the lower reservoir was estimated to vertically fluctuate 13-m (44-ft) on a weekly cycle. The powerhouse for this project would be underground.

The areas proposed for the upper reservoir, transmission corridor, and new access roads had land uses of forestry and range. The area of the lower reservoir was cited as being 57% privately-owned agriculture, 41% forestry and range, and 2% rural residences and transportation or utility corridors. The project lands would have contained a mix of Bureau of Land Management land and privately-owned lands.

A.3.2.1 Lorella impacts and mitigations

Geologic and soil resources
Erosion was the major geologic and soils resource impact concern for this project. All phases of the project were expected to create erosion, including disturbance during construction on project lands developed for roads or on slopes with little vegetation cover and during operations in and near the lower reservoir from regular and rapid drawdowns. Seepage losses from the reservoir bottom was also predicted as an impact.

Proposed mitigation for erosion in non-reservoir areas such as upland areas or areas along the reservoir access road included planting vegetation and using mulch and riprap to stabilize slopes. Proposed mitigation for erosion caused by reservoir fluctuations was installation of an impermeable asphaltic concrete liner on the upstream sides of the embankment and a compacted clay liner on the reservoir bottom. Liners would also be used to mitigate seepage losses from the reservoir.

Water resources
Water resource impacts were found in three secondary resource category types: Aquatic resources, Water quality and quantity, and Groundwater (Table 3).

- **Aquatic resources**

  Make-up water for the facility would be drawn from irrigation canals that can contain endangered shortnose (*Chasmistes brevirostris*) and Lost River suckers (*Deltistes luxatus*) during times of year when the canals contain water. To ensure the project would not harm these fish, interconnections between existing irrigation canals and water conveyances bringing water to the project would have been made during times of year when the irrigation canals were dewatered.

- **Water quality and quantity**

  Evaporation from project reservoirs would have led to increased total dissolved solids and minerals in the water, thereby reducing the water quality. To mitigate this impact, total dissolved solids criteria would be established and a filtration system installed once the reservoir water no longer met the criteria. Solid salt and mineral waste from filtration would be disposed of as solid waste. Water quantity impacts of the project would be due to decreased runoff from reservoirs capturing water that would typically be available to runoff into surface waters or recharge groundwater. This project proposed to construct mitigated wetlands for wildlife habitat that would provide sufficient increased groundwater recharge such that the net loss of runoff would be negligible. Potential biofouling from algal blooms was listed as a potential impact. This would be mitigated by water treatment including copper-based algicides.

- **Groundwater**

  Based on pumping tests, initial fill and refill water for the facility could have been pumped from deep aquifers below 1500-ft from the surface without impacting other users that primarily use shallow aquifers. A new steel casing was proposed to be installed to prevent withdrawal of water from more shallow aquifers.

Fisheries resources and aquatic ecology
No potential fisheries or aquatic ecology impacts or mitigations were reported for this project.

Terrestrial resources
This project proposed some off-site mitigation for impacts to terrestrial resources. Impacts to botanical resources and wildlife resources were reported for this project.

- **Botanical resources**

  Permanent loss of botanical resources due to reservoir and road construction were listed as impacts which did not have an associated mitigation. Loss of botanical resources that served as wildlife habitat was also reported and the proposed mitigation for these impacts were creation and enhancement of over 900-acres of wetland and planting fence-row vegetation throughout the mitigation area to provide additional deer and rabbit habitat.

- **Wildlife resources**

  The transmission line was linked to some wildlife impacts including loss of bird and bat nesting, roosting and other habitat and electrocution of raptors and other birds. These impacts were mitigated through designing the transmission line with lines sufficiently spaced to minimize bird electrocution hazards. It is also suggested that larger birds may positively benefit from the addition of perching and roosting opportunities provided by the transmission line structures. Loss of nesting and roosting habitat for birds and bats was proposed to be mitigated by installing nesting and roosting boxes and creating snags along the transmission line corridor to replace bird nesting and foraging habitat. Construction disruption of bird nesting was proposed to be mitigated through scheduling construction activities around nesting season for raptors including bald eagles and other birds and fawning season for mule deer. Nesting habitat would be protected where possible through marking and creating a buffer around known or suspected roosting perch and nesting trees for raptors and mitigated through providing nesting and roosting boxes for birds and bats throughout the project area. Project reservoirs would potentially be an attractive nuisance to birds and other wildlife which would be somewhat mitigated by stocking two nearby reservoirs with warmwater fishes to increase forage for eagles. Wildlife disturbance and habitat fragmentation for species such as mule deer was also listed as an impact and was proposed to be mitigated through closing new access roads to public use to limit human disturbance and creating wildlife crossings on new access roads where excessive earth cutting and filling would block wildlife movements.

Threatened and endangered species
Two federally endangered fish, the Lost River sucker and the shortnose sucker, are found in the Kalamath River basin and were determined to be potentially impacted by project water withdrawals from groundwater because of potential reduction in surface water flows. While no federal or state listed rare, threatened, endangered, or sensitive plant species were located within the project area, during applicant-conducted surveys, several state- and federally-listed or other designations of species of concern at the time of draft NEPA document issuance were found to be potentially impacted by the project including bald eagle (*Haliaeetus leucocephalus*; federally threatened), northern goshawk (*Accipiter gentilis*; Federal C2 Candidate species and State Sensitive Critical species), western pond turtle (*Actinemys marmorata*; Federal C2 Candidate species), and the tricolored blackbird (*Agelaius tricolor*; Federal C2 Candidate species). Five State Sensitive species were also observed within the proposed project area including the greater sandhill crane (*Grus canadensis*), Swainson’s hawk (*Buteo swainsoni*), pygmy nuthatch (*Sitta pygmaea*), white-headed woodpecker (*Picoides albolarvatus*), and western bluebird (*Sialia Mexicana*).

