UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Klamath River Renewal Corporation	**Project Nos. 14803-001;**
PacifiCorp	**2082-063**

AMENDED APPLICATION FOR SURRENDER OF LICENSE FOR MAJOR PROJECT AND REMOVAL OF PROJECT WORKS

EXHIBIT J
Reservoir Area Management Plan
(Amended December 15, 2021)

KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
FERC Project No. 14803

Reservoir Area Management Plan

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1.0 Introduction

The Lower Klamath River Project (Lower Klamath Project) (FERC No. 14803) consists of four hydroelectric developments on the Klamath River: J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate (Figure 1-1). In September of 2016, the Renewal Corporation filed an *Application for Surrender of License for Major Project and Removal of Project Works,* FERC Project Nos. 2082-063 & 14803-001 (License Surrender). The Renewal Corporation filed the License Surrender Application as the dam removal entity for the purpose of implementing the Klamath River Hydroelectric Settlement (KHSA). In November of 2020, the Renewal Corporation filed its Definite Decommissioning Plan (DDP) as Exhibits A-1 and A-2 to its Amended License Surrender Application (ALSA). The DDP is the Renewal Corporation's comprehensive plan to physically remove the Lower Klamath Project and achieve a free-flowing condition and volitional fish passage, site remediation and restoration, and avoidance of adverse downstream impacts (Proposed Action).

The Proposed Action includes the deconstruction of the J.C. Boyle Dam and Powerhouse (Figure 1-2), Copco No. 1 Dam and Powerhouse (Figure 1-3), Copco No. 2 Dam and Powerhouse Figure 1-4), and Iron Gate Dam and Powerhouse (Figure 1-5), as well as associated features. Associated features vary by development, but generally include powerhouse intake structures, embankments, and sidewalls, penstocks and supports, decks, piers, gatehouses, fish ladders and holding facilities, pipes and pipe cradles, spillway gates and structures, diversion control structures, aprons, sills, tailrace channels, footbridges, powerhouse equipment, distribution lines, transmission lines, switchyards, original cofferdams, portions of the Iron Gate Fish Hatchery, residential facilities, and warehouses.

This Reservoir Area Management Plan describes the management measures that the Renewal Corporation will implement as part of the Proposed Action in connection with the restoration, monitoring, and adaptive management of the Reservoir Areas (as defined in Section 1.3) and High Priority Tributaries (as defined in Section 1.3) as well as the fish passage monitoring the Renewal Corporation will conduct within the Reservoir Area Management Plan Fish Passage Monitoring Area (as defined in Section 1.3).

The Renewal Corporation has prepared 16 Management Plans for the review and approval of the Federal Energy Regulatory Commission (Commission) as conditions of the License Surrender Order. These Management Plans were developed in consultation with federal, state and county governments and tribes.

In February 2021, the Renewal Corporation filed the 16 Management Plans with the Commission. Since that time, the Renewal Corporation has undertaken further consultation, resulting in material revisions. Table 2-2 herein shows the material revisions to the February 2021 version of this Reservoir Area Management Plan. An updated Consultation Record for the Reservoir Area Management Plan is included as Appendix A.

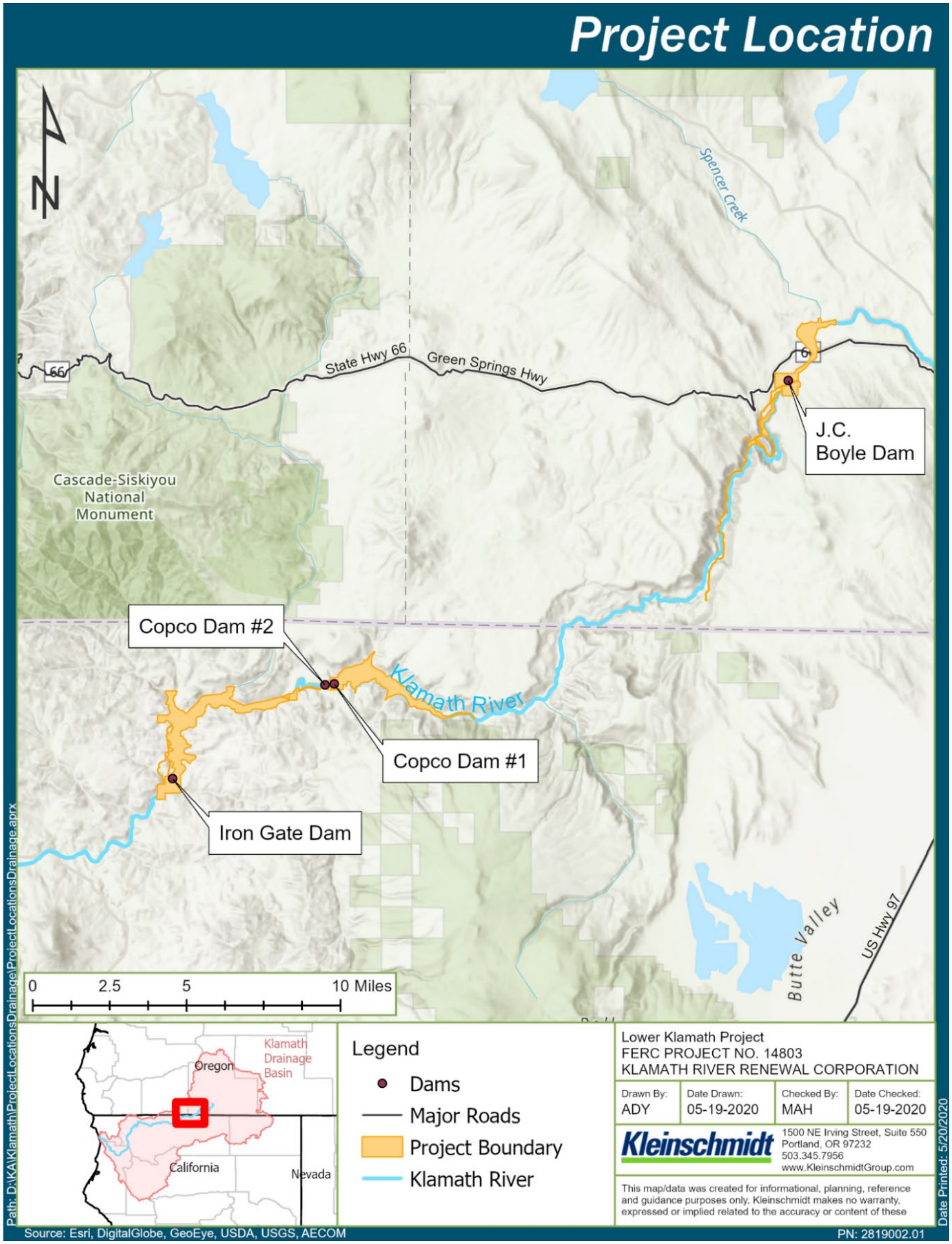


Figure 1-1. Lower Klamath Project Location

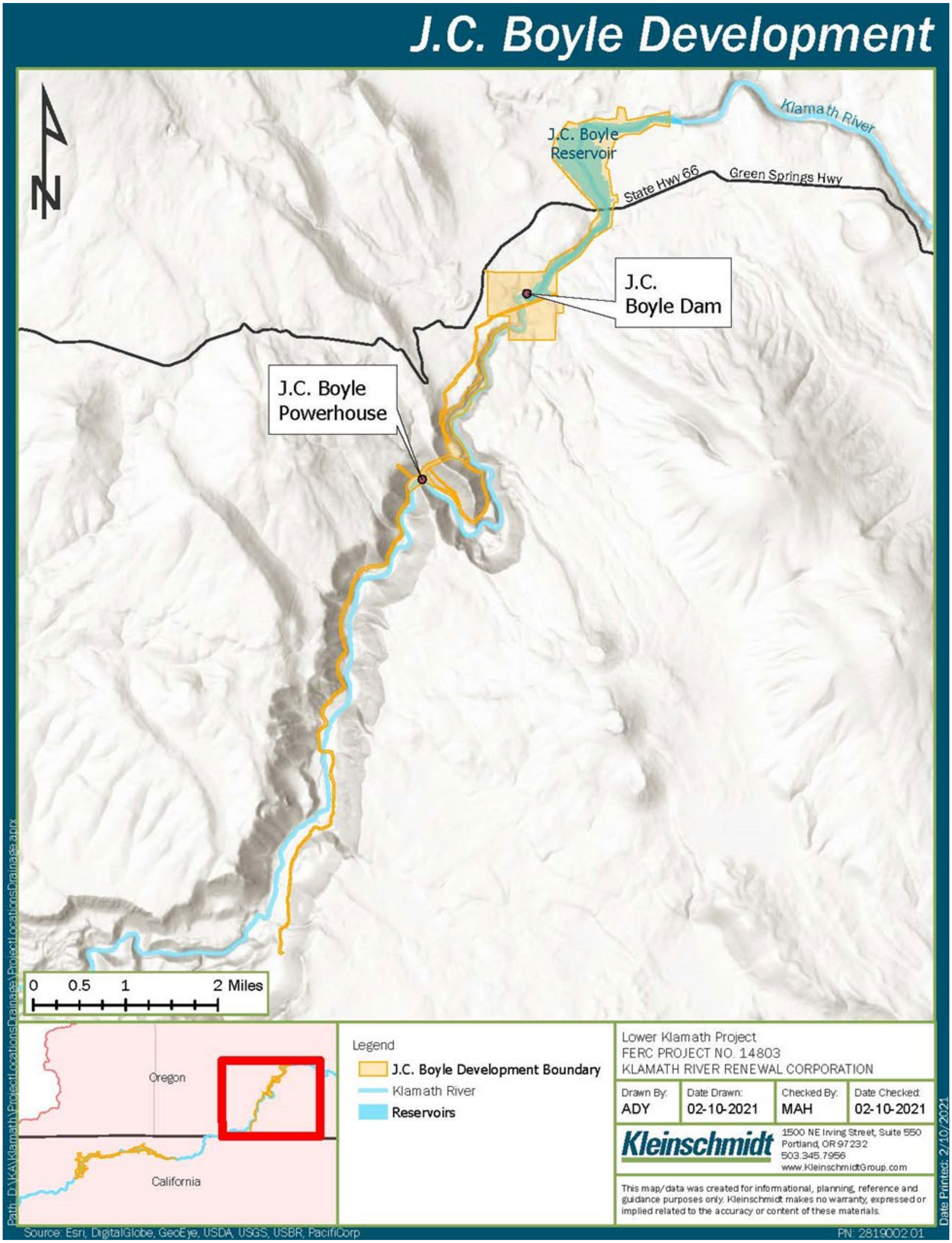


Figure 1-2. J.C. Boyle Development Area

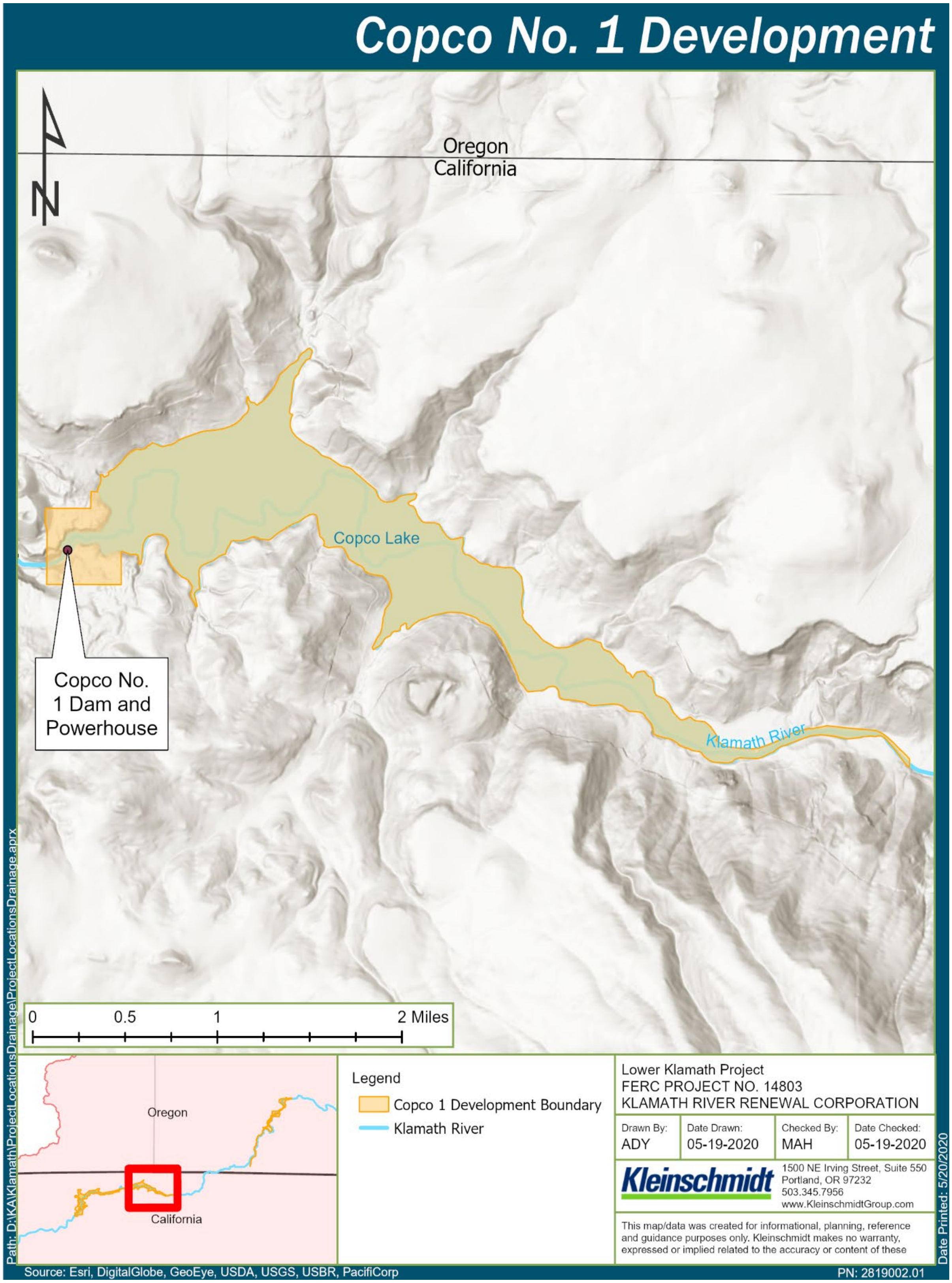


Figure 1-3. Copco No.1 Development Area

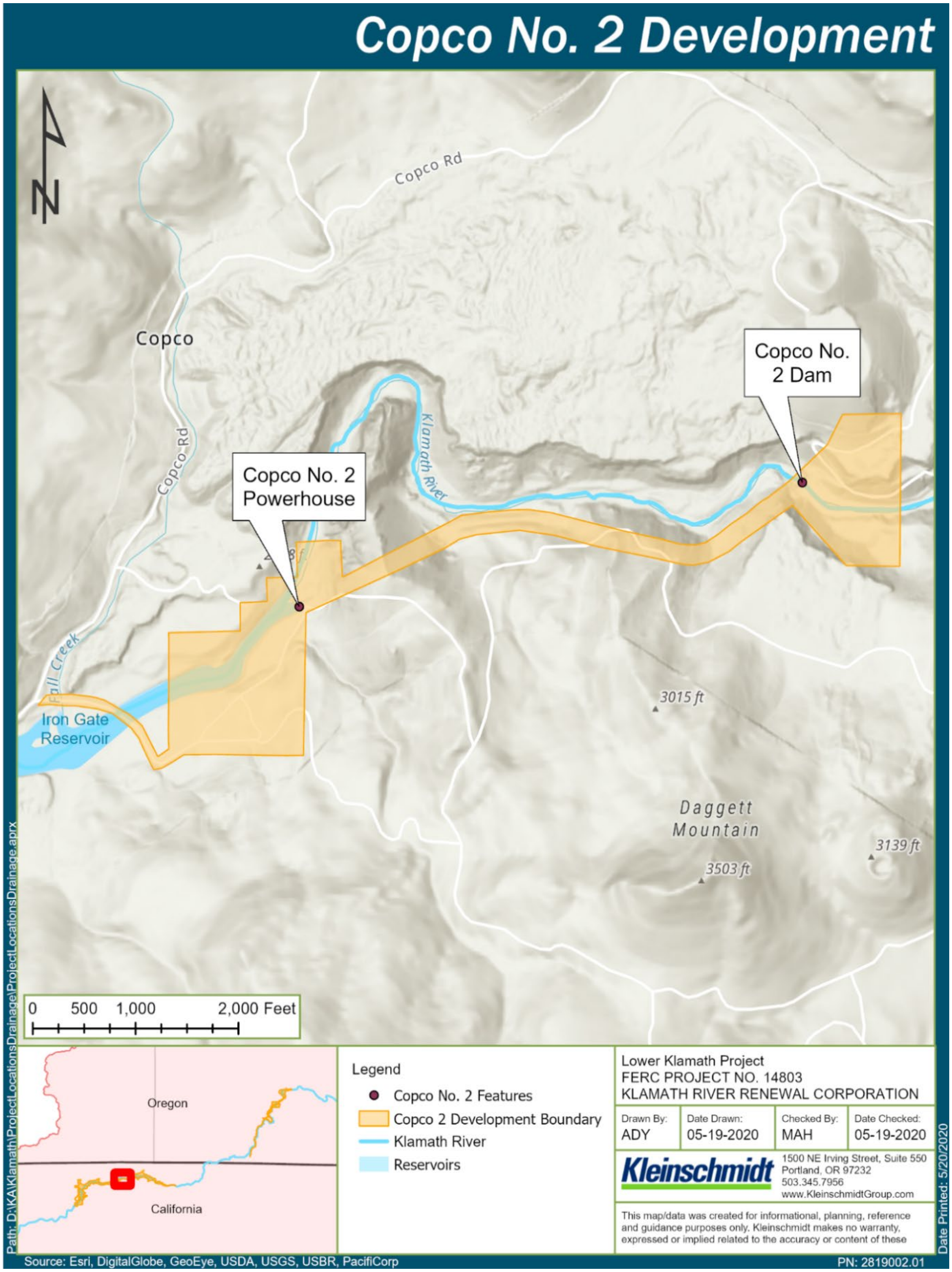


Figure 1-4. Copco No.2 Development Area

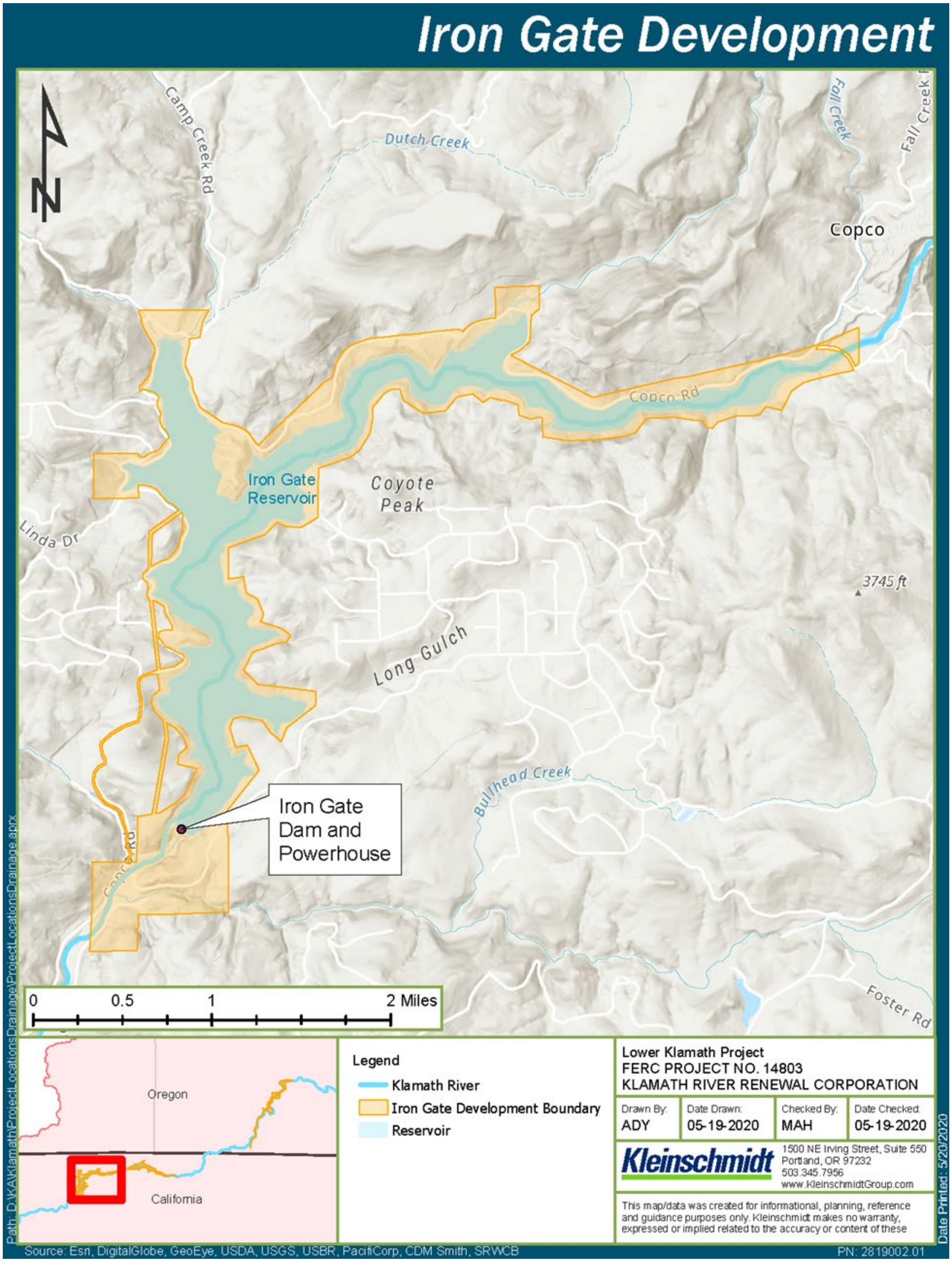


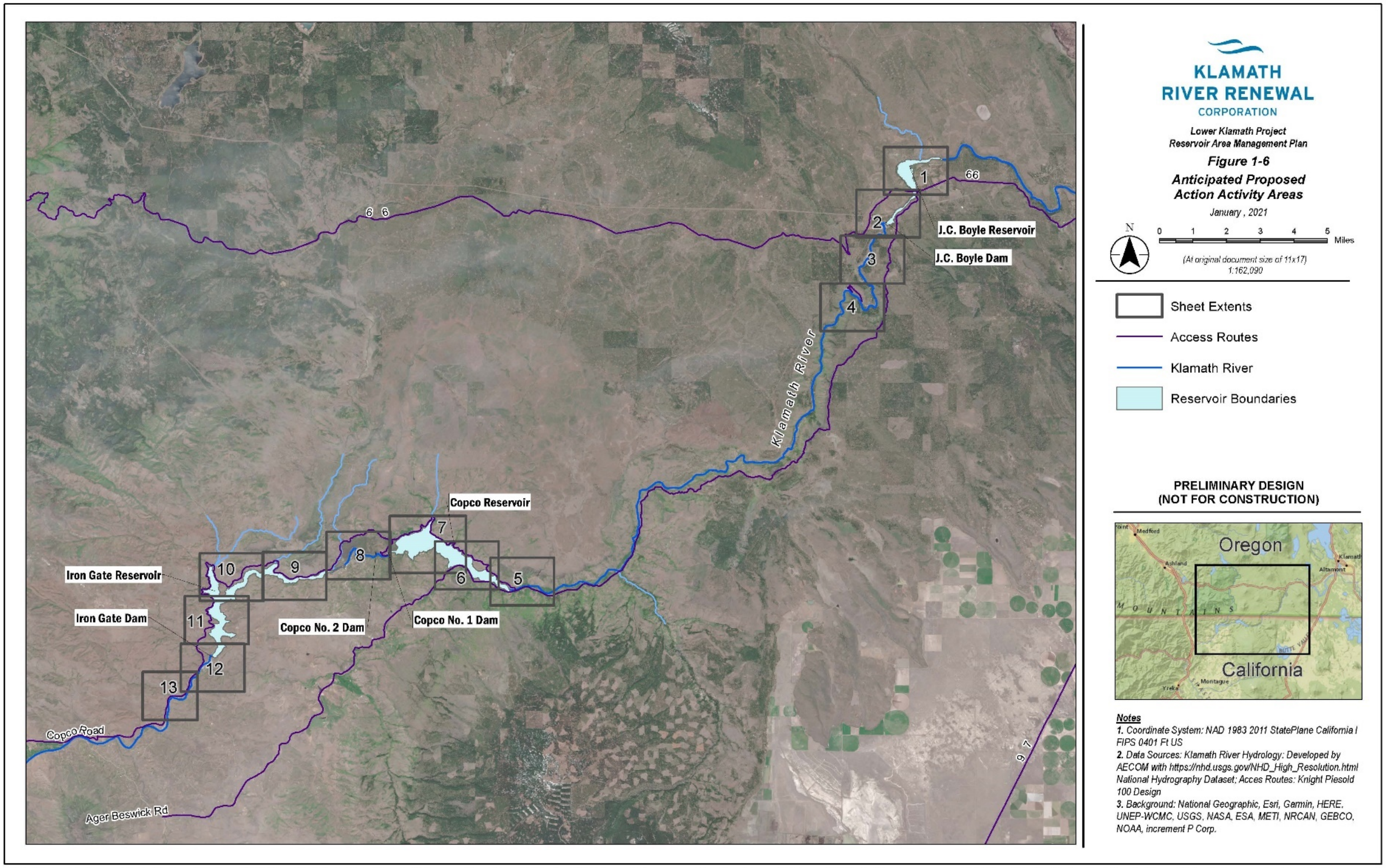
Figure 1-5. Iron Gate Development Area

1.1 Purpose of Reservoir Area Management Plan and Use

As the Renewal Corporation implements the Proposed Action, the currently inundated Reservoir Areas will become exposed and require restoration and stabilization of bare sediment deposits for long-term water quality, long-term ecological benefits, and restoration of natural river functions and processes. The Reservoir Area Management Plan describes proposed measures for restoration, monitoring, and adaptive management of the Reservoir Areas and High Priority Tributaries as well as fish passage monitoring within the Reservoir Area Management Plan Fish Passage Monitoring Area. In addition, for informational purposes only, Section 5.1 (Rehabilitation Measures Outside of the Reservoir Areas) sets forth additional rehabilitation measures that the Renewal Corporation may implement under other Management Plans.

The Renewal Corporation will prepare and submit an Annual Compliance Report within six (6) months of concluding drawdown activities, and annually thereafter for as long as the Renewal Corporation has performance obligations under the Reservoir Area Management Plan. For purposes of the Annual Compliance Report, drawdown activities will be considered concluded when the Klamath River lowers to, and permanently occupies, its original 100-year flood channel. The Annual Compliance Report will be submitted to the California State Water Resources Board (SWRCB) and Oregon Department of Environmental Quality (ODEQ), and copied to the Habitat Restoration Group (as defined in Section 1.3), by April 1. In addition, the Annual Compliance Report will be submitted to the Commission by April 15. The Annual Compliance Report will include the following:

1. Monitoring data, including graphical representations, as appropriate
2. Consultation record (Appendix A)
3. A narrative interpretation of the results of restoration
4. A summary of all significant interventions taken to remove fish passage barriers
5. Adaptive management recommendations and actions
6. A description of any tree removal activities performed in Ward’s Canyon
7. A summary of whether performance criteria is being met and/or whether restoration is on a trajectory to achieve the performance criteria



Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. McMillen Jacobs Associates has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. McMillen Jacobs Associates assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Figure 1-6. Anticipated Proposed Action Activity Areas

Note: Coversheet included herein and mapbook included in Appendix B.

1.2 Organizational Structure

The remainder of this Reservoir Area Management Plan follows the outline below:

- **Chapter 2.0: Regulatory Context** describes the regulatory framework for the Proposed Action and how the Reservoir Area Management Plan relates to the other management plans.
- **Chapter 3.0: Restoration Goals and Objectives** provides a high-level overview of how the Reservoir Area Management Plan will support the overall project goals of restoring volitional fish passage, stabilizing exposed sediment with native vegetation, establishing native plants and the secondary goal of enhancing native aquatic habitat.
- **Chapter 4.0: Anticipated Reservoir Conditions After Drawdown** summarizes the expected condition of the Reservoir Areas post-drawdown, specifically with respect to sediment, as well as how those conditions are expected to evolve in the short term.
- **Chapter 5.0: Restoration Measures** describes the measures the Renewal Corporation will implement to progress the Hydroelectric Reach (as defined in Section 1.3) from a lentic to a lotic system as the reservoirs are replaced by a free-flowing river.
- **Chapter 6.0: Monitoring and Adaptive Management** describes the qualitative and quantitative metrics that will be monitored by the Renewal Corporation, the performance criteria for the restoration goals described in the Reservoir Area Management Plan and the Renewal Corporation’s approach to adaptive management.
- **Chapter 7.0: Data Management and Reporting** summarizes the Renewal Corporation’s data management and reporting obligations under the Reservoir Area Management Plan.
- **Chapter 8.0: References** provides a list of the documents referenced in the Restoration Area Management Plan.

Additionally, to further inform implementation activities, the Reservoir Area Management Plan includes the following appendices, some of which may be updated during restoration as conditions change and the Renewal Corporation engages in adaptive management:

- **Appendix A:** Consultation Record
- **Appendix B:** Figures / Detailed Map Books
- **Appendix C:** Best Management Practices
- **Appendix D:** Current and Historic Conditions as a Reference for Restoration
- **Appendix E:** Methodologies for Calculating Anticipated Reservoir Conditions Post-Drawdown
- **Appendix F:** Establishment of Restoration Priorities within the Reservoirs
- **Appendix G:** Geomorphology Monitoring / Adaptive Management Field References
- **Appendix H:** Native Revegetation and Invasive Exotic Vegetation Treatment
- **Appendix I:** Habitat Restoration Group
- **Appendix J:** List of Preparers
- **Appendix K**: 60 Percent Assisted Sediment Evacuation Design for Copco Reservoir

- **Appendix L:** 60 Percent Assisted Sediment Evacuation Design for Iron Gate Reservoir
- **Appendix M:** Large Wood Stability Calculations

Note: Overview figures are included in the main text of this document. Where applicable, detailed map books are included in Appendix B to provide more detail.

1.3 Definitions of Terms

Habitat Restoration Group (HRG): A work group assembled by the Renewal Corporation to assist in the development and consult in the implementation of the Reservoir Area Management Plan. Members of the HRG are listed in Appendix I. See Section 1.4 for additional detail regarding the HRG.

High Priority Tributaries: Spencer Creek, Beaver Creek, Jenny Creek, Scotch Creek and Camp Creek. The Renewal Corporation will conduct restoration activities along each High Priority Tributary to remove reservoir sediment, facilitate fish passage, and/or enhance habitat. The methodology for identifying High Priority Tributaries is summarized in Appendix F (Establishment of Restoration Priorities within the Reservoirs).

High Priority Tributary Work Area: The area in which restoration of the High Priority Tributaries will occur. The High Priority Tributary Work Areas are set forth in Figure 5-7 (Spencer Creek), Figure 5-8 (Beaver Creek), and Figure 5-9 (Jenny Creek, Scotch Creek and Camp Creek).

Hydroelectric Reach: The reach between the upstream end of J.C. Boyle Reservoir and Iron Gate Dam.

Limits of Work: The geographic area that encompasses dam removal-related activities associated with the Proposed Action. Except where specifically noted, the Limits of Work are within the FERC boundary associated with the Lower Klamath Project.

Reservoir Area Management Plan Fish Passage Monitoring Area: The area defined in Section 6.2.5 in which the Renewal Corporation will conduct fish passage monitoring under the Reservoir Area Management Plan.

Reservoir Areas: The areas within the former reservoir locations of the J.C. Boyle Reservoir, Copco No. 1 Reservoir, Copco No. 2 Reservoir, and Iron Gate Reservoir, as set forth in Figure 1-6 of Appendix B. The Reservoir Areas do not include the reservoir footprints.

Year: For purposes of the Reservoir Area Management Plan, Year 1 refers to the year before drawdown, Year 2 refers to the drawdown year, Year 3 refers to the year following the drawdown year, Year 4 refers to the following year and so on. For schedule details, see Section 5.7 (Schedule of Construction and Restoration).

1.4 Habitat Restoration Group

The Renewal Corporation assembled a Habitat Restoration Group (HRG)[1] during development of the Reservoir Area Management Plan. The work group is comprised of members of the Renewal Corporation's team, federal and state resource agencies, and tribal entities, each of which is listed in Appendix I. The Reservoir Area Management Plan, including the metrics and objectives contained herein, reflect that consultation on best available science and management measures. Going forward, the Renewal Corporation will consult with the HRG regarding implementation of the Reservoir Area Management Plan.

To facilitate the consultative process, each member of the HRG will designate a lead who will represent it at HRG meetings and serve as its primary contact for all HRG-related matters. The Renewal Corporation will also establish protocols for consultation with the HRG. These protocols will address meeting logistics and frequency, agenda development, and recordkeeping and other procedures.

The Renewal Corporation will actively consult with the HRG during implementation of the Reservoir Area Management Plan. The Renewal Corporation will maintain a record of the topics covered, decision points reached, and actions items agreed to. Under the License Surrender Order, the Renewal Corporation will be responsible for implementation of the plan and is not delegating or assigning that responsibility to the HRG.

[1] The Habitat Restoration Group was formerly referred to as the Restoration Technical Work Group or RTWG in previous versions of the Reservoir Area Management Plan.

2.0 Regulatory Context

As described in Table 2-1, the Reservoir Area Management Plan is one of 16 Management Plans implementing the DDP.

Table 2-1. Lower Klamath River Management Plans

1. Aquatic Resources Management Plan	9. Remaining Facilities Plan
2. Construction Management Plan	10. Reservoir Area Management Plan
3. Erosion and Sediment Control Plan[2]	11. Reservoir Drawdown and Diversion Plan
4. Hatchery Management and Operations Plan	12. Sediment Deposit Remediation Plan
5. Health and Safety Plan	13. Terrestrial and Wildlife Management Plan
6. Historic Properties Management Plan	14. Waste Disposal and Hazardous Materials Management Plan
7. Interim Hydropower Operations Plan	15. Water Quality Monitoring and Management Plan
8. Recreation Facilities Plan	16. Water Supply Management Plan

2.1 Specific Regulatory Interests

The Renewal Corporation considered the following regulatory interests in the development of the Reservoir Area Management Plan:

- California Section 401 Water Quality Certification (SWRCB, 2020)
- Oregon Section 401 Water Quality Certification (ODEQ, 2019)
- California Department of Fish and Wildlife Memorandum of Understanding
- Oregon Memorandum of Understanding
- California Environmental Quality Act, Final Environmental Impact Report
- Biological Assessment (National Marine Fisheries Service (NMFS))
- Biological Assessment (U.S. Fish and Wildlife Service (USFWS))

[2] The Erosion and Sediment Control Plan (ESCP) referenced in Table 2-1 refers to the Management Plan filed with the Commission. The ESCP contains a subplan called the Oregon Erosion and Sediment Control Plan (Oregon ESCP). In addition, the Renewal Corporation will file a separate Erosion and Sediment Control Plan (1200-C ESCP) with ODEQ in connection with the National Pollutant Discharge Elimination System (NPDES) General Permit No. 1200-C (1200-C Permit) issued by ODEQ.

2.2 Reservoir Area Management Plan Development

This Reservoir Area Management Plan (2021) supersedes the 2018 Reservoir Area Management Plan and is intended to facilitate the coordinated implementation of restoration, monitoring, and adaptive management activities associated with the Proposed Action. The Renewal Corporation completed development of the Reservoir Area Management Plan in coordination with the HRG.

While the dam and infrastructure removal schedules in the Reservoir Area Management Plan are based on the current 100 percent design (Kiewit 2020), the restoration and fish passage monitoring schedules are based on the current reservoir restoration 60 percent design (RES 2020). The reservoir restoration design will be updated from 60 to 90 percent and final design after the Reservoir Areas respond and evolve under post-drawdown conditions during Year 2. Once completed, the final reservoir restoration design will be submitted to the SWRCB and ODEQ for approval. Once approved, the Renewal Corporation will file a report with the Commission within 14 calendar days, which shall include the final reservoir restoration design.

The Reservoir Area Management Plan (2021) incorporates the following items proposed by the Renewal Corporation in the ALSA:

- An overview of the actions required to implement restoration, monitoring, and adaptive management.
- A detailed description of the proposed restoration activities and preliminary maps identifying, to the extent possible, the proposed locations for those activities.
- A list of best management practices for limiting spread of invasive exotic vegetation, in-water work and herbicide application.
- Performance criteria for evaluating restoration efforts, including with respect to native vegetation, invasive vegetation management, sediment stability, bank stability, fish passage, floodplain connectivity, floodplain roughness and channel fringe complexity.
- Descriptions on the use of native plants to promote soil stabilization.
- A wetlands presence evaluation (including wetlands in the disposal areas).
- A monitoring plan for invasive weeds in the restored areas.
- Measures to ensure floodplain connectivity, no net loss of wetland habitat in Oregon or California, and no net loss of riparian habitat in California.
- A plan for installation of large woody material.
- Monitoring activities using aerial Light Detection and Ranging (LiDAR) reconnaissance surveys to measure sediment stability and estimate the volume of sediment export following the drawdown phases, supplemented annually with visual inspections and physical measurements.
- Adaptive management measures to be implemented if monitoring indicates that runoff from exposed embankment areas is causing erosion, sedimentation or lower water quality.

2.3 Results of Consultation since February 2021

On the basis of consultation since February 2021, the Renewal Corporation has revised the February 2021 version of this plan in the following material respects.

Table 2-2. Results of Consultation

CHAPTER	CHANGES TO FEBRUARY 2021 VERSION
Chapter 1.0: Introduction	• Added a section describing the Habitat Restoration Group.
Chapter 2.0: Regulatory Context	• Added a section listing the regulatory interests considered in the development of the Reservoir Area Management Plan.
Chapter 3.0: Restoration Goals and Objectives	• Updated Table setting forth goals and objectives.
Chapter 4.0: Anticipated Reservoir Conditions After Drawdown	• Added requirement to consult with HRG if unexpected post-drawdown conditions require development of site-specific restoration measures.
Chapter 5.0: Restoration Measures	• Updated sections describing rehabilitation covered under other plans or construction permits to include discussion of permits and references to the related plans and permits. • Deleted infrastructure-related restoration section. • Added section noting that the Copco No. 2 Bypass Reach, a section of Ward's Canyon, is outside the Limits of Work. • Added range (100-1000) of large wood features to be installed. • Added requirement that the relevant regulatory agencies approve the final reservoir restoration design. • Inclusion of Cultural Resources consideration for large wood placement. • Added description of wetland and riparian habitat preservation and restoration. • Added section regarding wetland and riparian habitat mitigation. • Excluded use of Aminocyclopyrachlor + chlorsulfuron (Perspective®) on Oregon Lands managed by BLM.
Chapter 6.0: Monitoring and Adaptive Management	• Added checkpoints with HRG if proposed action is not meeting performance criteria. • Updated monitoring timeline to require monitoring for a minimum of 5 years, independent of whether the performance criteria have been met. • Updated to require approval by applicable regulatory agencies to discontinue monitoring. • Revised definition of Anthropogenic Debris to include natural debris barriers caused by dam removal activities.