Recreation and land use
In this category, most of the impacts were to land use.

- **Recreation**

  The only recreation impacts listed were unsafe recreational conditions at project reservoirs caused by fluctuations during normal project operations. These impacts would be mitigated by fencing the reservoirs to keep people out.

- **Land use**

  Land use impacts included traffic impacts caused by increased construction traffic and a road that was removed for project construction. Traffic impacts were proposed to be mitigated through traffic advisory signs for increased traffic and road relocation for the road that was removed for project construction. Increased erosion in the transmission corridor from cattle grazing was listed as an impact. Locating salt licks and water troughs away from the transmission corridor were proposed as mitigations. Several irrigation impacts were listed and included impacts to water availability from construction of new canals for the project, impacts to the existing irrigation canal, and loss of irrigation payments to the local irrigation district. Mitigations proposed for irrigation impacts included timing construction of new canal facilities to avoid conflicts with irrigation needs, creating new infrastructure including a bypass channel, holding pond, and lift station that would prevent the irrigation water supply from being interrupted, and making payments to the irrigation district to compensate for irrigation payments lost during project construction.

Aesthetic resources
Impacts to aesthetic resources at the project were caused by land disturbance and the visual intrusiveness of the buildings on the landscape. For example, visual impacts were described as caused by both reservoirs and buildings and other infrastructure associated with the project. Land disturbance caused by constructing the road was also listed as causing visual impacts. Project construction was also cited as contributing to the cumulative impacts of new natural gas pipeline construction and other land conversion to energy production including transmission facilities that would change the visual character of the landscape. Mitigations proposed would use native plants and security fence screening to hide project features as well as minimizing clearing of existing vegetation to the extent possible. Mitigating visual impacts of the transmission line was proposed through selection of simple transmission tower structures and limiting vegetation removal in a way that maximizes visual screening.

Cultural resources
Impacts to known or potentially undiscovered archeological resources were listed as an impact of this project. Project construction was known to directly impact one archaeological site of undetermined origin or age and be near three prehistoric archaeological sites as well as two sites containing rock cairns which were frequently used to mark human burial sites. Among these impacts were potential disturbance to human burial sites, historic properties, and other undiscovered archeological resources. Mitigations proposed included monitoring of construction activities to ensure significant sites were not destroyed. Additional archeological investigations were also proposed so that additional significant sites could be identified and protected. Specifically, studies would be conducted to ensure the proposed site would not disturb a human burial site. Construction workers would also be instructed to avoid these significant sites and if they found they had disturbed a site during the construction process, they would immediately stop work in the immediate vicinity and notify the SHPO of the finding. It was noted in the NEPA document that if the additional archeological sites were found to contain human burials, the applicant would consult with the Klamath Tribe to develop mitigative measures that could include covering the site to protect from reservoir fluctuations, site excavation and reburial elsewhere, or off-site measures such as protection or enhancement plans for cultural resources. We must note here that no mitigations would likely be acceptable for disturbance of a human burial site.

Socioeconomics
The socioeconomics assessment identified impacts that may strain financial and other resources of the local community and potentially impact safety. Increased school enrollment from an influx of school-aged children of the construction workers was identified to potentially impact the ability of the school system to accommodate these additional students. This impact was determined to be negligible and no mitigation was proposed. The potential for a housing shortage was also identified as a potential impact of the project although no mitigation was proposed. Increased traffic from project construction activities including machinery and construction worker traffic was identified as an impact. This impact would be mitigated by monitoring traffic on local roads and implementing a program for worker carpooling or shuttling as needed. The addition of roads for the project would require increased snow removal costs to the county and state to maintain access to the construction site although this potential impact also had no mitigation proposed. It was identified that the relatively warm temperature of the reservoirs during the winter and other times of year may result in the formation of fog or ice near the project area. Impacts of fog or ice formation would be mitigated by posting signs warning about the potential for these conditions.

Air quality and noise
No air quality impacts were identified although the NEPA document did identify noise impacts associated with project construction. Noise impacts were proposed to be mitigated by meetings between project representatives and local residents to discuss potential noise issues prior to the onset of construction and implement one or more construction pauses.

A.3.3 Mineville P-12635

The Mineville Energy Storage Project was a proposed 240 MW project near Moriah, New York. The project draft NEPA document was issued in June 2019, but the applicant requested to withdraw their license application on December 11, 2020. The upper reservoir would be located within the upper section of the Harmony Mine and be capable of storing 1,374,097-m^3 of water. The lower reservoir would have been in the lower portion of the Old Bed Mine and would have been capable of storing 571,101-m^3 of water. All proposed project facilities were planned to be underground except for the proposed entry and service building. The proposed underground transmission line would have connected to a power substation in Mineville, New York and would have been just over 1-km in length. Initial fill and refill water would have come from groundwater.

Figure A 6 Location of the Mineville Energy Storage Project.

A.3.3.1 Mineville impacts and mitigations

Geologic and soil resources
Geologic and soil resource impacts generally fell into two categories: increased seismic risks and increased erosion. Proposed mitigations for increased seismic risks included developing a geotechnical investigation plan to collect data for both reservoirs on seismic risk, induced seismicity, and subsidence associated with project construction and operation and a seismic monitoring plan. Potential increased erosion was attributed to construction and ground disturbing activities that were part of sealing mine openings. Mitigation measures included implementation of the previously filed Erosion and Sediment Control Plan and amending that plan to include erosion associated with ground-disturbing activities that are part of sealing mine openings.

Water resources
This document described potential impacts to surface and ground water.

- **Surface water**

  Potential impacts could have included construction runoff and erosion that would reduce surface water quality. Proposed mitigations for surface water quality impacts included water quality monitoring at several sites through the life of the project as well as design of a water quality plan in consultation with natural resource agencies.

- **Groundwater**

  Groundwater impacts were mostly focused on groundwater intruding into the mines that could also potentially overflow during project construction and operation. These impacts were proposed to be mitigated through development of a groundwater monitoring plan, mine sealing to prevent groundwater intrusion into mines, and creating aeration and detention infrastructure that would treat any groundwater that would overflow during project construction and operation.

Fisheries resources and aquatic ecology
No fisheries or aquatic ecology impacts were reported for this project.

Terrestrial resources
Terrestrial impacts included destruction of wildlife habitat which would be mitigated through identification of timing and degree of ground disturbing and tree clearing activities taking place in each phase of project construction so that, through agency consultation, major disturbance during critical life history periods could be avoided. Additional mitigation involved conducting environmental landscaping to refoliate aboveground construction area.

Threatened and endangered species
Concerns on impacts of project construction and operation on bats were at the center of the impacts to threatened and endangered species. Specifically, there were concerns that tree clearing during specific seasons, and the mines creating an attractive nuisance to bats including exposing them to contaminated water outflow from the mines. Mitigations for bat impacts included development of a Bat Protection and Monitoring Plan, seasonal restrictions on tree clearing as specified through agency consultation, monitoring of environmental conditions and bat habitat use in mines, and sealing some mine openings and shafts to prevent bat exposure to contaminated water and other hazards.

Recreation and land use
There were no impacts to recreation or land use although recreational enhancement—provide support for the town to develop a multi-use recreation complex— was proposed.

Aesthetic resources
The aesthetic impacts of the architecture of project buildings were identified as an impact. This impact was proposed to be mitigated by matching the style of project building architecture to existing municipal buildings.

Cultural resources
Potential cultural resource impacts identified were the potential disturbance or destruction of sites listed on the National Register of Historic Places. Proposed mitigations for these impacts included implementation of the Historic Properties Management Plan that would be revised to include an updated project description, historic overview of the area, description of properties in the project area listed on the National Register, educate all staff on cultural resources, provide more detail on what to do in the event

historic artifacts or properties are discovered, and include more details on interpretive signage about historic properties.

Socioeconomics
No socioeconomic impacts were reported for this project.

Air quality and noise
No air quality and noise impacts were reported for this project.

A.3.4 Eagle Mountain P-13123

The Eagle Mountain Pumped Storage Hydroelectric Project is a currently licensed 1,300 MW project near the town of Desert Center, California and Joshua Tree National Park. The final NEPA document was issued in January 2012 and the original license order was issued on 21 July 2014. The project is situated on the site of the largely inactive Eagle Mountain Mine. The upper reservoir and lower reservoirs for this project are both above ground with an underground powerhouse. The planned upper reservoir will be placed in the existing central mining pit and has a surface area of 772,950-m^2 and stores 24,669,600-m^3 of water. The planned lower reservoir will be placed in the existing eastern mining pit and has a surface area of 659,638 and stores 27,013,212-m^3 of water. The proposed underground transmission system includes four 1829-m 18-kV transmission cables that travel through the powerhouse then 1,219-m overhead to a switchyard, a 150-m^2 switchyard, a 22-km-long, double circuit 500-kV transmission line connecting the switchyard to a new interconnection collector substation, and an interconnection collector substation located at the point of interconnection with Southern California Edison's planned Devers-Palo Verde No. 2 500-kV transmission line at Desert Center. Initial fill and refill water comes from groundwater. The powerhouse for this project would be underground. Water would fluctuate approximately 30-45-m each day in the upper and lower reservoirs.

The areas proposed for the upper reservoir, transmission corridor, and new access roads had land uses of forestry and range. The project area occupies 2.73-km^2 of federal lands managed by the United States Department of Interior, Bureau of Land Management, 1.89-km^2 of land owned by the state of California and administered by the California State Lands Commission, and 6.25-km^2 acres of private land owned by Kaiser Eagle Mountain, LLC.

A.3.4.1 Eagle Mountain impacts and mitigations

Geologic and soil resources
Increased risk of subsidence and seismic activity and erosion were identified as potential impacts to geologic and soil resources. There was concern that initial reservoir filling could increase frequency of small earthquakes and that daily movements of the large volumes of water needed to fill the reservoir could impose sufficient stress on the land that gradual land movement could occur. These impacts would be mitigated through additional studies and monitoring of the area including installation of two extensometers to measure potential land movements. However, because fill water would

Figure A 7 Location of Eagle Mountain project.

be lighter than the material to be excavated for the reservoir, increased seismic activity would not be expected. There was also concern that water seepage could increase risk of subsidence caused by hydrocompaction of swesxoils. Proposed mitigation for this potential impact was installation of liners in project reservoirs.

Construction erosion was identified as a potential impact that would be mitigated through implementation of the Erosion and Sediment Control Plan filed in 2010. This plan describes the erosion and sediment control practices that would be used to minimize soil erosion in construction areas and keep sediment out of stormwater discharges that drain out of the construction site.