CHAPTER	CHANGES TO FEBRUARY 2021 VERSION
	• Added requirement that the HRG be consulted if a natural barrier materially and unexpectedly restricts fish passage. • Expanded discussion of geomorphological monitoring, including rapid geomorphological and residual reservoir sediment stability assessments. • Added requirement that changes to Reservoir Area Management Plan due to Unforeseen Circumstances be approved by the applicable regulatory agencies. • Added requirement that adaptive management, in consultation with the HRG, will be undertaken if revegetation is not adequately progressing by the end of Year 6. • Added table documenting anticipated habitat acreage following dam removal/restoration.
Chapter 7.0: Data Management and Reporting	• Updated to require additional items be included in the Annual Compliance Reports.
Appendices	• Appendix C: Updated to incorporate all BMPs contained in the Construction Management Plan that are relevant to the restoration work described in the Reservoir Area Management Plan. • Appendix C: Updated to include In-Water Work Construction Windows. • Appendix C: Updated to include dust abatement BMPs. • Appendix C: Updated to exclude use of neonicotinoids.

2.4 Relationship to Other Management Plans

The Reservoir Area Management Plan is supported by elements of other management plans for effective implementation as described in Table 2-3.

Table 2-3. Management Plans Supporting Elements of the Reservoir Area Management Plan

MANAGEMENT PLAN	NOTES
Reservoir Drawdown and Diversion Plan (RDDP)	The RDDP describes the actions to be taken during drawdown, while the Reservoir Area Management Plan informs the associated assisted sediment evacuation measures. These are two (2) interrelated activities. In addition, the Slope Stability Monitoring Plan, a subplan of the RDDP, focuses on areas near existing infrastructure and generally prescribes proactive measures for site stabilization.

MANAGEMENT PLAN	NOTES
Aquatic Resources Management Plan (ARMP)	The Tributary-Mainstem Connectivity Plan, a subplan of the ARMP, includes overlapping monitoring and adaptive management activities related to the adaptive removal of fish passage barriers on key tributaries and select reaches of the mainstem Klamath River.
Historic Properties Management Plan (HPMP)	The Cultural Resources Plan, a subplan of the HPMP, states how culturally sensitive sites are identified and the restrictions that apply to such sites.
Construction Management Plan	The Construction Management Plan establishes BMPs that are applicable to the Renewal Corporation’s dam removal contractors and the restoration contractors responsible for implementing the Reservoir Area Management Plan.

Additional management plan activities will yield data that will inform adaptive management for the Reservoir Area Management Plan. These include, without limitation, the following:

- Data obtained pursuant to the Water Quality Monitoring and Management Plan will inform Reservoir Area Management Plan adaptive management activities. If water quality monitoring reveals a decrease in water quality, the data will be evaluated to determine the trigger. If the trigger is associated with local slope failures or restoration activities covered under the Reservoir Area Management Plan, additional monitoring and adaptive management will be conducted.
- Monitoring for tributary connectivity and reservoir sediment-derived fish passage blockages could trigger Reservoir Area Management Plan and Tributary-Mainstem Connection Plan (TMCP) monitoring activities and adaptive management.
- If data from the Fish Presence Monitoring Plan indicates fish are present in tributaries within the Limits of Work, that information will indicate that Reservoir Area Management Plan-related site stabilization is facilitating volitional fish passage.

Implementation of the Reservoir Area Management Plan may be constrained by sensitive resources areas or temporarily delayed by sensitive resource recovery activities required under either the HPMP or the Terrestrial and Wildlife Management Plan (TWMP). Upon receiving the License Surrender Order from the Commission, the Renewal Corporation will develop an environmental exclusion area/permissible work area map to define the seasonal and permanent no work zones associated with the plans listed above. Cultural resource exclusion areas will be contained separately in a confidential map. The Renewal Corporation will provide these maps to the Commission, ODEQ, CDFW and SWRCB (as applicable), subject to any confidentially constraints applicable to cultural resources.

Adaptive management actions, depending on their breadth and complexity, may entail consultation by the Renewal Corporation with the HRG. Members of the HRG are listed in Appendix I.

Adaptive management actions related to fish passage barrier removal under both the Tributary-Mainstem Connectivity Plan and the Reservoir Area Management Plan will be implemented in consultation with Aquatic Resources Group (ARG).[3] Members of the ARG are listed in Section 3.0 of the Aquatic Resources Management Plan. The HRG and ARG largely include members from the same tribes and agencies, which will facilitate coordination across management plans.

Finally, the activities undertaken by the Renewal Corporation as described in the Reservoir Area Management Plan will be implemented in conformity with applicable provisions of the following Management Plans:

- California Traffic Management Plan, a subplan of the Construction Management Plan
- Oregon Traffic Management Plan, a subplan of the Construction Management Plan
- Emergency Response Plan, a subplan of the Construction Management Plan
- Health and Safety Plan, a subplan of the Health and Safety Plan
- Fire Management Plan, a subplan of the Water Supply Management Plan
- California Waste Disposal Plan, a subplan of the Waste Disposal and Hazardous Materials Management Plan
- Oregon Spill Prevention, Control, and Countermeasure Plan, a subplan of the Waste Disposal and Hazardous Materials Management Plan
- Oregon Waste Disposal and Hazardous Materials Management Plan, a subplan of the Waste Disposal and Hazardous Materials Management Plan

2.5 Limitations

The Reservoir Area Management Plan does not include, and the Renewal Corporation will not undertake, activities outside of the Limits of Work, unless required under applicable law and regulations or as specifically proposed by the Renewal Corporation and approved by the applicable regulatory agencies.

2.6 Force Majeure

The Reservoir Area Management Plan includes metrics, objectives, and obligations that are dependent upon natural systems, which are inherently variable. Acts of God, natural disasters, flooding, fire, drought, labor shortages, and other events beyond the control of the Renewal Corporation (Force Majeure Event) may affect or delay compliance with a given obligation under the Reservoir Area Management Plan. If there is a Force Majeure Event, the Renewal Corporation will, following consultation with the HRG, report to the Commission, SWRCB, and ODEQ, proposing a variance or other appropriate adjustment of the Reservoir Area Management Plan.

[3] The Aquatic Resources Group was formerly referred to as the Aquatic Technical Work Group or ATWG in previous versions of the Reservoir Area Management Plan.

2.7 Regulatory Approval

The Renewal Corporation will implement the Reservoir Area Management Plan as approved by the Commission in the License Surrender Order. The Renewal Corporation will obtain and report to the Commission any required approvals from other agencies.

3.0 Restoration Goals and Objectives

Chapter 3.0 provides an overview of how the Reservoir Area Management Plan will support the overall Lower Klamath Project goals of restoring volitional fish passage, stabilizing exposed sediment with native vegetation, establishing native plants and the secondary goal of enhancing native aquatic habitat.

The goals and objectives described above are informed by the current and historic conditions in the Limits of Work, which are described in detail in Appendix D. Table 3-1 provides an overview of restoration goals, objectives and restoration measures during different time periods. Multiple restoration goals have already been accomplished, including vegetation test plot studies to better understand the impact of expected post reservoir drawdown conditions on native plant species.

Table 3-1. Goals, Objectives, and Restoration Measures

PERIOD	GOAL	OBJECTIVE	RESTORATION MEASURES AND STATUS
Pre-Construction Period	Prepare native plant materials for revegetation.	Collect and propagate native plant seed and grow container plants.	*In Process*. Identify potential species for seed collection and seed propagation, pole harvest cutting areas, and nurseries to grow container plants.
			In Process. Perform surveys to identify and map seed collection and pole harvest areas.
			In Process. Prepare seed collection, seed propagation, container plant growing, and pole harvest contract documents.
			In Process. Award and monitor native plant and seed contracts.
	Reduce invasive exotic vegetation (IEV).	Reduce and minimize the local occurrences of IEV.	*Complete*. Gather existing IEV data and perform IEV surveys.
			Complete. Review and evaluate potential herbicides for use, including their potential impact on fish and water quality.
		Implement an IEV management program.	*In Process.* Create management plan and review with stakeholders. This measure will be complete upon completion of the Reservoir Area Management Plan.
			Pending. Inspect and monitor IEV removal execution.

PERIOD	GOAL	OBJECTIVE	RESTORATION MEASURES AND STATUS
Pre-Construction Period (continued)	Understand likely evolution of reservoirs post-removal and responses to restoration and reservoir management.	Conduct studies to fill in data gaps from prior planning efforts.	*Complete.* Sample sediment and perform tests to investigate wetting and drying characteristics, plant nutrient availability, and natural revegetation potential.
			Complete. Perform revegetation pilot tests for native seed mixes.
			In Process. Identify reference physical and ecological conditions in tributaries.
Dam removal period	Maximize Reservoir Area restoration for ecological uplift.	Develop comprehensive restoration plan for post-removal reservoir conditions.	*During drawdown*. Actively promote erosion of reservoir deposits during drawdown using available techniques, including barge mounted hydraulic monitors or boats for assisted sediment evacuation.
			Post-drawdown. Modify or add site-specific restoration actions based on site conditions after drawdown.
			Post-drawdown. Identify culturally significant areas.
			Post-drawdown. Develop final engineering plans for implementation.
	Supplement the natural erosion and transport of reservoir sediment deposits.	Maximize erosion of reservoir deposits during drawdown.	*Post-drawdown.* Implement assisted sediment evacuation activities.
	Evaluate active restoration options (post-removal) for habitat development.	Define locations amenable to site-specific restoration actions.	*Post-drawdown.* Collect new topographic data to use as basis for restoration design progression.
			Post-drawdown. Delineate planting zones.
			Post-drawdown. Install pole cuttings and bare-root trees and shrubs.

PERIOD	GOAL	OBJECTIVE	RESTORATION MEASURES AND STATUS
Dam removal period (continued)	Stabilize remaining reservoir sediments.	Initiate native plant revegetation.	*Post-drawdown*. Seeding and establishment of riparian and upland vegetation.
	Restore volitional fish passage in mainstem and tributaries.	Monitor, evaluate and modify/remove fish passage barriers.	*Post-drawdown*. Conduct field monitoring within the Reservoir Area Management Plan Fish Passage Monitoring Area, evaluate potential fish barriers and modify or remove fish passage barriers to restore volitional fish passage.
	Minimize IEV.	Implement and monitor IEV removal during revegetation.	*Post-drawdown*. Remove IEV during revegetation implementation.
			Post-drawdown. Perform inspections of revegetation areas to verify IEV removal compliance.
Continued Monitoring and Implementation	Restore natural ecosystem processes.	Continue native plant revegetation, maintenance, and monitoring.	*Post-drawdown*. Monitor establishment of native plants and adaptively replace failed pole cuttings, acorns, and container plants.
			Post-drawdown. Selective irrigation.
			Post-drawdown. Re-seed areas as needed
	Implement natural process-based river and tributary restoration actions where applicable.	Work with the river, not against it.	*Post-drawdown*. Assess progress of channel evolution based on natural processes. Implement management measures where necessary per the adaptive management program described in Chapter 6.0 of the Reservoir Area Management Plan.
	Minimize IEV.	Continue IEV monitoring and removal.	*Post-drawdown.* Continue removal of IEV.
			Post-drawdown. Perform inspections of revegetation areas to verify IEV removal compliance.
	Restore volitional fish passage in mainstem and tributaries.	Monitor, evaluate and modify/remove fish passage barriers.	*Post-drawdown.* Conduct field monitoring within the Reservoir Area Management Plan Fish Passage Monitoring Area, evaluate potential fish barriers and modify or remove fish passage barriers to restore volitional fish passage.

PERIOD	GOAL	OBJECTIVE	RESTORATION MEASURES AND STATUS
Continued Monitoring and Implementation (continued)	Restore natural ecosystem processes.	Increase quantity and quality of in-stream and off-channel habitat for aquatic species.	*Post-drawdown*. Construct in-stream habitat features in High Priority Tributary Work Areas based on designs that are appropriate for the system.
			Post-drawdown. Construct wetlands, floodplains and off-channel habitat features where appropriate.
			Post-drawdown. Create floodplain roughness

As a result of the actions described in the Reservoir Area Management Plan, it is anticipated that volitional fish passage will be restored within the Limits of Work, exposed sediment will be stabilized, native plants will be established and native aquatic habitat will be enhanced. In addition, it is anticipated that natural river functions and processes will be restored within the Limits of Work. Natural river functions and processes are generally described as follows:

- Maintenance of Natural Hydrology: River flow is unimpeded through the Reservoir Areas and responds to natural hydrologic conditions.
- Maintenance of Sediment Transport Processes: Sediment aggradation and degradation is occurring and sediment is being transported through the Hydroelectric Reach and into the mainstem Klamath River below the former Iron Gate Dam location.
- Recruitment and Propagation of Vegetation: The natural recruitment and propagation of native plant species is occurring.
- Existence of Fish and Aquatic Invertebrate Habitat: Habitat for fish and aquatic invertebrates is available in the Hydroelectric Reach as well as in key tributaries.

4.0 Anticipated Reservoir Conditions After Drawdown

Chapter 4.0 summarizes the expected condition of the Reservoir Areas post-drawdown, specifically with respect to sediment, as well as how those conditions are expected to evolve in the short term.

Since the Reservoir Areas are currently submerged and will be impacted by reservoir drawdown activities, the precise topographic conditions of the Reservoir Areas will not be known until after drawdown. Unexpected post-drawdown conditions may require modified or additional site-specific restoration measures. For example, the location and thickness of residual sediment in the Reservoir Areas will vary depending upon both river and tributary flows during drawdown and, to a lesser degree, the effectiveness of assisted sediment evacuation methods. As a result, ease of access may be negatively and unexpectedly impacted by the distribution and amount of remaining residual sediment following drawdown in each of the reservoirs. In addition, the identification of previously unknown culturally sensitive areas post-drawdown may unexpectedly constrain or delay the implementation of the Reservoir Area Management Plan. If required by these or other unexpected post-drawdown conditions, the Renewal Corporation will develop, in consultation with the HRG, restoration measures tailored to site-specific conditions, which will be incorporated into the final restoration designs.

The Renewal Corporation developed a Reservoir Drawdown and Diversion Plan (RDDP) for the Proposed Action that specifies a four (4)-stage drawdown process for all three (3) reservoirs beginning in January of Year 2. The drawdown process is anticipated to extend into June (under 50th percentile water surface levels) of Year 2 given periodic reservoir refilling episodes are expected to occur.

Since each Reservoir Area has distinct features and characteristics, additional information on the anticipated post-drawdown condition of each Reservoir Area is provided below. Table 4-1 summarizes the miles of mainstem river, side channels and tributaries as well as area in acres currently inundated in each Reservoir Area.

Table 4-1. Summary of Klamath River Mainstem, Side Channel, Tributaries, and Area Currently Inundated in Each Reservoir

LOCATION	MAINSTEM RIVER LENGTH* (MILES)	SIDE CHANNEL LENGTH* (MILES)	TRIBUTARY LENGTH* (MILES)	NUMBER OF TRIBUTARIES*	INUNDATED RESERVOIR AREA (ACRES)	EXPOSED RESERVOIR AREA (ACRES)
J.C. Boyle	3.3	-	0.2	10	347	222
Copco No. 1 and No. 2	6.9	1.2	1.5	18	972	863
Iron Gate	6.8	-	2.5	52	942	840

LOCATION	MAINSTEM RIVER LENGTH* (MILES)	SIDE CHANNEL LENGTH* (MILES)	TRIBUTARY LENGTH* (MILES)	NUMBER OF TRIBUTARIES*	INUNDATED RESERVOIR AREA (ACRES)	EXPOSED RESERVOIR AREA (ACRES)
Total	17.0	1.2	4.2	80	2,261	1,925

*USFWS 2009

As described in more detail in the RDDP, J.C. Boyle, Copco No. 1 and No. 2, and Iron Gate reservoirs will be drawn down simultaneously. During drawdown, accumulated sediment will, to an extent, naturally mobilize and evacuate from the Reservoir Areas. The accumulated sediment is predominantly silt, clay, and organic material that is more than 80 percent water and highly erodible. USBR (2010) used both one-dimensional (1D) and two-dimensional (2D) sediment transport models to predict likely sediment transport and river conditions in the reservoirs after dam removal.

The assumed post-drawdown Reservoir Area surfaces (i.e., the anticipated topography of the Reservoir Areas) are based on historic bathymetry and updated bathymetric surface datasets as well as the sediment material properties (Appendix E). These assumed Reservoir Area surfaces were used in the development of the reservoir restoration 60 percent design (RES 2020). A description of the anticipated post-drawdown surface that is used as the basis for restoration activity mapping is included herein. Actual reservoir conditions post-drawdown will be updated by the end of Year 2 and used for the 90 percent and final reservoir restoration designs. Final drawdown is expected to occur by the end of June of Year 2, depending on hydrologic conditions in the basin during the drawdown period, and the preliminary restoration map will be updated following completion of final drawdown.

In general, and as described in more detail below, estimated post-drawdown sediment thickness is less at J.C. Boyle than Copco No. 1 and Iron Gate Reservoirs. Copco No. 2 Reservoir contains little to no fine-grained reservoir sediment. It is therefore not expected that early removal of Copco No. 2 would impact sediment evacuation of the Iron Gate Facility.[4] Descriptions of anticipated post-drawdown conditions and sediment thicknesses are provided in the following subsections. However, the actual locations and depths of sediments are expected to vary from those predicted below due to shifting and re-working of sediments within the reservoirs during and after drawdown (EPA, 2020 and USBR and CDFW, 2012).

4.1 J.C. Boyle Reservoir Sediments

For the majority of the J.C. Boyle Reservoir, estimated sediment thickness is less than two (2) feet with a localized area of thicker sediment reaching upwards of five (5) feet near the confluence of an unnamed tributary. During reservoir sediment testing at J.C. Boyle, sediment decreased in thickness by 40 percent and volume by 66 percent when air dried along with

[4] The RDDP includes a proposal to remove Copco No. 2 prior to Year 2.

significant crack development (KRRC, 2018). Therefore, a sediment shrinkage factor of 0.4 was applied to sediment thickness data to account for volumetric changes from drying post-drawdown.

Accumulated reservoir sediments are primarily limited to the historical channel and are thickest in the confined Canyon Reach between Highway 66 and the J.C. Boyle Dam (Canyon Reach). Lacking alternative flow pathways in the confined Canyon Reach, the river is expected to readily scour out the reservoir sediment down to the bedrock prominent in the historical river channel bed. Narrow but potentially several-feet thick deposits may persist outside the channel banks. The reach between the upstream end of J.C. Boyle Reservoir and Highway 66 (Upstream Reach) will be exposed early during drawdown because the water depths are shallow. It is estimated that the channel here will preferentially erode its historical channel bed and leave the broad (approximately 1,000-ft-wide) deposits on the channel margins relatively intact. Significant slumping of these deposits during drawdown is not expected because of shallow depths (< two (2) ft) and low topographic slopes (< 0.1 ft/ft). These deposits will reduce in height and volume by up to 50 percent as the material dries and consolidates. Water levels in the J.C. Boyle Reservoir are sensitive to river flows because of the small size of the reservoir. As a result, high flow events can inundate and modify the deposits in the period between the onset of drawdown and removal of the dam. A 5-year flow event, for example, will increase reservoir elevations by more than 20 ft during the drawdown period (USBR, 2011b) due to limited flow capacity of the gated spillways and diversion culverts. There are only a few tributaries on these marginal deposits, and some are ephemeral, so the Renewal Corporation expects little subsequent evacuation after removal of the dam. Given the low relief of the Upstream Reach, high flow events will periodically inundate and modify the remnant reservoir surfaces. The modeled 100-year flood inundates nearly the entire Upstream Reach (Figure 5-7and Appendix D, Figure D-3). It is uncertain if pre-dam bedforms, such as the large mid-channel bar (Appendix D, Figure D-2), will be reestablished post-drawdown.

The Canyon Reach is highly confined and will have relatively little upland or floodplain area available for revegetation. This geometry should efficiently evacuate the reservoir sediments, and the coarser pre-dam substrate will be readily exposed and will support revegetation with woody riparian species in some locations. The existing reservoir-dependent wetlands in the Upstream Reach, e.g., at the Spencer Creek confluence, may disappear after drawdown, but the seedbank germination study results suggest that wetlands may re-establish naturally, albeit in a new location closer to the historical channel. Sediments at J.C. Boyle contain the lowest amount of clay of the three (3) reservoirs, and they will be best suited for planting of native grassy vegetation and trees (e.g., Douglas fir, ponderosa pine, Oregon white oak) that are currently growing in the reservoir vicinity. Air temperatures at J.C. Boyle typically fluctuate diurnally above and below freezing during the winter months when drawdown is scheduled to occur. As a result, the sediments will drain and dry with warmer daytime temperatures but freeze at night. These conditions, which will persist for months in the Upper Reach, will be challenging for young plants, particularly those with shallower root systems. It is estimated that dried sediment thickness will be on the order of approximately one (1) foot thick, so the roots of plants that establish in the sediments will have access to the historical floodplain surface and materials. Sediments and hydrologic conditions in the historical materials may be more suitable for plant establishment, although it is unknown how reservoir inundation may have modified these characteristics.