Water resources
The NEPA document for the Eagle Mountain project identified water quality and quantity issues for surface water and groundwater several of which had implications for project safety.

- **Surface water**

  Among the main concerns was stormwater inflow causing reservoir overflow resulting in contamination of nearby waterways and undermine integrity of the dam. Mitigations for these potential impacts included operational changes designed to safely discharge water in a controlled manner. For example, during stormwater inflow to the lower reservoir, operations would be adjusted to account for the reduced availability of energy storage space to avoid overtopping the upper reservoir during pumping. In cases where inflow volumes were very large, the lower reservoir spillway could be opened to release extra water. Surface water quality impacts identified included increased dissolved mineral concentrations in reservoirs due to evaporation losses and other contaminants in recovered seepage losses would reduce water quality in the reservoirs. Mitigations for these water quality impacts include installation of a reverse osmosis water treatment system to treat reservoir water so that it would have water quality equal to that of local groundwater. There was concern that the wall of an evaporation pond used to condense dissolved salts from reservoir spillage could break and contaminate the nearby Colorado River, but no mitigation was proposed because it was determined that brine release would not reach the river. The potential for hydrologic alterations from the project to have cascading impacts on nearby surface waters was named as a potential impact. This would be mitigated through establishment of a Streambed Alteration Agreement that would identify the condition and location of all state jurisdictional waters including effects and mitigation measures and any compensation for lost or damaged acreage.

- **Groundwater**

  There was concern that water from the brine pond and project reservoirs could seep into the groundwater and the proposed mitigations were additional water quality studies and monitoring including well pumping tests and installing double liners in the evaporation ponds. Concerns that pumping would impact groundwater quantity were also identified. Groundwater monitoring for at least the first four years of project pumping was proposed as a mitigation.

Fisheries resources and aquatic ecology
No fisheries or aquatic ecology impacts were reported for this project.

Terrestrial resources
Potential terrestrial resource impacts generally included transmission line impacts, impacts to wildlife, invasive species establishment, and other impacts.

- **Transmission line impacts**

  While there was some concern on the loss of vegetation from transmission line corridor that would be mitigated through revegetation of disturbed areas using construction excavation topsoil, other identified impacts named impacts to or from birds because of transmission infrastructure. The transmission line would potentially provide a perching habitat for predatory birds and nesting and perching habitat for birds in general. Use of transmission infrastructure as bird habitat was not desirable because of increased risk of transmission line collision and electrocution to birds. Proposed impacts for these mitigations included constructing new transmission towers near to existing towers because the proximity of new towers to existing towers may reduce their suitability as habitat. Development and implementation of a transmission line design plan in consultation with the United States Fish and Wildlife Service that includes design measures for reducing potential electrocution and collision injuries, provides methods for surveying and reporting project-related raptor mortality, a worker education plan pertaining to avian-power line interactions, and procedures for managing nesting on transmission line infrastructure was also proposed as a mitigation.

- **Impacts to wildlife**

  The potential for construction activities to impact birds, burrowing animals including burrowing owls, bats, bighorn sheep, deer, coyotes, foxes and badger, small mammals, and reptiles was identified. Proposed mitigations included wildlife exclusion fencing, preconstruction surveys, relocation, and encouraging wildlife to relocate to safer habitats. Project maintenance activities during project operations, including repair of transmission line support structures or water pipeline, may require ground disturbance that may disrupt animal burrows. To mitigate this potential impact, proposed mitigation was that all maintenance activities that may require ground disturbance must occur in the presence of biological monitors that ensure activities do not impact burrowing animals. The reservoirs were identified as an attractive nuisance to wildlife such as birds, bats, small mammals, and reptiles whereby they may pose a drowning risk. This would be mitigated by exclusion fencing, habitat augmentation to make reservoirs less attractive, and hazing to keep animals away. Project lighting was cited to potentially increase insect abundance that would attract bats to the project area and there was also concern that the lights could disrupt native animals. Impact mitigation involved designing project lighting to prevent casting light into adjacent native habitat and evicting bats from the project area. The potential for increased predators brought about by habitat destruction and increased perching habitats on transmission structures for predatory birds would be mitigated through enacting a Predator Monitoring and Control Plan to mitigate impacts to mammal species from predators. Birds being attracted to brine ponds with poor water quality or newly established vegetation in the project area that would create an ecological trap for birds was proposed to be mitigated through minimizing attractiveness of brine ponds, preventing establishment of new vegetation, and developing and implementing a plan that would include plans for additional studies or monitoring to minimize brine pond attractiveness and access to birds.

- **Invasive species establishment**

  There was concern that invasive species may colonize disturbed areas caused by project construction. Mitigation measures proposed for these impacts included implementation of the Invasive Species Additional Studies or Monitoring and Control Plan filed in 2009 designed to minimize spread of invasive vegetation. The Control Plan would also be amended to include an adaptive management plan, areas to be monitored for invasive plants, additional studies or monitoring of water seepage and reservoirs following construction, vegetation establishment, and periodically throughout the life of the project.

- **Other impacts**

  Construction impacts to native vegetation was of concern which was proposed to be mitigated through implementation of the Revegetation Plan filed in 2009 which would be amended to include additional irrigation of transplanted vegetation for 2-years following transplanting. There was also the possibility of project operations to promote new vegetation to establish in the project area through providing water subsidies. The proposed mitigation for this impact was to prevent establishment of new vegetation in the project area. Potential for unspecified biological impacts was proposed to be mitigated through designating a staff member who would be responsible for implementing and overseeing the biological compliance program.

Threatened and endangered species
Impacts including reservoirs acting as an attractive nuisance to animals, construction impacts to plant species of special concern, light pollution disrupting migrations, increased traffic collisions, habitat fragmentation, potential increased predation from predatory birds and canines, and nesting impacts for several species including Nelson's bighorn sheep (*Ovis canadensis nelsoni*), desert tortoise (*Gopherus agassizzi*), Couch's spadefoot toad (*Scaphiopus couchii*), burrowing owl (*Athene cunicularia*), golden eagle (*Aquila chrysaetos*), and several species of burrowing mammals, and bats. Specific details on impacts to and mitigations for threatened and endangered species from this project can be seen in Figure 2-2.

Recreation and land use

- **Recreation**

  Several of the potential impacts of this project are related to its proximity to Joshua Tree National Park and construction or project activities or works disrupting park visitors or being visible from the park. For example, construction of the transmission line may potentially be disruptive to or delay hikers. The proposed mitigation was to post notices and signage informing visitors wanting to use the road that the transmission line will pass over of the construction schedule and potential closures. This proposed mitigation was thought to be acceptable by FERC because of the low volume of traffic on the road. Project construction activities would be visible from inside the national park. There was no mitigation proposed because the construction activities would be indistinguishable from previous mining activities and would be visible only from a small portion of the park. Other project features or supporting infrastructure like transmission lines also would potentially impact visitors to the national park. These impacts would be mitigated through measures that would help project features blend into the landscape or use products made to minimize these impacts. Lights at the project would potentially disrupt dark sky conditions for backcountry campers. The proposed mitigation for this potential impact was to develop additional studies and monitoring plans in consultation with the National Park Service on dark sky conditions to quantify the light pollution with the goal of selecting products that would offset project light pollution.

- **Land use**

  The lower reservoir of this project would create potential conflicts with certain mineral reserve interests by inundating the remaining mineral reserves in the mine. This potential impact was not mitigated because there were not plans at the time of drafting the NEPA document to recover these reserves. The project transmission line also has the potential to impact other resources including land belonging to the California State Water Board. Similarly, project features would cross into land belonging to the Metropolitan Water District. Mitigations for these impacts would involve coordination and/or consultation with the agencies. Specifically, the licensee would need to use the preferred alternative transmission line route of the California State Water Board. They would also have to consult and coordinate with the Metropolitan Water District regarding project design, construction and maintenance of project features that would over into the Water District's boundaries. The large footprint of the construction staging and material storage areas would be mitigated by combining and organizing staging areas needed for equipment operation and material storage to minimize the footprint.

Aesthetic resources Impacts to aesthetic resources for visitors to Joshua Tree National Park are among the most predominant impacts of the Eagle Mountain project. These impacts and mitigations are discussed at length in the Recreation and Land Use section of this case study because of their impact on recreators at the park and will not be revisited here.

Cultural resources
Project impacts listed were the potential for project construction to destroy or damage previously unidentified cultural resources including sites of human burial, sites of cultural importance, or other resources that may be listed on the National Register of Historic Places. There were a number of proposed mitigations for these impacts which included presence of cultural resource monitors during construction activities, evaluation of cultural sites for inclusion on the National Register of Historic Places, monitoring of sensitive areas during construction that would be most likely to contain a human burial site or other undiscovered archeological resources, develop a Historic Properties Management Plan developed in consultation with the California State Historic Preservation Officer, agencies, and interested tribes and overseen by a historic properties management coordinator in the event that historic properties or human remains are discovered, development of a cultural resources training plan for project employees are familiar with cultural resource laws and regulations including Historic Properties Management Plan protocols and requirements, and installation of interpretive signage outside the main gate of the project that would provide the public with information about the prehistory and history of the project area, the Native Americans that inhabited the area, and background information how the project functions developed in consultation with Native American tribes.

Socioeconomics
Increased construction traffic may delay others using roads near the project site. This potential impact would be mitigated by construction traffic using alternative roadways, posting notices stating hours of construction operation and dates or times of any temporary road or access closures, development and implementation of a construction employee transportation management plan, and coordination of construction activities with the Bureau of Land Management.

Air quality and noise
Noise and dust resulting from project construction activities were listed as an impact of this project. The noise and dust would potentially disrupt private property owners, wildlife, reduce air quality due to fugitive dust, construction vehicle emissions, and generator emissions, emit objectionable odors from construction vehicle and other emissions, and create increased noise from construction activities and operation of construction equipment. Potential impacts would be mitigated through using newer, lower emitting construction equipment and generators, abide by state laws for diesel truck idling, stabilize graded surfaces when grading is completed and subsequent development is delayed or is expected to be delayed by more than 30 days (unless precipitation dampens the surface), periodically apply surfactant for short-term stabilization of disturbed surfaces and storage piles, and conduct additional studies and monitoring. Wildlife disturbance from construction noise and road fragmentation of wildlife habitats did not have proposed mitigations because the project lands had been mined for decades with similar disturbance and fragmentation levels.

A.3.5 Swan Lake North P-13318

The Swan Lake North Pumped Storage Project is a currently licensed 393.3-MW project northeast of the town of Klamath Falls, Oregon. The final NEPA document was issued in January 2019 and the original license order was issued on 30 April 2019. The project area occupies 2.95-km^2 of federal lands managed by the Bureau of Reclamation, 5.30-km^2 of state, county, and private lands.