4.2 Copco No. 1 and No. 2 Reservoir Sediments

Estimated post-drawdown residual sediment thickness at Copco No. 1 reservoir is five (5) to six (6) feet throughout the lower half of the reservoir and decreases to approximately three (3) to four (4) feet in the upper half (KRRC, 2018). The Renewal Corporation expects the reservoir sediments in the sinuous historical channel footprint to erode during drawdown, and large areal extents of residual sediments several feet in thickness will persist on the low-gradient floodplain and upland surfaces of the historical lakebed.

The Renewal Corporation anticipates that reservoir deposits on the low-gradient floodplain and upland surfaces adjacent to the channel in the Downstream Reach (except at the edges of vertical bluffs) will be relatively stable and will not be subject to appreciable slumping or hydraulic erosion. Gradients on these surfaces are typically less than two (2) degrees, as measured from the high-resolution bathymetric data, and are well below even the lowest estimates (six (6) degrees) for the aerial angle of repose for the reservoir sediments.

Larger tributaries, such as Deer Creek and Beaver Creek, will begin to rework their delta deposits and contribute bedload to the mainstem upon aerial exposure. Large-flow events following initial aerial exposure will increase the amount of sediment reworking by the mainstem and tributaries through repeated cycles of filling and emptying. Copco No. 1 Reservoir sediment thicknesses vary with pre-existing valley topography such that the lower elevation historical channel contains deeper deposits than higher elevation terraces and ancestral lakebed. USBR predicted the spatial patterns of erosion by 2-dimensional (2-D) morphodynamic modeling of Copco Reservoir during drawdown (USBR, 2011b). Erosion more than five (5) ft was concentrated within the sinuous historical channel and in the cut-off meander bend, which will be re-occupied by Beaver Creek following drawdown, but the model predicts nearly zero erosion outside of the historical channel. The model does not simulate fluvial bank erosion or bank failure, nor does it incorporate erosion from tributaries, springs, or concentrated surface runoff from hillslopes. Therefore, the spatial extent of modeled erosion is potentially a minimum prediction, and it is likely that more material will naturally evacuate from other areas during drawdown. 2D modeling used the formulation for the erosion rate of fine-grained cohesive sediments and measured parameter values from Simon et al. (2010) to simulate erosion under easier to erode and harder to erode scenarios and is far more sensitive to the modeled hydrology than the variation in the erosion rate parameters. While hard to erode, critical shear stress values used were more than an order of magnitude lower and higher than the maximum values measured in the wetting-drying experiments, the modeling results do not change with the new shear strength data given the large proportion of sediment eroded during the drawdown period and its location in the historical channel. Hardened, resistant sediment is more likely located in upland and higher elevation floodplain areas less affected by initial drawdown and erosion by the Klamath River.

Given the high relative elevation, low gradient, and large width of ancestral lakebed and upland surfaces, reservoir deposits two (2) to six (6) feet thick and hundreds of feet in lateral extent may persist in areas that are relatively distant from the main channel and therefore not impacted by fluvial erosional processes. Tributaries and springs may erode these deposits in some places, and the remaining sediments will undergo the physical changes associated with desiccation. Volume reduction during consolidation may lower the surfaces up to 50 percent of the deposit thickness, and the Renewal Corporation expects cracks to form. These cracks may concentrate flow from surface runoff in the future and be foci of subsequent erosion of the deposit by rilling and gullying.

Historical Copco No. 1 valley topography was created by a complex sequence of geologic and geomorphic events. Therefore, a diversity of landforms and materials will be exposed following drawdown. The pre-dam valley relief was high in the Downstream Reach with elevation differences in excess of 50 ft between the channel bed and the higher-elevation, low-gradient ancestral lakebed. These steep five (5) ft to 50 ft tall banks on the outside banks of the meander bends and the material underlying much of the historical valley bottom are composed of fine-grained and porous diatomite. The diatomite, which is mechanically capable of supporting tall vertical bluffs when dry, has been inundated for 100 years, and the pores are likely now filled with water. The effect of saturation on diatomite mechanical strength and the result of dewatering with drawdown are addressed in the Slope Stability Management Plan. Products of a diatomite slope failure, if it occurred, could persist in the valley bottom and potentially alter the course, though probably not dramatically, of the Klamath River away from the historical alignment and cause increased lateral erosion of adjacent diatomite bluffs. The Renewal Corporation expects access by the Klamath River to its historical floodplain to be limited only by the presence of local deposits of residual reservoir sediments along the riverbanks that are not removed during drawdown. Even if floodplain access is locally limited due to accumulated sediment deposits, significant vertical incision into the historical valley floor (i.e. below the reservoir sediment build up layer) is not expected post-drawdown because of the presence of bedrock grade control upstream of Copco No. 1 dam and the relatively coarse gradation of historic riverbed sediments.

Reservoir sediment texture at Copco No. 1 Reservoir is, on average, much finer than that at J.C. Boyle Reservoir and ranges from clay to silty clay loam on a U.S. Department of Agriculture texture triangle, and the size grades from fine texture near the dam to the coarsest texture at the upstream portion of the reservoir (KRRC, 2018). Textural gradations will be reflected in the vegetation palette, which will include a larger proportion of native perennial bunch grasses, trees, and shrubs in the upstream area where coarser, well-aerated soils will be able to support these deep rooting species. Air temperatures at Copco No. 1 Reservoir typically fluctuate diurnally above and below freezing during the winter months when drawdown is scheduled to occur. As a result, the sediments will drain and dry with warmer daytime temperatures but freeze at night, a combination that will be challenging for young plants. Irrigation may not be possible in the ancestral lakebed uplands and many other upland portions of the Copco valley given the large areal extents and distance from surface water sources. Because each planting zone species assemblage successfully established in the moist Copco No. 1 Reservoir sediments and the riparian bank and riparian floodplain species were able (with frequent irrigation and moderate temperatures) to grow in desiccated samples, the Renewal Corporation is hopeful that the initial revegetation efforts are successful despite the challenging environment. If areas do not meet the performance criteria after initial seeding, the Renewal Corporation will reseed the areas during warmer periods in the summer and fall of Year 2 as described in Section 5.3.2.1.2, Diversity Seed Mixes. If required to meet the performance criteria, the Renewal Corporation will subsequently implement adaptive management measures as set forth in Section 6.3, Revegetation Adaptive Management.

Copco No. 2 Reservoir is primarily a run of the river reservoir and, as a consequence, the combination of periodically unimpeded flows through the Reservoir Area and the canyon topography have resulted in little sedimentation. As such, little sediment is anticipated in this reservoir.

4.3 Iron Gate Reservoir Sediments

At Iron Gate Reservoir, sediment thickness is an estimated four (4) to five (5) feet immediately upstream of the dam, decreasing to two (2) to three (3) feet at the upstream extent of the impoundment. At Iron Gate, the Renewal Corporation anticipates the Klamath River to efficiently evacuate the majority of the reservoir sediment because the reservoir deposit layers are thin, the reservoir water depths are large, and the historical channel occupied a narrow pre-dam valley with steep adjacent hillslopes (USBR, 2011a). Drawdown of the 2,330-ft elevation reservoir water surface will begin on January 1 of Year 2. It is estimated that Fall Creek (approximately 2,310 ft) will be completely exposed early in the drawdown process, and mobilization of the local deposits at Fall Creek are expected during subsequent storm events. Jenny Creek delta (minimum elevation approximately 2,270 ft) will have full aerial exposure later in the drawdown period and will experience reworking during subsequent high flows. In addition, the Jenny Creek delta has the thickest and coarsest deposits in the Iron Gate Reservoir and will function as a source of bedload to the mainstem. The Camp Creek confluence area (elevation approximately 2,230 ft) will not be exposed until late in the drawdown period, although upstream portions of Camp Creek and its tributaries will rework their deposits (maximum sediment thickness five (5) feet) at all stages of drawdown.

Most of the historical roads and the railroad along the Downstream Reach of Iron Gate are not exposed until reservoir levels are below 2,230 ft. Several weeks will likely be required before reservoir sediment has stabilized and the certainty of road stability has been verified. Until that point, the floodplain in the Downstream Reach of Iron Gate and Camp Creek may be inaccessible. Drawdown operation at Iron Gate will be impacted not only by hydrology, but also by releases from Copco No. 1 and the discharge capacity of the diversion tunnel. Based on updated drawdown modeling described in the Drawdown Diversion Plan, a secondary refilling of the Iron Gate reservoir during the drawdown period is likely. This secondary inundation could persist for days to weeks depending on the elevation and magnitude of the event and will potentially re-saturate and/or erode residual sediments. Fine-grained sediments will be subject to potential breakdown and mobilization from additional cycles of wetting and drying.

Because reservoir sediments are not expected to exceed five (5) ft in thickness except at the Jenny Creek delta, the Renewal Corporation expects residual sediment persisting after drawdown to reduce in thickness to less than three (3) ft. Given the relatively more rapid drawdown proposed at Iron Gate and steep side slopes, reservoir deposit erosion from slumping should be more efficient (USBR, 2011a). There are several mapped low relief terraces, fans, and historical floodplains in the valley bottom (particularly in the Downstream Reach) on which larger areal extents of sediment may be stable. The greatest uncertainties relate to the deposit erosion by tributaries, particularly the Camp/Scotch Creek Complex. The Camp Creek valley is wider relative to the size of the historical tributary channels, and therefore, the Renewal Corporation expects a larger areal extent of sediment relative to the mainstem areas to remain after drawdown. These deposits are only two (2) to three (3) ft thick and will consolidate upon drying.

Sediment texture at Iron Gate Reservoir is the finest of all three (3) reservoirs, with clay content up to 78 percent at one of the Iron Gate sampling sites. Similar to other reservoirs, the sediment textural gradient progresses from finest near the dam to coarsest at the upstream end of the reservoir and at the Jenny Creek confluence. This gradation will be reflected in the vegetation palette, which will include a larger proportion of native perennial bunch grasses, trees, and shrubs in the upstream area where coarser, well-aerated soils will be able to support these deep-rooting species.

5.0 Restoration Measures

Chapter 5.0 describes the measures the Renewal Corporation will implement to progress the Hydroelectric Reach from a lentic to a lotic system as the reservoirs are replaced by a free-flowing river.

The Renewal Corporation will implement restoration measures in the Reservoir Areas and the High Priority Tributary Work Areas. These restoration measures generally relate to the restoration of natural systems. Restoration activities are primarily process-based and largely rely on the river and natural processes to shape the environment with targeted assistance. The Renewal Corporation will focus geomorphic management activities on the High Priority Tributaries and will actively revegetate the Reservoir Areas.

The restoration measures described in this chapter will be supplemented by monitoring and adaptive management measures. Chapter 6.0 describes the qualitative and quantitative metrics that will be monitored by the Renewal Corporation, the performance criteria, and the Renewal Corporation's approach to adaptive management. As described in more detail below, an adaptive design and implementation feedback loop will govern where, and when, physical reconstruction of High Priority Tributaries will take place.

For informational purposes only, Section 5.1 (Rehabilitation Measures Outside of the Reservoir Areas) sets forth rehabilitation measures that the Renewal Corporation may implement outside the Reservoir Areas. These rehabilitation measures are primarily associated with infrastructure removal and upgrades, geomorphic management of the dam footprints and/or final stabilization measures to protect water quality. Though exceptions exist, rehabilitation activities outside the Reservoir Areas can generally be considered direct actions whereby the site is physically returned to a desired state.

5.1 Rehabilitation Measures Outside of the Reservoir Areas

Many of the rehabilitation measures will be implemented under and/or in accordance with the following Management Plans and permits:

- The Erosion and Sediment Control Plan (ESCP) referenced in Table 2-1 and filed with the Commission. The ESCP contains a subplan called the Oregon Erosion and Sediment Control Plan (Oregon ESCP).

- The Reservoir Drawdown and Diversion Plan (RDDP) referenced in Table 2-1 and filed with the Commission.

- The Bureau of Land Management Use and Occupancy Plan, a subplan of the Construction Management Plan referenced in Table 2-1 and filed with the Commission.

- The National Pollutant Discharge Elimination System (NPDES) General Permit No. 1200-C (1200-C Permit) issued by ODEQ. The Renewal Corporation will apply for, obtain and comply with the 1200-C Permit. The 1200-C Permit includes temporary and permanent best management practices and monitoring to regulate stormwater runoff to surface waters. In connection with the 1200-C Permit, the Renewal Corporation will file an Erosion and Sediment Control Plan (1200-C ESCP) with ODEQ. A NOT will be filed with respect to the 1200-C Permit with the ODEQ (and copied to the ODFW). Once the NOT has been approved by ODEQ, no further monitoring with be required in Oregon, except as otherwise required under ODEQ's Clean Water Act Section 401 Certification.

- The California NPDES Construction General Permit (CGP) issued by the North Coast Regional Water Quality Control Board (RWQCB). The Renewal Corporation will apply for, obtain, and comply with the CGP. The CGP includes temporary and permanent best management practices and monitoring to regulate stormwater runoff to surface waters. As part of the CGP, the Renewal Corporation will develop a Stormwater Pollution Prevention Plan (SWPPP). A Notice of Termination (NOT) will be filed with respect to the SWPPP with the North Coast RWQCB (and copied to the SWRCB and CDFW). Once the NOT has been approved by North Coast RWQCB, no further monitoring will be required in California.

5.1.1 Construction Area Rehabilitation

The Renewal Corporation may implement rehabilitation measures outside of the Reservoir Areas under other Management Plans at the following construction areas, the locations of which are depicted in the dam demolition drawings in the RDDP:

- **Disposal sites for placement of embankment or concrete material**: For details regarding disposal site construction and rehabilitation (including with respect to the J.C. Boyle scour hole, powerhouse and tailrace), see the Oregon Waste Disposal and Hazardous Materials Management Plan, Oregon ESCP and Bureau of Land Management Use and Occupancy Plan with respect to disposal sites in Oregon, and the California Waste Disposal Plan and SWPPP with respect to disposal sites in California.
- **Staging areas and temporary access road areas adjacent to demolition sites**: For details regarding rehabilitation of these areas, see the 1200-C Permit and Bureau of Land Management Use and Occupancy Plan with respect to areas in Oregon and the RDDP and SWPPP with respect to areas in California.
- **Hydropower infrastructure demolition areas**: For details regarding demolition area rehabilitation, see the 1200-C Permit and the Oregon Remaining Facilities Plan with respect to locations in Oregon and the California Remaining Facilities Plan and SWPPP with respect to locations in California. Details on the demolition of structures is contained within the Definite Decommissioning Plan.
- **J.C. Boyle Power Canal**: For details regarding power canal rehabilitation, see the Bureau of Land Management Use and Occupancy Plan.
- **J.C. Boyle Penstock Roads**: For details regarding rehabilitation of the penstock access roads, see the Bureau of Land Management Use and Occupancy Plan.

- **Former recreation areas**: For details regarding recreation area construction and rehabilitation, see the Recreation Facilities Plan, Oregon Remaining Facilities Plan, and 1200-C Permit with respect to recreation areas in Oregon, and the Recreation Facilities Plan, California Remaining Facilities Plan, and SWPPP with respect to recreation areas in California. Table 5-1 lists the recreation sites slated for either removal or modification as part of the Proposed Action. Unless otherwise indicated in the footnotes to Table 5-1, each of the sites listed below is slated for complete removal.

Table 5-1. Recreation Areas Slated for Removal or Modification by Location

STATE	RESERVOIR	SITE NAME
OR	J.C. Boyle	Pioneer Park East
		Pioneer Park West[1]
		Topsy Campground[1]
CA	Copco No. 1 and No. 2	Mallard Cove
		Copco Cove
	Iron Gate	Fall Creek Day Use Area and Fall Creek Trail[2]
		Overlook Point
		Wanaka Springs Day Use Area
		Jenny Creek Day Use Area and Campground
		Camp Creek Day Use Area and Campground
		Juniper Point Day Use Area and Campground
		Mirror Cove Day Use Area and Campground
		Long Gulch Day Use Area and Campground

1. While Pioneer Park East will be completely removed, Pioneer Park West and Topsy Campground will be modified. See the Recreation Facilities Plan for additional details.
2. A portion of the Fall Creek Day Use Area may be retained to provide boater access. If a portion is retained, Fall Creek Day Use Area and Fall Creek Trail will only be partially demolished. All other CA recreation areas on the table will be completely demolished.

5.1.2 Dam Footprints

Following removal of the dams, the Renewal Corporation will configure the Klamath River channel within the former dam footprints to match its pre-dam dimensions as closely as practicable, as described in the RDDP. Pre-dam channel morphology was determined from historical photographs taken prior to and during construction. In general, the Renewal Corporation will achieve pre-dam configurations by blending the post-removal river contours to upstream and downstream contours. For informational purposes only, approaches for each dam are summarized below. For additional detail, see the RDDP.

5.1.2.1 J.C. Boyle

The bed of the Klamath River at J.C. Boyle dam was made up of bedrock, large cobble, and boulders. During dam construction, it appears large material, including boulders and cobble, was pushed out of the dam footprint with bulldozers to create direct contact between the embankment and the river bottom. The Renewal Corporation's rehabilitation of the dam footprint will focus on returning the channel to pre-dam conditions. This can be achieved by removing the earthen embankment down to the rough bedrock channel and reconfiguring the channel to match upstream and downstream contours.

Returning the channel to its pre-dam condition will largely achieve the overarching goal of restoring volitional fish passage to the Klamath River. Though there is photographic evidence of boulders and other materials lining the channel bottom, the uncertainty of their presence after dam removal makes it unclear what the texture of the channel bottom will be once the dam is removed. To increase the likelihood of fish passage, fringe roughness elements are included in the channel design to increase roughness near the channel margins, which will reduce near-bank velocity and create pathways for fish to move upstream. Rock comprised of material generated during dam removal activities will be used for fringe roughness, and no material will be imported for this purpose.

5.1.2.2 Copco No. 1 and No. 2

Copco No. 1 was constructed on alluvial material, which was excavated approximately 100 ft to accommodate the concrete dam foundation. Since the dam abuts canyon walls on either side of the structure, returning the channel to pre-dam conditions will be largely achieved by removal of the dam itself. The bed will be made up of material suspected to have been removed during its construction, and the bed will match upstream and downstream elevations to recreate a largely consistent slope through the reach. The Klamath River channel in the vicinity of Copco No. 2 will largely mimic that of Copco No. 1 as the bed will also match existing grades upstream and downstream of the former dam footprint.

5.1.2.3 Iron Gate

Like J.C. Boyle, Iron Gate Dam was constructed on bedrock. Rehabilitation of the Klamath River in the dam footprint will consist of removing the earthen embankment down to the bedrock channel and matching contours upstream and downstream of the dam. The Renewal Corporation will selectively line banks within the dam footprint with boulders to increase roughness to reduce velocities and to provide seams for fish passage. The Renewal Corporation will use rock comprised of material generated during dam removal activities for fringe roughness, and no material will be imported for this purpose.

5.1.3 Ward's Canyon and Copco No. 2 Bypass Reach

Ward's Canyon is the reach of the mainstem Klamath River in which Copco No. 1 and Copco No.2 Dams were constructed. Ward's Canyon extends from a point approximately 1,000 feet upstream of the Copco No. 1 Dam to the Copco No. 2 Powerhouse. The Copco No. 2 Bypass Reach is within Ward's Canyon and extends from Copco No. 2 Dam to the Copco No. 2

Powerhouse. The Renewal Corporation will not undertake any decommissioning, monitoring, restoration, rehabilitation, or adaptive management work in the Copco No. 2 Bypass Reach, which is outside of the Limits of Work. Notwithstanding the previous sentence, the Renewal Corporation may remove a limited number of trees located in the Copco No. 2 Bypass Reach river channel, if needed to protect public safety for navigation. Such tree removal will be based on consultation with the CDFW and SWRCB. Renewal Corporation will report any such tree removal work in the Annual Compliance Report that will be prepared and submitted in accordance with Section 7.0.