The upper reservoir and lower reservoirs for this project will both be newly constructed above ground with a partially underground powerhouse. The planned upper reservoir has a surface area of 259,849-m^2 and stores 3,167,577-m^3 of water. The planned lower reservoir has a surface area of 243,378-m^2 and stores 3,183,612-m^3 of water. Initial fill water will come from local agricultural groundwater pumping and delivered to the lower reservoir using a preexisting agricultural irrigation conveyance. Water in the upper and lower reservoirs would fluctuate a maximum of approximately 15-m every 30-h.

Electricity would be transmitted from the powerhouse to an adjacent substation before being transmitted through a 53-km-long, 230-kV aboveground transmission line. This transmission line would interconnect with an existing substation not associated with the project.

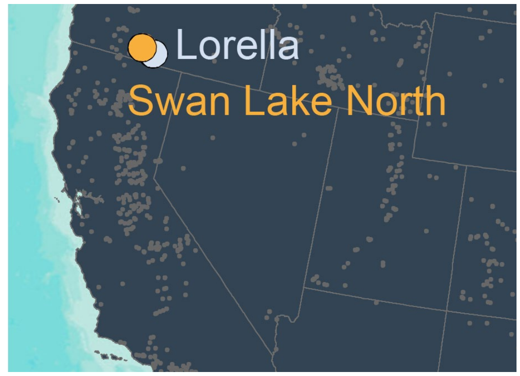

Figure A 8 Location of the Swan Lake North project.

Geologic and soil resources
Construction erosion was the only geologic and soil resources issue identified for this project.

Proposed mitigations for construction erosion at this project included development of a soil erosion control plan that includes site-specific best management practices to control erosion during project construction such as construct portions of the upper reservoir access road that cross intermittent waterbodies during the dry season to minimize erosion and sediment deposition.

Water resources
Potential water resource impacts at this project included changes in surface water runoff due to creation of reservoirs, seepage or leakage of water out of project reservoirs into groundwater, and deterioration of reservoir water quality.

Proposed mitigation measures for these impacts included construction of berms around reservoirs so the project does not capture as much runoff and minimize changes to surface hydrology in the Swan Lake drainage area, install liners in the reservoirs to prevent seepage of project water into groundwater, and develop an adaptive water quality management program to ensure water quality does not impair project operations or impact wildlife that may have incidental contact with project waters. The NEPA document for this project specified that the proposed adaptive water quality management program must include specific project reservoir water quality monitoring methods, water quality standards and measures that would be taken if standards are not met, and measures for reporting on water quality monitoring results.

Fisheries resources and aquatic ecology
No fisheries or aquatic ecology impacts were reported for this project.

Terrestrial resources
Most of the potential terrestrial resource impacts identified for this project centered on loss of native plant or wildlife habitat. Specifically, these impacts included destruction of native plants, including plants of cultural significance, during construction that may lead to noxious weed establishment, loss of wildlife habitat including habitat for ungulates and their migration corridors, loss of bird habitat including raptor habitat, and avian collisions with transmission lines including raptor collisions with transmission lines. Other terrestrial resource impacts included potential harm to wildlife caused by the project or its operations and potential wildfire risk due to project construction and operations.

Mitigations for most potential impacts involved development or implementation of or updates to some sort of plan. Plans proposed as mitigations for this project included a Revegetation and Noxious Weed Management Plan, updates to the Wildlife Habitat Restoration and Enhancement Plan, Conservation Land Management Plan, Avian Protection Plan, Ungulate Protection Plan, and a Fire Prevention Plan (Table 2). Other mitigations proposed that are not mentioned in Table 2 include the specification that the state wildlife agency must be notified if there is an emergency or unanticipated circumstance where large numbers of wildlife will be endangered, the licensee must contact the state wildlife agency to specify the nature of the event and the restorative actions taken.

Threatened and endangered species

Potential threatened and endangered species impacts for this project were disturbance, habitat destruction, or damage for sensitive plant species and bald eagles.

Proposed mitigation measures for these impacts including conducting preconstruction surveys for sensitive plants and, if located, flagging and fencing or translocating individual plants and development of a bald eagle conservation plan. Measures required to be included were similar to those listed for the Avian Protection Plan shown in Table 2.

Recreation and land use

There were only impacts to land use identified for this project including irrigation disruption during installation of the proposed transmission line and take of agricultural lands that would be crossed by the transmission line.

While there were mitigation measures proposed for project land use impacts, several enhancements were also proposed that were not identified as a mitigation measure for a specific impact. These enhancements included development of an interpretive facility in consultation with parties having local interest in the facility, development of a staging area for periodic guided tours of the facility, and design of the Bureau of Land Management's Swan Lake Rim Trail. Proposed mitigations for impacts to irrigation and agricultural lands included a coordination plan with two irrigation districts and a local dam to coordinate timing and installation of the transmission line to minimize disruption to agricultural activities.

Aesthetic resources

Project aesthetic resource impacts identified were visual impacts of the project and transmission structures to the overall landscape and impacts to dark night skies.

Mitigations for these impacts were to use construction materials that could preserve the character of the overall landscape. For example, proposed mitigations suggested to use locally quarried rock, preferably dark basalt, for the outer berm faces of the reservoirs, use paint colors on other project structures that match the landscape or dull surfaces of structures that cannot be painted, and use weathering steel that will develop a rust-like appearance and minimize their contrast with the surrounding landscape. Low impact construction techniques such as using helicopters to place materials in sensitive or difficult to reach locations, dust-suppression measures, and replanting all disturbed areas with permanent vegetation as specified in the Noxious Weed Management Plan. Night sky mitigations included use of lamps, covers, timers, or motion sensors and fully shielded lighting to minimize light pollution on the surrounding landscape.

Cultural resources

Potential disturbance or destruction of culturally important sites was identified as an impact including impacts to resources of the Klamath Tribes and sites on or eligible for the National Historic Register. Some of these historic sites included pre-contact archeological sites where impacts cannot be avoided or mitigated. Revising the Historic Properties Management Plan was proposed as a mitigation. This revision included several components such as additional background context for National Register eligibility determinations, map revisions created in consultation with the Oregon State Historic Preservation Officer, Bureau of Land Management, Bureau of Reclamation, and the Klamath Tribes to include additional potentially impacted areas, determinations of National Register eligibility of additional sites, specific measures to evaluate and avoid project impacts on cultural resources, and detailed descriptions of future construction and operation activities that would be subject to review by the Oregon SHPO, BLM, and the Klamath Tribes including how the review would be conducted and how adverse effects would be resolved. This plan revision would also include any additional studies or monitoring that would be ongoing during construction along with detailed procedures for addressing additional cultural resources found during construction.

Socioeconomics

Potential socioeconomic impacts identified included potential human safety issues from construction, reservoir operation, and hazards to hikers using nearby trails from construction vehicles and activities.

Mitigations proposed for these impacts included development of a public safety plan in consultation with state, federal and county agencies to protect the public during construction and project operations (e.g., safe operation of reservoirs, emergency vehicle access, ensuring safety of recreators using nearby trails during project construction). Development of a traffic safety plan was also proposed that would include traffic control measures, procedures for notifying and directing the public around traffic pattern changes, and control of recreational off-highway vehicles using public lands in the project's right -of-way. The license applicant would also have to attest that they would minimize public roadway and drainage facility maintenance disruptions and weight restrictions for local bridges would be followed.

Air quality and noise

Air quality and noise impacts identified were fugitive dust from construction activities along with emissions from construction vehicles. Development of an air quality control plan centered on controlling construction fugitive dust and construction vehicle emissions were proposed as the mitigation.

A.3.6 Gordon Butte P-13642

The Gordon Butte Pumped Storage Hydro Project is a currently licensed 400 MW project located approximately 5-km west of the town of Martinsdale, Montana. The final NEPA document was issued in September 2016 and the original license order was issued on 14 December 2016. The project plans to use an existing diversion structure on a creek, and an irrigation canal and flume owned and operated by a local ranch to provide water for filling project reservoirs. This project would not occupy federal lands.

The upper reservoir and lower reservoirs for this project will both be newly constructed above ground with a partially underground powerhouse. The planned upper and lower reservoirs have surface areas of 279,243-m^2 and 356,136-m^2, respectively, and store 254,541,406-m^3 of water in each reservoir. Initial fill water will come from local agricultural groundwater pumping and delivered to the lower reservoir using a preexisting agricultural irrigation conveyance.

Figure A 9 Location of the Gordon Butte project.

Electricity would be transmitted from the powerhouse to an adjacent substation before being transmitted through a 9-km-long, 230-kV aboveground transmission line to a new substation where power would be stepped up to 500-kV and would interconnect with an adjacent existing non-project 500-kV transmission line.

A.3.6.1 Gordon Butte impacts and mitigations

Geologic and soil resources
Construction erosion was identified as an impact to geologic and soil resources.

Mitigations proposed for this impact included revision of the preliminary Erosion and Sediment Control Plan based on the final design of the project. This revision would include site-specific best management practices to control erosion and storm water runoff during project construction.

Water resources
The major impact identified at this project was project fill and refill flow diversions may impact water quantity in nearby surface waters particularly a nearby creek. Mitigations proposed for this impact involved restricting water diversions for initial fill and refill to spring months when flows are naturally high. Meeting minimum flow requirements and documenting that these requirements are met was also proposed in their mitigation measures.

Fisheries resources and aquatic ecology
No fisheries or aquatic ecology impacts were reported for this project.

Terrestrial resources
Impact evaluations identified several potential impacts to botanical resources including plant habitats and establishment of invasive plant species, impacts to birds including raptors, and impacts to wildlife and wildlife habitat.

- **Botanical resources**

  Vegetation disturbance from construction activities was thought to create conditions for noxious weed establishment and the potential for import of noxious weeds from construction materials and equipment. Project construction was also thought to potentially impact lands outside the project boundaries including the diversion structure, irrigation canal, and upper reservoir access road by introducing noxious weeds and their seeds from construction equipment or materials. Proposed mitigation measures for botanical resource impacts included development of a vegetation management plan that defines best management practices to minimize existing vegetation and wetland disturbance and to quickly revegetate disturbed areas to control erosion and protect wildlife habitat. Revision of the preliminary Noxious Weed Control Plan to include site-specific measures and best management practices including cleaning equipment to remove weed seeds from construction equipment before moving them to a new site and inspecting construction materials at their source to verify they are weed-free and quickly revegetating disturbed areas. This revision would also include extension of the plan to the diversion structure, irrigation canal, and upper reservoir access road even though they are outside of the proposed project boundaries.