5.2 Adaptive Design and Implementation

The restoration measures within the Reservoir Areas and High Priority Tributary Work Areas will follow a feedback loop of systematic adaptive design and implementation. Channel response within the mainstem Klamath and High Priority Tributaries will be monitored by the Renewal Corporation following drawdown, and information obtained during the monitoring process will be used by the Renewal Corporation to inform decisions regarding design for restoration construction and revegetation as well as continued monitoring of channel response. This process is illustrated in Figure 5-1.

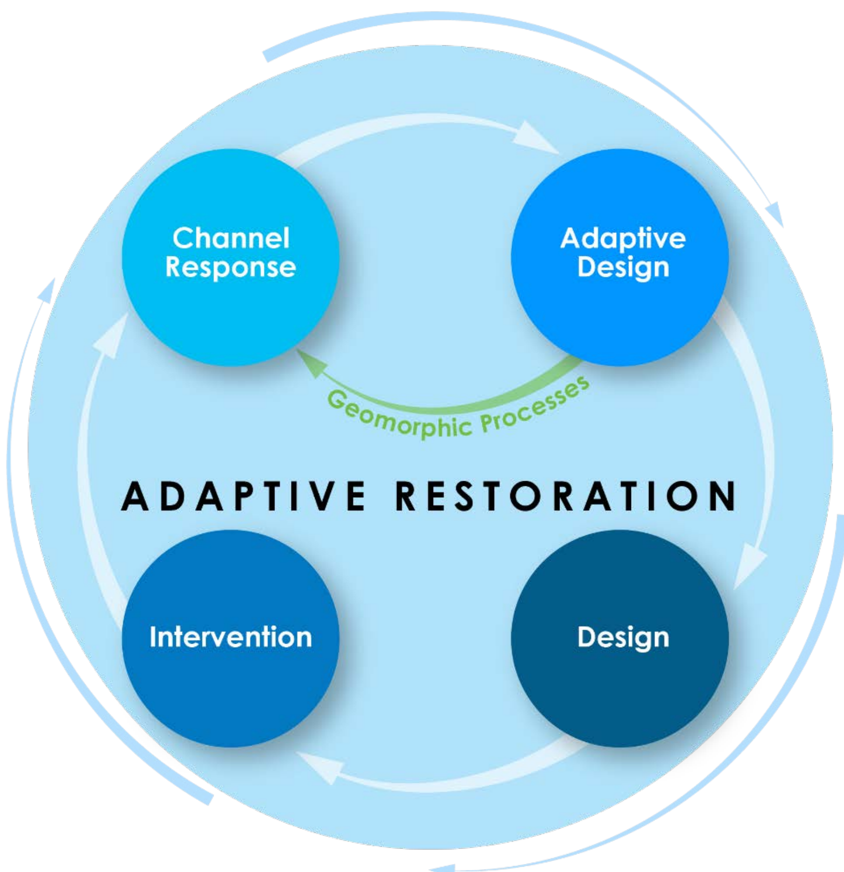


Figure 5-1. Adaptive Design Feedback Loop

Primary restoration actions by the Renewal Corporation for the reservoirs will be the following: (1) reservoir drawdown, (2) sediment evacuation, and (3) dam removal. Additional restoration actions by the Renewal Corporation will be performed to restore volitional fish passage, stabilize exposed sediment, and establish native plants. In addition, supplemental restoration actions by the Renewal Corporation will be taken to enhance native aquatic habitat.

Restoration actions described herein include numerous measures, each of which will be applied by the Renewal Corporation depending upon post-drawdown conditions and the final restoration design. Among other things, restoration measures include the following, each of which are described in more detail below:

- Assisted sediment evacuation
- Selective grading
- Removing fish barriers and replacing culverts to improve tributary connectivity
- Placing large wood to increase channel fringe complexity, improve floodplain connectivity and enhance habitat
- Installing willow baffles to provide floodplain roughness and selectively stabilize sediments
- Installing boulder clusters to increase channel fringe complexity, improve tributary connectivity and enhance habitat
- Revegetating formerly inundated areas to slow erosion and re-establish native plant communities, primarily through seeding
- Selectively planting locally salvaged and nursery-sourced plants
- Using grubbing (hand pulling), mowing/cutting, herbicides and other methods to control IEV.
- Fencing High Priority Tributary Work Areas to protect restored areas from trampling and herbivory by cattle and wild horses.

5.2.1 Assisted Sediment Evacuation

A primary objective during the reservoir drawdown period is to maximize natural erosion and evacuation of stored reservoir sediments. This objective has two purposes: (1) to reduce the amount of unnatural, stored sediment remaining on the historical floodplain and Reservoir Area surfaces and (2) to minimize the potential for future sediment releases in the Klamath River. For a median water year, hydraulic modeling predicted that approximately half of the stored sediment would naturally erode and vacate the Reservoir Area (USBR, 2011b). Existing sediment in the Reservoir Area is highly erodible and has a high water content. To further maximize the amount of sediment eroded during drawdown, the Renewal Corporation will use additional manual augmentation during drawdown as described below. The assisted sediment evacuation work window will be limited to January 1 to March 15 of Year 2.

The Renewal Corporation will use sediment jetting with an air-boat-mounted water jet to maximize stored sediment erosion at the Copco No. 1 and Iron Gate Reservoirs. This approach is not anticipated to be used at the J.C. Boyle Reservoir. Sediment jetting will occur as conditions allow, predicated by hydrologic conditions of Year 2, and will be primarily focused on High Priority Tributaries and the mainstem channel margins, with work occurring at non-High Priority Tributaries as conditions and time allow. If airboat sediment jetting becomes infeasible due to hydrologic conditions, the Renewal Corporation will mount pump and hose apparatus on side-by-side utility terrain vehicles for land-based applications.

If access allows, the Renewal Corporation will grade reservoir sediment during reservoir drawdown to promote evacuation by water flowing in the High Priority Tributaries and mainstem river using machinery such as small excavators. Culturally sensitive areas will be designated by the Renewal Corporation prior to drawdown to ensure that these areas are not entered with machinery. The Renewal Corporation will perform area grading between January 1 and March 15 of Year 2. The Renewal Corporation will only grade depositional surface sediment and will not extend grading to below the historical pre-dam ground surface.

The assisted sediment evacuation methods referenced above rely on flowing water in either the river or a tributary to transport sediment away from the site. The Renewal Corporation will therefore attempt to locate all application sites either directly adjacent to, or upslope and draining to, a tributary and/or the mainstem of the Klamath River. Some exposed Reservoir Areas will not be adjacent to flowing water. When the Renewal Corporation uses assisted sediment evacuation in these areas, it may apply water to the area to wash the actively eroded sediment downslope to the reservoir pool. When the actively eroded sediment meets the reservoir pool, some portion will remain suspended while some portion will resettle, forming a temporary delta. Temporary deltas may also form at the interface (confluence) where the flowing tributaries and river meet the reservoir due to the resettling of eroded sediment. As the reservoir pool lowers, the tributary or river will transport both the delta sediment referenced above as well as incoming sediment from active, assisted sediment evacuation sites. Thus, the volume (load) of sediment being eroded and carried downstream in the tributary or mainstem will increase as the reservoir pool lowers and the cumulative volume of sediment from sources upslope and upstream increases.

For optimal sediment evacuation, the sediment eroded from both upslope and upstream locations as well as deposited in deltas will need to be transported downstream. This means that adequate flows in the tributaries and the mainstem of the Klamath River are critical for active sediment evacuation activities. Active measures to increase discharge in the river are infeasible. However, the channels of the tributaries are relatively small and, therefore, pumps and temporary pipelines may be used by the Renewal Corporation to convey reservoir water upstream to the point of maximum reservoir elevation (i.e., the location of upstream extent of the aggraded sediment deposits) and discharge that water into the tributary channel. The augmented flow will boost the ability of that tributary to transport sediment downstream to its confluence with the comparatively larger Klamath River where river flows will be sufficient to entrain and transport sediment out of the reservoir.

The Renewal Corporation does not expect that J.C. Boyle will require assisted sediment evacuation due to low sediment thicknesses and valley confinement along the lower reach. The Renewal Corporation does anticipate assisted sediment evacuation for Copco No. 1 and Iron

Gate, and planned locations were ranked as primary or secondary. Primary locations include active sediment evacuation sites along the main channel, riparian/floodplain, and High Priority Tributary channels. Secondary locations include other tributary confluences. For Copco No. 1, the following three (3) primary sediment evacuation areas were identified by the Renewal Corporation: the historic side channel complexes located upstream of Ward's Canyon, the Beaver Creek and Copco No. 1 Unnamed Tributary 2 confluence, and a portion of the Klamath River upstream and downstream of the Deer Creek confluence. The following four (4) secondary locations were identified by the Renewal Corporation for Copco No. 1: the confluences of Copco No. 1 Unnamed Tributary 1, Raymond Gulch, Spannaus Gulch, and Long Prairie Creek. The following three (3) primary evacuation areas were identified by the Renewal Corporation for Iron Gate: the Long Gulch confluence, the Camp Creek confluence, and the Jenny Creek confluence. Iron Gate had the following three (3) secondary sediment evacuation locations identified: the confluences of Long Gulch, Iron Gate Unnamed Tributary 1, and Fall Creek. The locations of Copco No. 1 Unnamed Tributary 1 and Copco No. 1 Unnamed Tributary 2 are depicted in the 60 Percent Assisted Sediment Evacuation Design for Copco Reservoir (Appendix K). The location of Iron Gate Unnamed Tributary 1 is depicted in the 60 Percent Assisted Sediment Evacuation Design for Iron Gate Reservoir (Appendix L).

5.2.2 Selective Grading

The expanded and connected tributary confluences at the Klamath River mainstem channel will allow for a range of dynamic geomorphic processes and support resilient habitat structure and fish passage conditions. Select grading will be performed by the Renewal Corporation as needed to:

- Remove unnatural, erosion-resistant deposits that create fish passage barriers (such as the coarse delta deposits at Jenny Creek and the Camp Creek complex); and
- Stabilize un-evacuated sediment at vulnerable high-sediment-yield locations.

Additional grading may occur at select locations to enhance wetland and/or floodplain connectivity when appropriate.

On the High Priority Tributaries, the existing riparian vegetation upstream of the reservoir confluence is typically located within a vertical band ranging from one (1) ft to six (6) ft above the channel invert. This serves as a basis for selective grading actions on the High Priority Tributaries. In addition, selective grading may be used by the Renewal Corporation to lay back tributary channel banks (for example, 3H:1V slopes on alternating banks) opportunistically to mimic reference channel geometries and support revegetation. Areas for selective bank grading will be identified and prioritized based on the location of other restoration actions and depending on observed and monitored post-drawdown conditions.

5.2.3 Tributary Connectivity

As reservoir water surfaces are lowered during drawdown and beyond, High Priority Tributaries will be further exposed creating longer reaches of free-flowing water conditions (for a discussion of actions related to the connectivity of tributaries outside the Reservoir Areas, please see the

Tributary Connectivity Management Plan). While the flow of newly exposed tributaries will likely transport depositions of fine sediment downstream during and following reservoir drawdown, some larger sediment and debris may create fish passage barriers or unnatural discontinuities in the longitudinal profile of the tributary. To rectify this, the Renewal Corporation will use light equipment and manual labor to remove sediment-derived fish passage barriers and enhance access and longitudinal connectivity of the tributaries with the mainstem Klamath River. In addition, the Renewal Corporation may add large wood to tributaries either in the channel or on the floodplain/terrace to promote habitat complexity and connectivity as further described below. Figure 5-2 shows an example of wood toe installed to increase fringe roughness and improve bank stability.

Many of the tributaries have road crossings at the reservoir water surface with culverts and stream crossings that do not allow volitional fish passage. Copco Road culverts at Camp Creek and Scotch Creek, as well as the Daggett Road crossing of Fall Creek, will be replaced by the Renewal Corporation to allow fish passage upstream of the roadway. The replacement culverts will be approved for fish passage per NMFS' fish passage requirements (NMFS, 2019). In addition, the Renewal Corporation will remove historic culvert crossings at Long Gulch within the Iron Gate Reservoir inundation zone.

5.2.4 Riverbank Stability and Channel Fringe Complexity

Lack of initial roughness along channel margins results in higher than normal near-bank velocity and shear stress. This increase in active channel margin energy negatively affects aquatic species by requiring increased energy for migration and holding while also transporting desired gravels and materials that otherwise form depositional features downstream. Velocity shadows created by bankline complexity (i.e., vegetation, rootwads, etc.), large wood, and boulders create regions of complex hydraulic interactions that provide resting zones, feeding seams, cover, and velocity refugia during high flow (See Figure 5-2). High Priority Tributary reaches that will benefit from channel fringe complexity are typically single thread, where the channel is laterally confined. In addition, bank roughness can improve bank stability and reduce unnatural erosion that degrades water quality. Channel fringe complexity measures will not be implemented where it would disrupt natural, process-based channel and floodplain evolution within the Reservoir Areas. In order to provide future stream habitat, the Renewal Corporation will, where practicable, leave the root mass and a stump four (4) to six (6) feet above the ground surface from any trees removed from the stream bank within the Limits of Work, unless doing so could potentially cause unintended harm to recreational river users.

Figure 5-2. Example of Toe Wood Being Installed to Improve Fringe Complexity
Source: M. Adams, 2017

5.2.4.1 Large Wood Features

The Renewal Corporation will place large wood features along the High Priority Tributaries for three (3) main reasons:

- In-channel habitat enhancement to provide cover, shade, velocity refuge, and foraging areas for fish and other aquatic species
- In-channel hydraulic complexity, including connectivity with floodplains, roughness, and flow guidance to enhance and encourage sediment transport and volitional fish passage
- Facilitation of natural geomorphic processes of scour and deposition within and outside of the channel

The large wood placed by the Renewal Corporation will be sourced from nearby, permitted timber harvest sites and transported to the High Priority Tributary Work Areas via truck or helicopter.

5.2.4.2 Large Wood Feature Design

Large wood features will be designed and implemented in a manner that emulates natural river processes to allow the wood features to be dynamic and provide long-term complexity. The large wood habitat features placed within tributary channels will consist of several rootwad logs or whole trees. Placement and orientation of multiple structures will be used to create areas of flow constriction, direct or turn flow, and to induce scour, and the Renewal Corporation may cluster the wood to increase complexity and diversity. When submerged, rootwads are an important component of the structure and when submerged provide complex cover for juvenile salmonids as well as locations for macroinvertebrates and other food sources to reside. Whole trees placed adjacent to the channel on the floodplain will promote floodplain roughness and provide aquatic refugia during overbank flow events.

The Renewal Corporation will not use artificial anchoring to ballast any large wood features. While it will not be artificially anchored using bolts or cables, ground-placed large wood will be partially buried into the existing tributary bank or with natural earth materials. Since it will be capable of withstanding all but the largest flow events due to its larger size (i.e., whole trees), helicopter-placed wood on floodplains will not be anchored or buried. While large flow events may reposition helicopter-placed wood, it will be placed in a manner that limits movement and minimizes the likelihood that the wood becomes completely mobile and gets transported downstream.

The Renewal Corporation will place between 100 and 1,000 large wood features along the High Priority Tributaries. The basic design parameters for these large wood structures are listed in Table 5-2. The exact design, architecture, placement locations, and material characteristics for each large wood feature will be determined by the Renewal Corporation based on actual topographic field conditions during and after the reservoir drawdown phase and will be reflected in the final reservoir restoration design, which will be submitted to the Commission, SWRCB and ODEQ for approval. Once approved, the Renewal Corporation will file a report with the Commission within 14 calendar days, which shall include the final reservoir restoration design.

Table 5-2. Large Wood Features

PLACEMENT TYPE	TYPE OF WOOD	DIMENSIONS	BALLAST METHOD
Ground Based Placement	Rootwad logs	12-24 in. diameter 35-50 ft in length	natural earth materials or dug into existing bank
Aerial Helicopter Placement	Full Length trees	18-30 in. diameter 50-100 ft in length	None

5.2.4.3 Large Wood Stability

For purposes of the Reservoir Area Management Plan, mobility is defined as the displacement of placed large wood by buoyant and hydrodynamic forces. Design tolerances for mobility depend on the risks associated with the displacement of large wood. As described below, the criteria used during design included a factor of safety and was based on flooding flow criteria. The factors of safety and other design criteria were derived from the U.S. Bureau of Reclamation's (USBR) Large Woody Material Risk Based Design Guidelines, (USBR, 2014). The stability calculations used by the Renewal Corporation can be found in Appendix M.

Two (2) main risk considerations were considered by the Renewal Corporation with respect to large wood placement: public safety and property protection. The main public safety concern is boater safety as the Klamath River will be used for whitewater kayaking, rafting, and fishing. Since boat use will be focused on the mainstem of the Klamath River, rather than the High Priority Tributaries where large wood will be located, placement of large wood is preliminarily categorized by the Renewal Corporation as a relatively low public safety risk. This risk factor was informed by hydraulic modeling of the primary tributaries and their interactions with the mainstem Klamath River. Hydraulic conditions for both the 10-year and 25-year flood event were compared to the Risk Based Design Guidelines (USBR, 2014). In addition, the risk of downstream property damage is considered low based on the following considerations:

- Limited number of in-channel structures following dam removal, including existing bridges and future recreational boat docks.
- Limited number of structures located in the floodplain immediately downstream of the dams.
- Future land use of former reservoirs as open space.

The minimum recommended factors of safety for large wood stability were selected based on the values recommended by the USBR (2014), which are reproduced in Table 5-3.

Table 5-3. Minimum Recommended Factors of Safety from USBR (2014)

PUBLIC SAFETY RISK	PROPERTY DAMAGE RISK	STABILITY DESIGN FLOW CRITERIA	FACTORS OF SAFETY		
			SLIDING	BUOYANCY	ROTATION AND OVERTURNING
High	High	100-year	1.75	2.0	1.75
High	Moderate	50-year	1.5	1.75	1.5
High	Low	25-year	1.5	1.75	1.5
Low	High	100-year	1.75	2.0	1.75
Low	Moderate	25-year	1.5	1.75	1.5
Low	Low	10-year	1.25	1.5	1.25

Source: Table 4, Large Woody Material Risk Based Design Guidelines (USBR, 2014).

Given the risk assessment described above (i.e., low public safety risk and low property damage risk), the recommended stability design flow criterion is the 10-year event (Table 5-3) and the factors of safety are as follows:

- Sliding – 1.25
- Buoyancy – 1.5
- Rotation and Overturning – 1.25

Depending on actual post-drawdown conditions, large wood placement designs will be re-evaluated and refined by the Renewal Corporation to finalize large wood stability calculations The Renewal Corporation will design large wood habitat features to the factor of safety specifications for the 10-year design storm event, but design will be highly dependent on post-dam removal topography and hydraulic conditions, as we well as the trajectory of geomorphic evolution. Under larger storm events, large wood may become mobile within the tributary corridor and Reservoir Area, much like natural wood movement under normal ecological processes.

5.2.4.4 Large Wood Placement

The Renewal Corporation will strategically place large wood features at High Priority Tributaries, with a particular focus on the mainstem confluences and adjacent floodplain or off-channel wetlands. The Renewal Corporation will base the location and density of large wood features on post-drawdown topographic and hydraulic conditions. On-site field practitioners will define the exact geographic locality, arrangement, and architecture of each large wood complex during implementation.

The Renewal Corporation will place large wood using a combination of ground and aerial helicopter methods based on the specific location and post-drawdown conditions. Helicopter-placed large wood will be placed in the spring and summer of Year 2 to provide immediate floodplain roughness and promote sediment evacuation. Ground-placed large wood will be installed along the High Priority Tributary channels to provide in-water habitat complexity and promote pool and streambank stability.