- **Wildlife resources**

  Removal of grassland vegetation to construct project reservoirs, lay-down areas, powerhouse, and access road could potentially disrupt nesting migratory birds. Construction and initial operation of the transmission line could lead to bird-line collisions and electrocutions and clearing of the transmission corridor may destroy active raptor nests. There was additionally concern for wildlife safety near project reservoirs and substations due to drowning or electrocution risk. Proposed mitigation measures for impacts to wildlife resources included restricting grassland vegetation removal from April 15th to July 15th to protect nesting migratory birds near the reservoirs, lay-down areas, powerhouse, and access road. Monitoring effects of construction and initial operation of the transmission line on birds and a pre-construction survey of the proposed transmission line corridor to determine if there were any active raptor nests and, if so, if juvenile birds had fledged. If raptor nests were found to be active, delay of construction activities or implementation of additional protective measures such as a 0.5-mile buffer were proposed. To reduce potential for avian electrocution and collision, the transmission line would be designed to minimize avian electrocution and collision potential including installation of visual markers on the transmission line near a local creek. Measures to reduce wildlife drowning and electrocution risk included installing fencing around project reservoirs and substations.

Threatened and endangered species
Potential impacts to bald eagles were the only impact to threatened and endangered species identified for this project. Proposed mitigation measures for protecting bald eagles included maintaining a 0.5-mile buffer between transmission line construction and bald eagle nests during the nesting period from February 1st to August 15th.

Recreation and land use
No recreation and land use impacts or mitigation measures were identified for this project.

Aesthetic resources
Identified potential project impacts included visual impacts of the project not matching the character of the native landscape. Proposed mitigation measures for visual project impacts included using topographic features to shield the lower reservoir from the highway and use landscaping and landscape restoration techniques to blend the project features with the surrounding natural landscape. Colors and materials that would blend project facilities with the native landscape was also proposed to minimize project impacts. Ground disturbance and construction needed for roads, staging areas, and crane pads would also be minimized as much as possible.

Cultural resources
Cultural resource impacts for this project included potential disturbance or destruction to known and previously unidentified cultural resources during construction including prehistoric sites and traditional cultural properties of the Crow Nation and early European-American settlements.

Proposed mitigation measures to cultural resource impacts included fencing around culturally sensitive sites to avoid their accidental disturbance or destruction. This project would also have an on-site archeological monitor to identify and protect any previously unknown resources.

Socioeconomics
There were several socioeconomic impacts identified for this project. Impacts to local infrastructure such as hospitals, roadways, housing availability, and potentially schools if workers moved their families to the project vicinity during the multiple years' long project construction. Expanding this infrastructure to accommodate the influx of workers would permanently change the character of the area even though the infrastructure expansion needs would not be permanent. Traffic impacts were identified due to the increased construction traffic and potential for increased safety hazards or traffic congestion during times children are being transported. Potentially unsafe on-site parking for construction workers due to heavy equipment operation and hazardous materials, and on-site theft, vandalism, or other crimes that could burden local law enforcement resources was also identified as potential impacts. Reservoirs and project substations creating an attractive nuisance for members of the public that could put them at risk for drowning or electrocution were also identified as impacts.

Proposed mitigation measures for socioeconomic impacts included development of a hazardous materials plan defining procedures for proper containment or disposal of hazardous substances during project construction and operation and creation of a Spill Prevention, Control, and Containment Plan defining protocols for hazardous substance management and cleanup during project construction and operation. Measures proposed to minimize local infrastructure impacts included development of a construction workforce management plan, developing a traffic management plan for a highway near the project, providing a bus to the project site for project personnel, and staggering work shifts and project deliveries so project traffic doesn't contribute to traffic congestion and safety impacts during hours when children are being transported. On-site security would also be used to lessen the burden on local law enforcement. To ensure public safety near project reservoirs and substations, fencing would be installed around project reservoirs and substations.

Air quality and noise
Potential air quality and noise impacts included increased noise and dust from construction activities.

Increased dust and noise impacts would be mitigated through revision of the preliminary Construction Noise Mitigation and dust plans. These plan revisions would include incorporation of site-specific best management practices to limit construction noise and maintain good air quality during construction.

Appendix B – Interview Guide

1. In general, how does the level of environmental impacts for closed-loop pumped storage hydropower (PSH) compare to open-loop PSH?

   For the purposes of this report, closed-loop PSH is defined as a PSH facility that is not continuously connected to a naturally flowing water feature. In other words, PSH facilities that draw their initial filling and replacement water from a river are still considered closed-loop.

2. What environmental issues come up during environmental review, permitting, or licensing discussions for closed-loop PSH?
   a. What environmental issues aren't accounted for that should be?
   b. What environmental issues are accounted for that do not need to be?
   c. Are the environmental issues different for open-loop PSH? If so, how?
   d. What protection, mitigation, and enhancement (PM&E) measures are mentioned during these discussions?
3. How do specific project sites or characteristics impact environmental impacts?
   a. What sites or characteristics have fewer impacts?
   b. What sites or characteristics have more impacts?
   c. What PM&E measures are discussed or would be appropriate for these impacts?
4. What aquatic resource impacts would be expected for closed-loop PSH?
   a. Surface water quality and quantity
   b. Groundwater quality and quantity
   c. Aquatic ecology
5. What terrestrial resource impacts would be expected for closed-loop PSH?
   a. Geology and Soils
   b. Terrestrial ecology
   c. Land use, recreation, visual resources, and cultural resources
6. What PM&E measures would be appropriate to mitigate the impacts described above?
7. What other impacts of closed-loop PSH should be investigated?
8. What other PM&E measures might be appropriate or should be investigated?
9. Who else would you recommend we talk to? This could be a specific person or someone with a different expertise.
10. What proposed closed-loop PSH projects in the United States or other countries would serve as good case studies?

Appendix C

Dataset of environmental impacts and mitigations from six National Environmental Policy Act documents reviewed for this project.

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