When considering placement locations, cultural resources will be evaluated and considered by the Renewal Corporation, and any placement will be coordinated with cultural specialists and/or on-site tribal monitors.

5.2.4.5 Other Habitat Enhancement Features

In addition to large wood, the Renewal Corporation will install willow baffles and boulder clusters along or in the High Priority Tributaries. Willow baffles are live roughness elements installed on the floodplain to reduce flow velocities and trap fine sediment. Willow baffles are proposed as short-term measures to help stabilize newly exposed channel overbank areas until riparian revegetation establishes. Willow baffles are ‘hedges’ of willow poles planted perpendicular to the flow direction. The poles are densely planted in trenches that are back-filled with soil and small rock to provide some initial resistance to flows. Willow baffles will be approximately 15 to 30 feet long and spaced between 60 to 120 feet apart adjacent to the channel.

The Renewal Corporation will also install small clusters of locally sourced, oversized boulders (approximately two (2) to six (6) ft in diameter) at select locations in High Priority Tributaries to enhance habitat. The number and size of boulders will vary depending on location and function. Clusters of three (3) to 10 boulders will be used by the Renewal Corporation to disrupt high-flow fields, encourage site-scale sediment sorting and provide resting for migrating adult anadromous fish. Generally, boulder clusters will be located by the Renewal Corporation in a manner that preserves existing riffles or in predicted high velocity areas to provide velocity shelter. In addition, boulder placement will be staggered downstream, with adequate spacing between boulders to allow flow-through. Denser boulder fields (up to 12 boulders, depending on tributary size) may be installed adjacent to near-channel wetlands to locally elevate water levels and enhance connectivity. The Renewal Corporation will place boulder clusters using land-based equipment in readily accessible areas.

5.2.5 Wetlands, Floodplains, and Off-Channel Habitat Features

Incorporating natural features, such as surface undulations, into newly exposed floodplains is a restoration strategy that promotes ecosystem diversity and natural processes. Likewise, floodplain roughness features can be incorporated to further instigate natural processes while enhancing wildlife habitat. The features described in this section include design measures that reduce the likelihood of aquatic organism stranding. Based on historical pictures, it appears three (3) main types of floodplain features could be supported on the newly exposed floodplains within the Reservoir Areas: wetlands, floodplain swales, and side channels.

Wetlands are depressional or low-lying features with standing water or soils that are saturated for a portion of the growing season that support wetland vegetation such as willows, sedges, and rushes. Wetlands provide a wide range of ecological functions such as water quality improvement, flood attenuation, and habitat for both terrestrial and aquatic organisms. Including wetlands in the restoration design addresses several key issues, including water quality impacts and a lack of habitat diversity for wildlife. Wetland restoration strategies for the Reservoir Areas include preservation of existing wetlands, hydrologic connection of off-channel wetlands with the river, and creation of new wetlands at lower elevations corresponding to the post-dam removal surfaces and hydrologic regime.

Floodplain swales are small depressional areas incorporated into the floodplain that provide microsites where floodplain vegetation can establish at slightly lower elevations (closer to the water table) than adjacent floodplain surfaces. Floodplain swales provide storage for flood water and sediment at variable flows and broaden the range of ecological niches available on the floodplain surface to support different life stages (and behaviors) of plant, bird, amphibian, and other terrestrial wildlife species. To maximize diversity, floodplain swales will be designed to vary in size and depth, but will not extend below the anticipated baseflow elevation.

Side channel restoration is a strategy to improve in-stream habitat diversity. Side channels provide off-channel habitat for juvenile rearing and high-flow refugia for other aquatic species. Like floodplains, side channels exchange water, sediment, and nutrients between the main channel and off-channel areas, thus supporting diverse vegetation communities. Side channel restoration strategies include modifying inlet and outlet hydraulics, improving hydraulic complexity with wood structures or realignment, and ensuring water flow to higher floodplain surfaces.

Floodplain roughness is a technique applied to newly exposed areas where frequent interaction with the river channel is anticipated. Floodplain roughness helps address the initial geomorphic limiting factor of newly exposed areas—lack of established, stable vegetation. Floodplain roughness also reduces browse pressure by making access more difficult, particularly for geese, which require unobstructed runways for landing and takeoff. Installation of roughness features creates complexity and microsites on new floodplain surfaces to trap and protect seed and other plant propagules and to provide resistance to erosion by reducing velocities and limiting rill formation. Floodplain roughness is created using equipment to roughen the floodplain surface with microtopography and partially bury brush, limbs, and wood in the soil. Microtopography creates variation in the constructed floodplain surface ranging from 0.5 ft above to 0.5 ft below the existing or design floodplain surface. Brush, limbs, and wood in the soil will increase moisture retention, create protective microsites for establishing seed and plants, and promote soil development by introducing organic material. Ultimately, restoration actions should lead to vegetative cover, as illustrated in Figure 5-3**.**

Figure 5-3. Example of Existing Floodplain Features Upstream of Copco No. 1 Reservoir (i.e., Wetland Area)

Source: KRRC, 2018

5.2.6 Wetland Preservation, Restoration and Mitigation

The Renewal Corporation conducted investigations of wetlands and riparian habitat within the Limits of Work from May 6-16, 2019 and from July 15-26, 2019. Potential wetland areas in California and Oregon were investigated in accordance with the *1987 U.S. Army Corps of Engineers Wetland Delineation Manual* and the *Western Mountains, Valleys, and Coast Regional Supplement (Version 2.0*). While riparian areas in California were delineated as part of the investigations, riparian areas in Oregon were not. The Renewal Corporation characterized pre-drawdown wetlands within the Limits of Work according to their primary hydrological source or association (Figure 5-4). During its wetland investigation, the Renewal Corporation identified the following three (3) types of wetlands within the Limits of Work:

- **Non-Reservoir-Dependent Wetlands:** Existing wetlands that are not anticipated to be impacted by drawdown are termed "non-reservoir-dependent" (NRD) or "reservoir-independent" wetlands. The primary hydrological sources of these wetlands are the Klamath River, a stream or seep, and/or precipitation. If there are restoration enhancements or construction activities in the vicinity of non-reservoir-dependent wetlands, the Renewal Corporation will use fencing to create a 20-foot buffer. The buffer will protect and preserve the non-reservoir-dependent wetlands by avoiding impacts (e.g., the placement of dredge or fill material) from the Proposed Action. If site-specific conditions require adjustment of the 20-foot buffer, the Renewal Corporation will implement the adjustment in a manner that is acceptable to a qualified biologist and remains protective of the non-reservoir-dependent wetlands.

- **Reservoir-Dependent Wetlands**: The primary hydrological sources for reservoir-dependent (RD) wetlands are J.C. Boyle Reservoir, Copco No. 1 Reservoir and/or Iron Gate Reservoir. While the majority of reservoir-dependent wetlands will likely be desiccated over time following the drawdown, some may persist.

- **Infrastructure-Dependent Wetlands**: The primary hydrological sources for infrastructure-dependent (ID) wetlands are associated with infrastructure related to the operation of the dams, such as penstocks, that will be removed as part of the Proposed Action. While the majority of infrastructure-dependent wetlands will likely be desiccated over time following the drawdown, some may persist or opportunistically serve as source materials for wetland creation sites elsewhere.

5.2.6.1 Wetland and Riparian Habitat Preservation and Restoration

As noted above, the Renewal Corporation will implement a 20-foot buffer around non-reservoir-dependent wetlands to minimize impacts from the Proposed Action and preserve wetland habitat. In addition, the Renewal Corporation will attempt to preserve and protect the reservoir-dependent and infrastructure-dependent wetlands within the Limits of Work by directing construction activities away from these sites to the extent practicable.

In addition to preserving current wetlands, the Renewal Corporation will also create new wetland and riparian habitat as part of its restoration of the Reservoir Areas and High Priority Tributary Work Areas. Following the drawdown, the Renewal Corporation will document wetland hydrology conditions using aerial data collection methods to verify/identify depressional features and hillslope seep or spring-fed areas with a high potential for wetland and riparian habitat creation. To the extent practicable based on cost and safety considerations, the Renewal Corporation will also collect information regarding water volume and water temperature.

Once potential areas are identified, riparian areas will be created through the application of native seed mixes, bare root stock, willow cuttings, and supplemental plantings. Restoration of non-reservoir dependent wetland communities will rely on recruitment from the existing seedbank of hydrophytic species as well as the enhancement plantings described in Section 5.3. The tables below describe the dominant native hydrophytic species occurring in Iron Gate Reservoir (Table 5-4), Copco Reservoir (Table 5-5), and J.C. Boyle Reservoir (Table 5-6) (CDM Smith 2020). In addition, High Priority Tributary Work Areas may be graded to enhance the topography and foster wetland hydrology and the survival of hydrophytic vegetation.

The Renewal Corporation expects topography conducive to wetland and riparian habitat to re-form naturally along both the mainstem and currently inundated tributaries following the drawdown as the Klamath River reestablishes its historic channel, off-channel wetlands, floodplain terrace wetlands, and riparian fringe. Where conditions (e.g., hydrology) permit, the Renewal Corporation expects to rely on natural formation to create wetland and riparian habitat within the Reservoir Areas and the High Priority Tributary Work Areas with only minimal outside influence in the form of riparian and wetland seeding. This will allow the Renewal Corporation to focus its resources on areas where wetland and riparian habitat creation will be more challenging.

Table 5-4. Iron Gate Reservoir Dominant Native Hydrophytes

SPECIES	COMMON NAME
Scirpus acutus	hardstem bulrush
Salix exigua	narrowleaf willow
Fraxinus latifolia	Oregon ash
Salix lucida	Pacific willow
Drymocallis glandulosa	sticky cinquefoil
Eleocharis sp.	spikerush
Phalaris arundinacea	reed canarygrass
Cornus sericea	red osier dogwood
Carex pellita	woolly sedge
Juncus tenuis	slender rush
Scirpus pendulus	drooping bulrush
Salix scouleriana	scouler willow
Alnus rhombifolia	white alder
Rhus trilobata	fragrant sumac
Toxicodenderon diversilobum	poison oak
Pinus ponderosa	Ponderosa pine
Carex densa	sedge
Polygonum hydropiperoides	water pepper
Ribes lacustre	swamp currant

Table 5-5. Copco Reservoir Dominant Native Hydrophytes

SPECIES	COMMON NAME
Salix exigua	narrowleaf willow
Fraxinus latifolia	Oregon ash
Salix lucida	Pacific willow
Scirpus acutus	hardstem bulrush
Phalaris arundinacea	Reed canarygrass
Alnus rhombifolia	white alder
Rhus trilobata	fragrant sumac
Toxicodenderon diversilobum	poison oak
Carex densa	sedge
Polypogon hydropiperoides	water pepper
Ribes lacustre	swamp currant
Carex amplifolia	ample leaved sedge
Veronica americana	American brooklime
Mimulus guttatas	seep monkeyflower
Eryngium petiolatum	Oregon coyote thistle
Quercus garryana	white oak
Juniperus occidentalis	Western juniper
Acer macrophyllum	bigleaf maple
Salix sp.	willow
Equisetum sp.	horsetail
Quercus kelloggi	black oak
Salix lemmonii	Lemmon’s willow
Mahonia aquifolium	Oregon grape

Table 5-6. J.C. Boyle Reservoir Dominant Native Hydrophytes

SPECIES	COMMON NAME
Sparganium eurycarpum	broadfruit bur reed
Typha sp.	cattail
Quercus garryana	white oak
Eleocharis sp.	spikerush
Eleocharis palustris	common spikerush
Eleocharis acicularis	needle spikerush
Juncus balticus	wire rush
Phalaris arundinacea	reed canarygrass
Carex pellita	woolly sedge
Carex sp.	sedge
Spirea douglasii	Douglas's spirea
Dodecatheon sp.	shooting star

5.2.6.2 Wetland and Riparian Habitat Loss Mitigation

The anticipated loss of wetland and riparian habitat will primarily be caused by the impacts of drawdown and facility removal on areas where wetland hydrology is dependent on reservoir sources (i.e., reservoir-dependent wetlands, infrastructure-dependent wetlands, and riparian areas). These losses will be offset by the wetland and riparian habitat created by both natural recruitment and the restoration measures described in Section 5.2.6.1.

The Renewal Corporation expects the amount of riparian habitat created within the Limits of Work in California to significantly exceed the amount of riparian habitat lost in connection with the Proposed Action. The Renewal Corporation therefore anticipates mitigating 100% of the lost riparian habitat in California with the newly created riparian habitat at a 1:1 mitigation ratio in accordance with the SWRCB's General Order 2020-0039 for in-kind, in-watershed mitigation.

Conversely, the Renewal Corporation expects the amount of wetland habitat lost within the Limits of Work in California to exceed the amount of wetland habitat created in connection with the Proposed Action. The Renewal Corporation anticipates using the newly created wetlands to partially mitigate the wetland losses in California at a 1:1 mitigation ratio in accordance with the SWRCB's General Order 2020-0039 for in-kind, in-watershed mitigation. As noted above, the combination of natural recruitment and active restoration is expected to create a significant net gain in riparian habitat within the Limits of Work in California. The Renewal Corporation anticipates using this net gain of riparian area to mitigate the remaining wetland losses in California at a 3:1 mitigation ratio in accordance with the SWRCB's General Order 2020-0039 for out-of-kind, in-watershed mitigation.

During Year 7 or Year 8, the Renewal Corporation will conduct an investigation of wetland and riparian habitat within the Limits of Work. Potential wetland areas in California and Oregon will be investigated in accordance with the *1987 U.S. Army Corps of Engineers Wetland Delineation Manual* and the *Western Mountains, Valleys, and Coast Regional Supplement (Version 2.0*). In addition, riparian areas in California will be delineated as part of the same investigation. Data from the investigation will be compiled into a Wetlands Delineation Report, which will be submitted to the Commission, SWRCB and ODEQ, and copied to the HRG. If the Wetland Delineation Report indicates that the mitigation requirements set forth above have been met, the Renewal Corporation will notify the applicable regulatory agencies and request confirmation that the mitigation requirements related to wetlands and riparian areas have been met. If the Wetland Delineation Report indicates that the mitigation requirements have not been met, the Renewal Corporation will develop, in consultation with the HRG, an adaptive management plan to meet the mitigation requirements. Once completed, the Renewal Corporation will submit the adaptive management plan to the applicable regulatory authorities for approval.

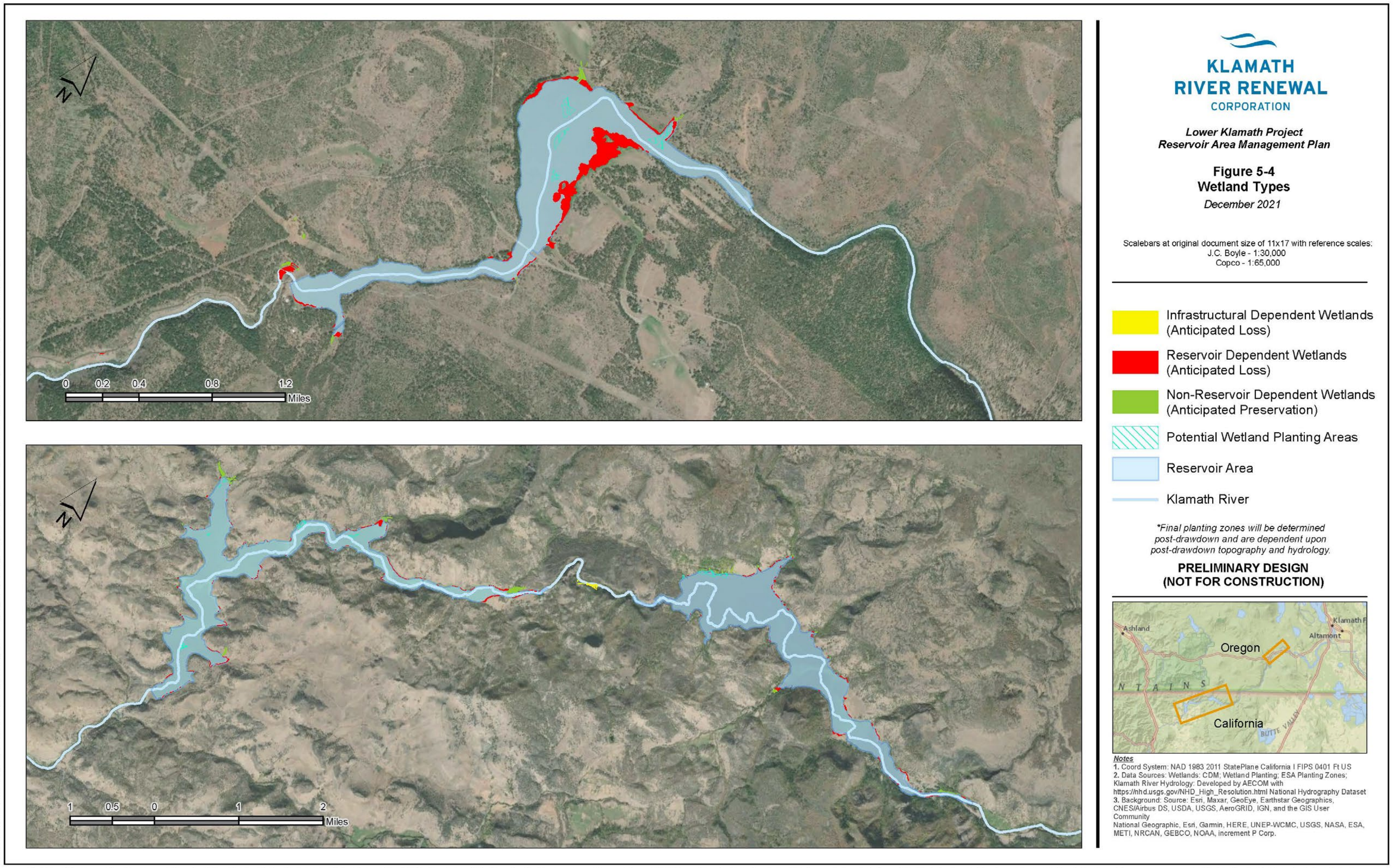


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Figure 5-4. Wetland Types

5.3 Revegetation

The Renewal Corporation will undertake revegetation design per these elements:

- Develop an additive layering system within each broad vegetation community type that (1) sets a matrix condition with seed and then (2) builds upon the matrix condition with supplemental woody species plantings where appropriate.
- Respond to unfolding field conditions and subtleties in the landscape such as remnant wetland/riparian vegetation, post-drawdown soil conditions, microtopography, soil moisture, seeps, rocky areas, and drainages within each wetland zone.
- Use inexpensive and robust plant material in the form of seed, cuttings, and bare root stock that are easily transported, establish well in difficult restoration conditions, and reduce the likelihood of spreading pathogens such as phytophthora.
- Plant bare root woody species in dense clusters within the seeded matrix to concentrate resources, increase survival rates via facilitation mechanisms and create island patches of trees and shrubs that will accelerate vegetation structural diversity and community development.
- Use existing adjacent vegetation cover types and post-drawdown topography and soil conditions to guide revegetation efforts.
- Allow for modifications to planting densities within an area while adhering to the total quantity of plant material being installed and managed to better mimic the subtle changes in densities across communities and the strata (i.e., tree, shrub, groundcover) within those communities.
- Incorporate salvaged wetland vegetation (i.e., sod, plugs or woody vegetation) opportunistically.

The Renewal Corporation will achieve revegetation of the Reservoir Areas through a combination of IEV management, seeding native herbaceous and woody species, planting bare root trees and shrubs, and natural recruitment of vegetation. The total amount of mainstem riparian, tributary riparian, dry uplands and palustrine wetlands habitat acreage anticipated for each reservoir following dam removal is set forth below in Table 6-17.

The Renewal Corporation plans to use irrigation in the Iron Gate and Copco No. 1 newly established riparian areas, as needed, and strategically place fencing around High Priority Tributary Work Areas.

5.3.1 Plant Material Collection and Propagation

A variety of plant materials will be used to revegetate the reservoirs including:

- Seed
- Bare root plants
- Container plants
    - Herbaceous plugs

    - Woody plants
- Live cuttings
    - Pole cuttings
    - Live-stakes
- Salvaged material
- Natural, native vegetation colonization

Proposed collection and propagation methods for seed and plant material are discussed in Sections 5.3.1.1 through 5.3.1.4.

5.3.1.1 Seed Collection, Propagation, and Storage

Forbs and grass seeds are the foundation of the restoration seed mix. The Renewal Corporation anticipates using approximately 32,400 to 90,000 pounds of pure live seed (80 to 100 pure live seeds per square foot (ft^2)) to seed the 1,800-acre reservoir area twice. Since seed weight and production in seed increase fields vary by species, the number of pounds of pure live seed necessary to seed the restoration area will also vary. For each target species, seeds have been collected from sites within the watershed or from an adjacent watershed of similar elevations and have been selected to ensure representative genetic variation. Future collections will follow similar guidelines. Collections began in 2018 and continued in 2019, 2020 and 2021. Additional collections are planned for the remainder of the 2021 season and beyond, as needed. The total number and distribution of collection sites varies according to size, density, continuity of populations, and biology of the species sampled, as well as the desired quantity of seed to be obtained. Seed collection as described in the 2018 Definite Plan Report is being employed throughout the collection areas for the Proposed Action. Boundaries for all collection areas are depicted in Figure 5-5. Seeds collected to date are summarized in Appendix H.

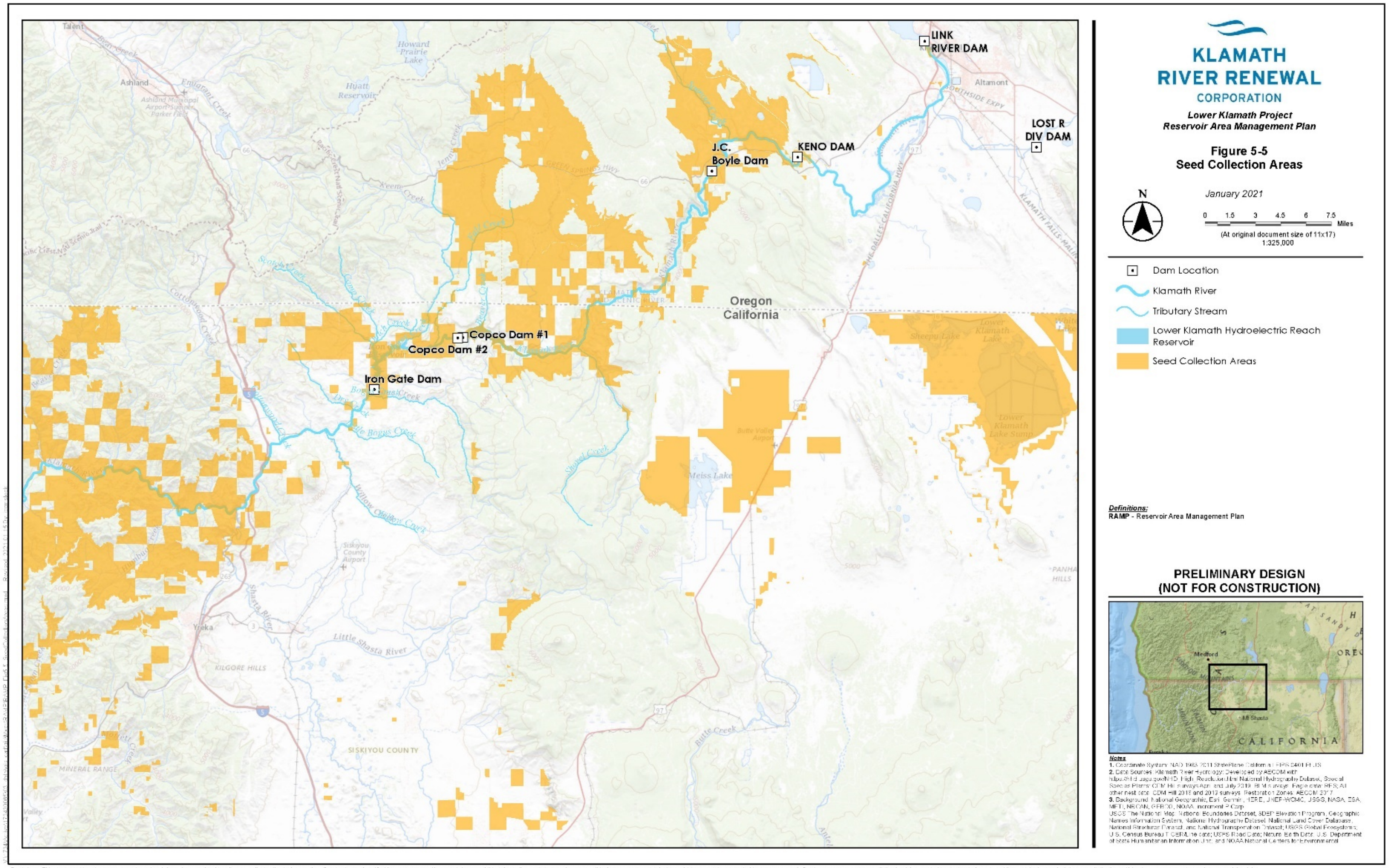


Figure 5-5. Seed Collection Areas

Seed collection methods are tailored to maximize volume of seed collected, depending on the species. Grass seed is harvested by stripping or shaking it off the stem, or by clipping the stem with scissors or small scythes just below the spikelet. Shrub seed is picked or lightly beaten or shaken using a tarp or bags to catch the falling seed. For species that dehisce explosively, the entire inflorescence is cut prior to maturity and allowed to dry in mesh, paper bags, or under netting. Ladders, tree climbing, or light pruning with telescoping pole pruners are used for seed collection from taller shrubs and trees. Collections are conducted in a manner that does not damage existing vegetation or other resources. At least 50 percent of the seed crop at a given site is left intact to allow for natural recruitment and regeneration of the native population. Botanists closely monitor seed maturation to match the timing of seed collection. Collectors made multiple trips to a site to determine when the seed was mature and ready for collecting. Collection throughout the maturation period prevented inadvertent selection for early- or late-maturing genotypes. Field data sheets (Appendix H) have been and will continue to be used to document seed collections.

Genetically appropriate, commercially available seeds were purchased when available, supplementing the seeds produced in custom seed increase fields to ensure species diversity and to obtain the quantities of seed needed to meet project goals. Purchases were made from the following growers:

- Silvaseed Company in Roy, Washington
- Bureau of Land Management (Medford, Oregon Office) via Rogue Native Plant Partnership
- BFI Native Seeds in Moses Lake, Washington
- Klamath Siskiyou Native Seeds in Applegate, Oregon
- Local ‘micro-growers’ in the Rogue Valley via Rogue Native Plant Partnership

Wild, native seeds collected from the Klamath watershed are the primary source of seed sown into seed increase fields for the Lower Klamath Project because such seeds are locally adapted and more likely to survive. The first contracted seed increase fields were established in 2019. Additional fields were established in the winter of 2019, the fall and winter of 2020, and the spring of 2021. Multiple nurseries in the region have been contracted for seed yield increase operations to achieve the target seed quantities for the variety of native species best suited to restoring the Reservoir Areas. Propagating native species is not a common endeavor, and expertise for each species varies by nursery. Current contracts for seed are expected to produce a minimum of 43,000 pounds of seed from 28 species, providing enough seed to complete at least two (2) applications at 80 seeds per square foot (Appendix H). Nurseries commercially producing seed for the Lower Klamath Project include the following:

- BFI Native Seed in Moses Lake, Washington
- S&S Seed in Carpinteria, California
- Hedgerow Farms in Winters, California
- Corvallis Plant Material Center in Corvallis, Oregon
- J. Herbert Stone Nursery in Central Point, Oregon

Many ecologically important species are unsuccessful when grown commercially but can be collected directly from the wild and added to seed mixes. Although the total volume of wild collected seed will be low compared to the volume produced from increase fields, wild collected seed provides important ecologically and culturally significant species to the revegetation project that can be selectively added to seed mixes in strategic locations. *Lomatium* species are particularly important ecologically and culturally and are known to perform well in seed mixes. Wild seed collected to date includes the 25 native species listed in Table 5-7.

Table 5-7. Wild Collected Seed Currently in Storage for the Proposed Action

SPECIES	COMMON NAME	HABITAT	TYPE
Acmispon americanus	Spanish lotus	Riparian/Wetland	Annual forb
Balsamorhiza deltoidea	deltoid balsamroot	Upland	Perennial Forb
Bidens frondosa	Devil's beggartick	Riparian/Wetland	Annual forb
Carex nebrascensis	Nebraska sedge	Riparian/Wetland	Perennial Sedge
Carex praegracilis	clustered field sedge	Riparian/Wetland	Perennial Sedge
Carex simulate	short-beaked sedge	Riparian/Wetland	Perennial Sedge
Carex subbracteata	small bract sedge	Riparian/Wetland	Perennial Sedge
Distichlis spicata	saltgrass	Riparian/Wetland	Perennial Grass
Grindelia nana	Idaho gumweed	Upland	Perennial Forb
Lomatium californicum	California lomatium	Upland	Perennial Forb
Lomatium dissectum	fernleaf biscuitroot	Upland	Perennial Forb
Lomatium macrocarpum	bigseed biscuitroot	Upland	Perennial Forb
Lomatium nudicaule	barestem biscuitroot	Upland	Perennial Forb
Lomatium triternatum	nineleaf biscuitroot	Upland	Perennial Forb
Lupinus albifrons	Silver bush lupine	Upland	Perennial Forb
Lupinus andersonii	Anderson's lupine	Upland	Perennial Forb
Lupinus latifolius	broadleaf lupine	Upland	Perennial Forb
Monardella odoratissima	Mt mondardella	Upland	Perennial Forb
Penstemon deustus var deustus	hot rock penstemon	Upland	Perennial Forb
Penstemon laetus	Mt blue penstemon	Upland	Perennial Forb
Penstemon speciosus	Royal penstemon	Upland	Perennial Forb
Persicaria amphibia	water smartweed	Riparian/Wetland	Perennial Forb

SPECIES	COMMON NAME	HABITAT	TYPE
Phacelia heterophylla var. *virgate*	varied leaf phacelia	Upland	Perennial Forb
Stipa occidentalis	Lemon's needlegrass	Upland	Perennial Grass
Xanthium strumarium	rough cocklebur	Riparian/Wetland	Perennial Forb

Note: Table is as of Fall 2021. Seed collection began in 2018. Cleaning and testing is in progress for seed collected in 2021.

The seeds will be stored until Proposed Action implementation. Proper storage is imperative to ensure viability as overheating and temperature fluctuations can kill seeds. In addition, storage in prolonged high-moisture environments can promote mold growth and reduce viability. Therefore, seeds are stored at nurseries with adequate, monitored storage facilities to minimize the potential for catastrophic loss due to improper storage. Each of the storage locations listed below follows the University of California, Davis Seed Biotechnology Center guidance that the sum of temperature (degrees Fahrenheit) and relative humidity (percent) should not exceed 100 (U.C. Davis, 2020); commonly known as the "100 rule of thumb." Seed has been, and will continue to be, stored at the following locations:

- Sampson Creek Reserve near Ashland, Oregon
- BFI Native Seed in Moses Lake, Washington
- Hedgerow Farms in Winters, California
- Pacific Coast Seed in Tracy, California
- Corvallis Plant Material Center in Corvallis, Oregon
- J. Herbert Stone Nursery in Central Point, Oregon

Additional information on seed increase and storage facilities is provided in Appendix H.

5.3.1.2 Native Bare Root Plants

The Renewal Corporation will propagate bare root material (trees, shrubs, and herbaceous) and plant this material into the Reservoir Areas to add woody plant diversity and structure in seeded areas. The Renewal Corporation will prioritize the propagation of woody species that are important components of the surrounding existing plant communities and are tolerant of clay soils. In addition, direct seeding (e.g., acorns) and containerized root stock will also be used. Seed used to propagate bare root or container plants will be collected from the watershed or adjacent areas to ensure genetic integrity. The Renewal Corporation's production target is 260,000 woody plants from a minimum of 33 species.

Herbaceous species that are difficult to seed will be propagated as plugs. The plugs will be 12 cubic inches or smaller, depending on species. These include wetland species, such as salt grass, and showy species, such as royal penstemon (*Penstemon speciosus*). Rhizomatous species will also be propagated and planted as rhizomes.

Bare root propagation requires one (1) to two (2) years, depending on the species. Many species are ready after one (1) growing season and are shipped in late winter. If drawdown period hydrologic conditions permit, the first round of bare root plants will be planted as soon as practicable after dam removal, maximizing survival rates in the moist sediments. Bare root materials will be stored temporarily at facilities close to the dams in a location to be determined. Plants will either be removed from shipping bags and stored in mulch piles to keep the root systems moist until planting or stored in environmentally controlled conex boxes designed for plant storage. Bare roots will be stored a maximum of six (6) weeks.

Bare root plant materials will be tested for *Phytophthora* sp., a plant pathogen detrimental to native plant communities. A minimum of three (3) percent of all bare root material will be tested. Any detections of *Phytophthora* in a particular species will result in removal of all plants of that species (from the same nursery) from the Proposed Action. Exact testing methods are to be determined based on current science and expert recommendations. More information regarding bare root plant collection is provided in Appendix H.

5.3.1.3 Pole Cutting and Live Stake Cutting Collection and Storage

Pole cuttings are a component of the large wood features, willow baffles, mixed willow clusters, and cottonwood clusters. Pole planting should occur after November 20 when plants are dormant. While live cottonwood and willow pole cuttings are ideally collected after leaves have fallen from donor plants, pole collection may occur sooner due to the construction schedule and the quantity of pole cuttings necessary for each reservoir. Pole cuttings will be collected as close to complete dormancy as feasible. Pole cuttings may be purchased from a nursery or collected from plants growing along the river, or from logs, stumps, or other horticultural methods that produce hardwood poles of the desired species, lengths, and diameter.

Pole cutting diameter is a good proxy of the amount of energy reserves stored in the cutting and desiccation vulnerability. Smaller diameter poles need more poles installed in each planting to ensure that one (1) pole survives, whereas larger diameter poles require fewer poles per planting to ensure survival. Live hardwood pole diameters at the largest end should be 1.5 inches minimum and three (3) inches maximum. Live hardwood poles lengths should be a minimum length of 10 feet.

Following collection, the smaller diameter end of each hardwood pole will be color coded with latex paint to indicate plant species and pole direction, facilitating layout. After pole cuttings are color coded, they will be bundled into groups of 25 and soaked. Each bundle will be prepared with a mixture of diameter ranges. Individual bundles will be labeled with an aluminum tag that may indicate the collector(s), species, date and location of collection, and the date soaking began and ended. Poles will be soaked for no more than 16 days and no less than seven (7) days before planting.

In the event that pole cuttings cannot be immediately installed after soaking, poles will be placed in cold storage. Poles can be stored for up to six (6) months at 41 degrees Fahrenheit. Prior to installation, the stored poles will repeat the soaking cycle for approximately four (4) to five (5) days if necessary.

Pole cuttings will be delivered to the revegetation site in tagged bundles of 25 poles. Approximately 2,300 pole cuttings will be installed in the Reservoir Areas. Delivery to the jobsite from storage will be carefully coordinated to ensure that pole cuttings do not dry out. Effort will be taken to deliver to the site no more poles than can be planted within 24 hours after removal from storage. If daily average air temperatures exceed 80 degrees Fahrenheit, on-site poles will be temporarily stored in the shade under wet burlap sacks. Poles that are not used in a day will be wrapped in wet burlap sacks and stored in a cool location until the next planting day.

Live-stake cuttings will be used for direct staking into riparian and wetland areas that do not require heavy equipment for planting. Approximately 25,750 live-stakes will be installed in the Reservoir Areas. Live-stake cutting diameters will be 0.25 inches minimum and one (1) inch maximum. Cutting lengths will be a minimum of 24 or 48 inches, depending on application and to be specified by the restoration designer. Management and storage of live-stake cuttings will follow the same methods described above for pole cuttings.

5.3.1.4 Native Plant Salvage

During reservoir drawdown, the Renewal Corporation will identify for relocation areas of opportunistic salvage of native plants presently around the reservoir rim, with emphasis placed on avoiding introduction of IEV species. Salvaged native plants will be installed as soon as practicable to newly exposed wetlands or riparian areas. Wetland sod will be opportunistically salvaged by hand or using heavy equipment. Small woody species (trees and shrubs) may also be salvaged during drawdown.

5.3.2 Planting Strategies and Species

The following subsections describe the Renewal Corporation's proposed methods for seeding and installing woody material, including species that are expected to be planted.

5.3.2.1 Seeding Strategies and Species

The Renewal Corporation's objectives in seeding native herbaceous species include the following:

- Supplement natural revegetation
- Minimize surficial erosion of sediment
- Accelerate vegetation cover
- Minimize nonnative plant establishment

Most of the seeding will be by hand using belly grinders or other manual methods. In areas with challenging access, aerial seeding with helicopters, drones and/or fixed-wing aircraft may be used. To the extent mechanical methods are used to seed, the Renewal Corporation may use filler, such as rice hulls, to ensure that seed mixes are spread evenly over the planting area.

Seed mixes will be modified for elevation. There will be a minimum of two (2) seeding events with pioneer seeding mixes sown as soon as practicable after reservoir drawdown and secondary seed mixes (diversity mixes) being sown in a year or two. Additional seeding may be needed during the maintenance and monitoring period (see Section 6.3, Revegetation Adaptive Management).

Proposed pioneer and diversity seed species and mixes are discussed in the following sections. Going forward, the species lists in the following sections will continue to be refined and updated by the Renewal Corporation based on the following:

- Observed species patterns around all three (3) reservoirs
- Seed availability
- Propagation feasibility
- Likelihood of species to colonize naturally, including the following:
    - Long-distance dispersal ability
    - Presence in the seed bank
    - Seed maturation season

More species may therefore be added as additional information becomes available. The Renewal Corporation's proposed planting palette differs somewhat between the dam sites, as described in Sections 5.4.6, 5.5.6, and 5.6.6. While estimated planting areas are depicted in Figure 5-6, these estimates are based on hydrology estimates from the Yurok Tribe and will likely need to be updated following drawdown to reflect post-drawdown conditions.

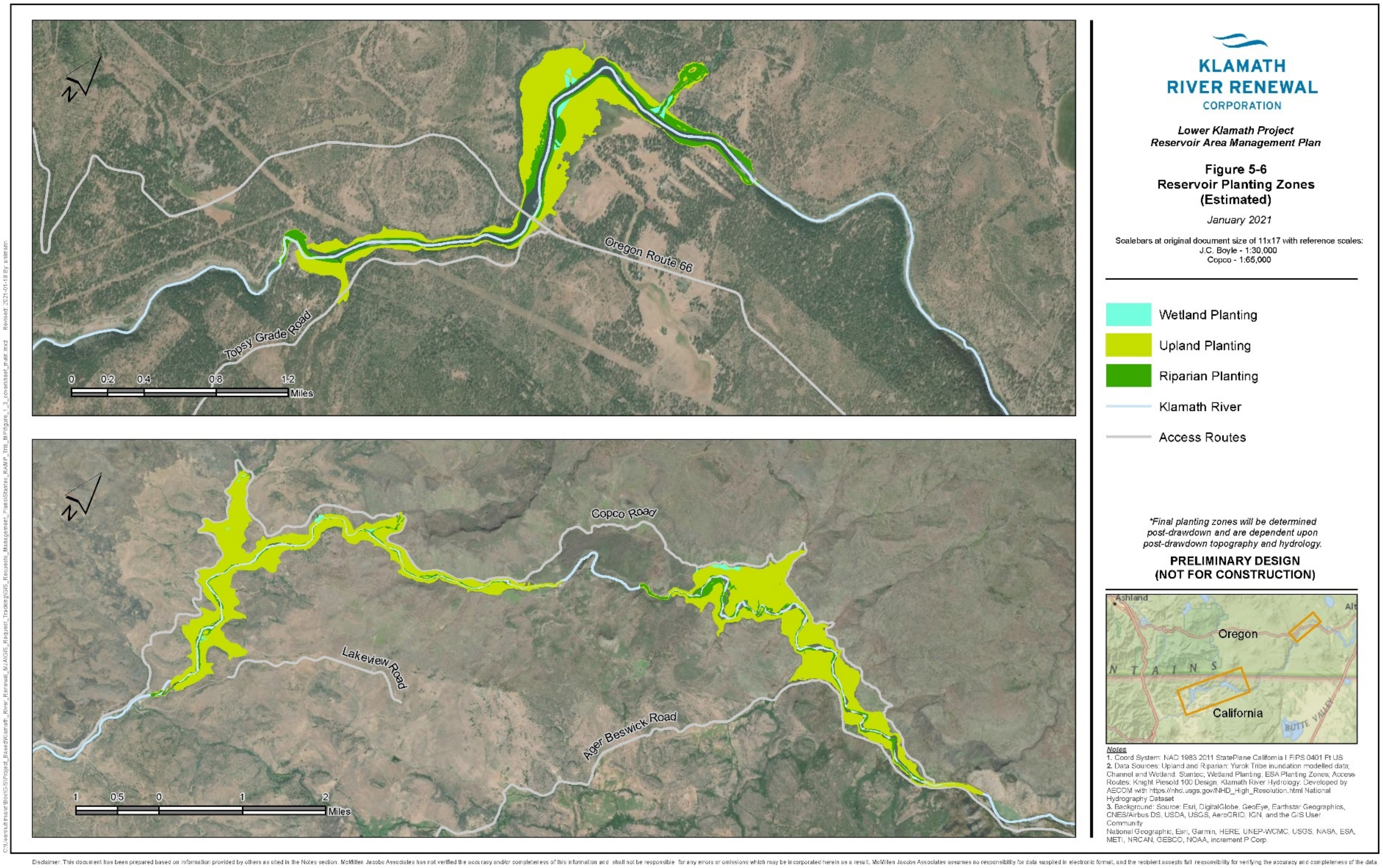


Figure 5-6: Reservoir Planting Zone (Estimated)

Note: Final planting may vary significantly and will be based on post drawdown conditions.

5.3.2.1.1 Pioneer Seed Mixes

The Renewal Corporation will apply two pioneer seed mixes: one (1) for upland areas and one (1) for wetland/riparian areas. The primary function of the pioneer mixes is to break apart the soil crust, begin the development of a more complex soil structure, create pore space for precipitation penetration, support development of the soil microbial ecosystem, and create cover over the soil to prevent erosion and support future plantings. The design criteria prescribes inclusion of a minimum of seven (7) forb species and four (4) grass-like species in the pioneer mix. The priority is to use the greatest diversity of species possible for the initial seed mix. High diversity introduced early in plant succession is an important strategy to ensure success in unprecedented ecological conditions. High species diversity and richness provides ecosystem resilience over time. Seeds will be applied at a rate of 80 to 100 seeds per square foot. Actual seed mix species composition, including species percentages, will be determined during final design and will be based on the results of seed collection and production results from seed increase fields.

The Renewal Corporation will apply pioneer seed mixes as soon as practicable following drawdown before the sediments dry out. Seeding as soon as practicable after drawdown will ensure good establishment rates because of the residual moisture left behind by reservoir drawdown. During the following winter and early spring, over-seeding diversity mixes are proposed to add to species diversity where needed and seed areas that performed poorly during the first summer. Seed will be broadcast by hand from helicopters, drones, and/or fixed-wing aircraft and/or other mechanical seeding methods (e.g., all-terrain vehicle-mounted seeders) in areas difficult to access on foot or in which foot access is restricted under the HPMP or TWMP. Proposed species for the upland and riparian pioneer seed mixes are provided in Tables 5-8 and 5-9, respectively.

Table 5-8. Species List for the Upland Pioneer Seed Mixes

SPECIES	COMMON NAME
Achillea millefolium	common yarrow
Amsinckia menziesii	Menzies' fiddleneck
Bromus carinatus	California brome
Croton setigerus	turkey mullein
Drymocallis glandulosa	sticky cinquefoil
Elymus elymoides	squirreltail
Elymus glaucus	blue wildrye
Elymus spicatus	blue bunch wheat grass
Eriophyllum lanatum	Oregon sunshine
Eschscholzia californica	California poppy

SPECIES	COMMON NAME
Festuca idahoensis spp. roemeri	Roemer's fescue
Grindelia camporum	great valley gumweed
Koeleria macrantha	June grass
Lupinus microcarpus var. densiflorus	chick lupine
Lupinus microcarpus var. microcarpus	valley lupine
Mentzelia laevicaulis	smoothstem blazingstar
Penstemon roezlii	Rozel's penstemon
Penstemon speciosus	royal penstemon
Poa secunda	Sandberg's bluegrass
Solidago elongata	Cascade goldenrod
Stipa lemmonii	Lemmon's needlegrass
Trichostema lanceolatum	Vinegarweed

Note: The list and ratios of species will be modified by reservoir and depend on final seed production results.

Table 5-9. Species List for the Riparian Pioneer Seed Mixes

SPECIES	COMMON NAME
Artemisia douglasiana	California mugwort
Deschampsia cespitosa	California hairgrass
Drymocallis glandulosa	sticky cinquefoil
Elymus cinereus	great basin wildrye
Elymus glaucus	blue wildrye
Elymus triticoides	creeping wildrye
Grindelia camporum	great valley gumweed
Hordeum brachyantherum	meadow barley
Hordeum jubatum	foxtail barley
Trichostema lanceolatum	vinegarweed

Note: The list and ratios of species will be modified by reservoir and depend on final seed production results.

5.3.2.1.2 Diversity Seed Mixes

The Renewal Corporation will undertake a second round of seeding designed to add species diversity, reseed areas not meeting performance criteria, and seed areas impacted by construction in the summer and fall of Year 2. Wild collected seed will be selectively added to the base mix of species used in the pioneer mix. Anticipated species to be included in diversity mixes are provided in Tables 5-10 and Table 5-11. The diversity seed applied at a given reservoir will be tailored to include species local to that reservoir (see site-specific discussions in Sections 5.4.6, 5.5.6, and 5.6.6). These mixes will incorporate more perennial, forb, and woody species as well as additional sedge and rush species (Table 5-10). The diversity mixes will be seeded in the fall of Year 2 and early spring of Year 3, depending on species availability from seed increase fields and weather conditions. When the application window for these two (2) mixes approaches, the landscape will have had at least one (1) season to respond to the drawdown, and managers will be able to identify pioneer seed success and failures, natural regeneration patterns, and emerging habitat zones for appropriate application locations. This will allow for a more strategic (i.e., adjusting seeds per square foot as needed) and successful application of seed mixes that are more expensive and in limited supply. Areas identified with dense vegetation that is not native or has low diversity may be prepped prior to seeding to ensure that open ground and sunlight are available. Surface preparations may include tilling or other surface roughening and/or mowing tall vegetation.

Table 5-10. Potential Riparian/Wetland Species for Diversity Seed Mixes

SPECIES	COMMON NAME	LIFEFORM	SEED STATUS
Acmispon americanus	Spanish lotus	Annual forb	Stored
Bidens frondosa	Devil’s beggarticks	Annual forb	Stored
Carex nebrascensis	Nebraska sedge	Perennial sedge	Stored
Carex praegracilis	clustered field sedge	Perennial sedge	Stored
Carex simulata	short beaked sedge	Perennial sedge	Stored
Deschampsia danthonioides	annual hairgrass	Annual grass	Stored
Erythranthe guttata	yellow monkey flower	Annual/Perennial forb	To be collected
Kyhosia bolanderi	Bolander’s tarweed	Perennial forb	To be collected
Muhlenbergia richardsonis	mat muhly	Perennial grass	To be collected
Paspalum distichum	Knotgrass	Perennial grass	To be collected
Persicaria amphibia	water smartweed	Perennial forb	Stored
Sidalcea oregana	Oregon checkermallow	Perennial forb	To be collected
Trifolium willdenovii	Tomcat clover	Annual forb	To be collected
Xanthium strumarium	Cocklebur	Annual forb	Stored

Table 5-11. Potential Upland Species for the Diversity Seed Mixes

SPECIES	COMMON NAME	LIFEFORM	SEED STATUS
Amsinckia menziesii	Menzies' fiddleneck	Annual forb	To be collected
Acmispon americanus	Spanish lotus	Annual forb	Stored
Angelica arguta	Lyall's angelica	Perennial forb	To be collected
Artemisia tridentata	big sagebrush	Shrub	Stored
Danthonia californica	California oatgrass	Perennial grass	To be collected
Ericameria nauseosa	Rabbitbrush	Shrub	To be collected
Festuca microstachys	small fescue	Annual grass	To be collected
Grindelia nana	Idaho gumweed	Perennial forb	Stored
Lomatium dissectum	fernleaf biscuitroot	Perennial forb	Stored
Lomatium nudicaule	barestem biscuitroot	Perennial forb	Stored
Lomatium triternatum	nineleaf biscuitroot	Perennial forb	Stored
Monardella odoratissima	mountain mondardella	Perennial forb	Stored
Penstemon deustus	rock penstemon	Perennial forb	Stored
Perideridia gairdneri	Gairdner's yampah	Perennial forb	To be collected
Phacelia heterophylla var. virgata	varied leaf phacelia	Perennial forb	Stored
Stipa occidentalis	western needlegrass	Perennial grass	To be collected

Exact composition of diversity species mixes will vary, and the Renewal Corporation will continue to refine the composition based on the criteria outlined in section 5.3.2.1.

5.3.2.1.3 Mulching

Where application is feasible, the Renewal Corporation will apply native straw mulch or sterile wheat mulch as a seeding mulch on bare soils and exposed sediment. The Renewal Corporation's outdoor seed germination tests found that the straw mulch greatly improved germination and survival of seedlings (RFI RES-08). The study suggested that the mulch served two (2) key purposes: it retained surface soil moisture and it offered the seedlings thermal protection from below-freezing nighttime temperatures.

Straw mulch is commonly used to aid in germination and protect exposed soils in many types of seeding and erosion control applications. The risk of applying straw mulch is that the straw may contain unwanted weed seeds. The native straw mulch will be procured in advance to monitor for the presence of weedy species. The native straw mulch or sterile wheat straw mulch will be applied with the pioneer seed mix after drawdown in select areas. During subsequent years, the widespread use of straw mulch will not be necessary. Straw mulch may be used as an adaptive management technique in areas that show poor coverage and require reseeding.

The Renewal Corporation may also use deep mulching or other types of mulch such as wood chips, wood shavings and/or pine needle shavings for adaptive management of strategic locations.

5.3.2.1.4 Irrigation

The Renewal Corporation will install irrigation systems as needed in the riparian areas of Iron Gate (approximately 109 acres) and Copco No. 1 (approximately 98 acres) to increase the likelihood of seeding success, facilitate establishment of native vegetation, and promote stabilization of the floodplain of the Klamath River and its tributaries within the Limits of Work post-drawdown. Additional areas will receive supplemental irrigation, with primary focus on south facing slopes with lower soil moisture, as needed to meet vegetative performance criteria and achieve sediment stabilization. Wide-scale irrigation use is not anticipated for any parts of the Limits of Work after Year 2. Water used for irrigation will be pumped directly from the Klamath River or tributaries, with diversion points being determined at a later time as needed. Upon license transfer, Renewal Corporation will hold applicable water rights for such diversions.

5.3.2.2 Woody Species Planting Strategies and Species

The Renewal Corporation will plant native woody species to supplement natural and seeded vegetation, enhance slope stability, accelerate succession of trees and shrubs, and provide habitat for fauna. The majority of bare roots and container plants will be installed as soon as practicable following drawdown. Trees and shrubs will be planted in distinct clusters (facilitation patches) with specifications outlined in an annual planting plan. Planting in dense clusters, as opposed to spreading out the plants is preferred because high density patches more closely mimic early plant successional patterns. This will increase overall survival rates of plants due to facilitation mechanisms common to ecosystems in extreme climates (Callaway, 1995).

As with seed source (Section 5.3.1.1), the proposed planting palette for trees and shrubs will vary based on availability and tailored to each reservoir (see Sections 5.4.6, 5.5.6, and 5.6.6). Proposed species that may be used are listed in Table 5-12. Additional native woody species may be considered based on data collected from reference sites.

Table 5-12. Native Tree and Shrub Species Palette

SCIENTIFIC NAME	COMMON NAME	STRATA
Abies concolr	white fir	Tree Layer
Acer macrophyllum	bigleaf maple	Tree Layer
Alnus rhombifolia	white alder	Tree Layer
Amelanchier alnifolia	western serviceberry	Shrub Layer
Amelanchier utahensis	Utah serviceberry	Shrub Layer

SCIENTIFIC NAME	COMMON NAME	STRATA
Artemisia tridentata	big sagebrush	Shrub Layer
Berberis aquifolium	Oregon grape	Shrub Layer
Calocedrus decurrens	incense cedar	Tree Layer
Ceanothus cuneatus	buckbrush	Shrub Layer
Ceanothus integerrimus	deerbrush	Shrub Layer
Cercocarpus betuloides	birchleaf mt. mahogany	Shrub Layer
Cornus glabrata	smooth dogwood	Shrub Layer
Cornus sericea	red-osier dogwood	Shrub Layer
Ericameria bloomeri	rabbitbush	Shrub Layer
Ericameria nauseosus	rubbery rabbitbrush	Shrub Layer
Fraxinus latifolia	Oregon ash	Tree Layer
Holodiscus discolor	oceanspray	Shrub layer
Lonicera interrupta	chaparral honeysuckle	Shrub Layer
Philadelphus lewisii	Lewis' mock orange	Shrub Layer
Physocarpus capitatus	ninebark	Shrub Layer
Pinus contorta var. marrayana	lodgepole pine	Tree Layer
Pinus lambertiana	sugar pine	Tree Layer
Pinus ponderosa	ponderosa pine	Tree Layer
Populus balsamifera	black cottonwood	Tree Layer
Populus fremontii	Fremont cottonwood	Tree Layer
Prunus emarginata	bitter cherry	Tree Layer
Prunus subcordata	Klamath plum	Tree Layer
Prunus virginiana	chokecherry	Tree Layer
Pseudotsuga menziesii	Douglas-fir	Tree Layer
Purshia tridentata	antelope bitterbrush	Shrub Layer
Quercus garryana	Oregon white oak	Tree Layer
Quercus kelloggii	California black oak	Tree Layer
Rhus aromatica	fragrant sumac	Shrub Layer
Ribes cereum	wax currant	Shrub Layer
Ribes velutinum	desert gooseberry	Shrub Layer
Rosa gymnocarpa	dwarf rose	Shrub Layer
Rosa woodsii	wood rose	Shrub Layer
Salix exigua	coyote willow	Tree Layer

SCIENTIFIC NAME	COMMON NAME	STRATA
Salix lasiolepis	arroyo willow	Tree Layer
Salix lucida ssp. lasiandra	shining willow	Tree Layer
Sambucus nigra	blue elderberry	Shrub Layer
Spiraea douglasii	rose spirea	Shrub Layer
Symphoricarpos albus	common snowberry	Shrub Layer

See Section 5.3.2.1.4 for a discussion of irrigation.

5.3.2.2.1 Fencing

The Renewal Corporation will make strategic use of temporary fencing at High Priority Tributary Work Areas to prevent browsing of newly planted vegetation. Fencing installation will vary by location based on topography and obstructions (e.g., steep slopes, rocks, trees). The use of fencing may be constrained by construction access, flooding, and cost-effectiveness. Where feasible, exclusion zones will be created around each of the High Priority Tributary Work Areas rather than protecting individual plants with tubes. Fencing is intended to exclude cows and horses. The only fencing currently contemplated is fencing of High Priority Tributary Work Areas. Fencing of stream crossing areas will be minimized.

The Renewal Corporation will install taller fencing if herbivory by deer becomes a management problem. The Renewal Corporation is not proposing taller fencing at this time but will investigate such fencing as an adaptive management practice if it observes unacceptable levels of herbivory by deer.

5.3.3 Invasive Exotic Vegetation (IEV) Management

Non-native plant species currently are common in the area and are expected to recolonize disturbed areas following dam removal. Many non-native species provide beneficial habitat elements for wildlife species in the vicinity. Others may provide less benefit but are not priorities for removal either because of their low ecological impact or difficulty to contain. A number of non-native species are considered to be detrimental and are medium to high priorities for control or removal by regulatory agencies. These species are referred to herein as IEV.

Dam removal will create large areas devoid of vegetation, providing opportunities for IEV to colonize and attain dominance. The Reservoir Areas will therefore be particularly susceptible to invasion by IEV post-drawdown. If left unchecked, the establishment of invasive species in the Reservoir Areas will degrade potential salmon habitat by dispersing propagules (seeds, rhizomes) downstream. Managing IEV will be a concern at all three (3) Reservoir Areas. Iron Gate, and to some extent Copco No. 1, will be particularly challenging as those areas have the most aggressive and widespread existing IEV coverage adjacent to the boundaries of the Lower Klamath Project.

The IEV management period covers the pre-dam removal period (i.e., Year 0 and Year 1) and the dam removal and restoration phase (i.e., Year 2 and Year 3). IEV management will be completed annually in early season and late season implementation phases, as necessary, to maximize IEV treatment effectiveness for specific plant species. The post-restoration period, which will last for 5 years beginning in Year 4, will be managed under a forthcoming IEV management strategy (to be produced during Year 3 and updated annually) and based on the status and abundance of IEV in Year 3.

5.3.3.1 Existing IEV Populations and Species Prioritization

PacifiCorp documented IEV in the lower Klamath River watershed in 2002-2003 (PacifiCorp, 2004). The Renewal Corporation revisited PacifiCorp's documentation of IEV in 2017 and 2018 (KRRC, 2018). Existing IEV coverage ranges from approximately 16 percent at J.C. Boyle to 19 percent at Copco No. 1 and 75 percent at Iron Gate. The Renewal Corporation developed a prioritized target list of 52 invasive species based on data collected during field studies in 2018 (KRRC, 2018). The priority list was subsequently modified to reflect 2019 agency ratings (Tables 5-13 and 5-14). Of the 52 species of concern identified on the priority list, only 22 were present in the latest survey by the Renewal Corporation in 2018. Fourteen of the 22 species present have been identified as high or medium priority for treatment (Table 5-13), while the other eight (8) species have been identified as low priority (Table 5-14). The Renewal Corporation may modify the priority list and/or Tables 5-13 and 5-14 based on future field studies and changes to agency ratings and priorities.

Table 5-13. Medium and High Treatment Priority IEV Species

SCIENTIFIC NAME	COMMON NAME	PRIORITY	TOTAL OBS	CONTROL OPPORTUNITY	
				ERADICATION	CONTAINMENT
Onopordum acanthium	Scotch thistle	High	2	High	-
Centaurea diffusa	diffuse knapweed	High	1	High	-
Acroptilon repens	Russian knapweed	High	1	High	-
Linaria dalmatica	Dalmatian toadflax	High	1	High	-
Centaurea solstitialis	yellow star thistle	High	107	Low	High
Isatis tinctorial	dyer's woad	Medium	1	High	-
Bromus madritensis ssp. rubens	foxtail brome	Medium	4	High	-
Foeniculum vulgare	fennel	Medium	2	High	-
Xanthium spinosum	spiny clotbur	Medium	1	High	-

SCIENTIFIC NAME	COMMON NAME	PRIORITY	TOTAL OBS	CONTROL OPPORTUNITY	
				ERADICATION	CONTAINMENT
Rubus armeniacus	Himalayan blackberry	Medium	54	Moderate	Moderate
Bromus tectorum	cheatgrass	Medium	185	Low	High
Dipsacus fullonum	teasel	Medium		Low	High
Elymus caput-medusae	medusahead	Medium		Low	High
Phalaris arundinacea	reed canarygrass	Medium		Low	High
Conium maculatum	poison hemlock	Medium	13	High	High

Table 5-14. Low Treatment Priority IEV Species

SCIENTIFIC NAME	COMMON NAME	PRIORITY	TOTAL OBS	CONTROL OPPORTUNITY	
				ERADICATION	CONTAINMENT
Brassica nigra	Black mustard	Low	4	High	-
Bromus diandrus	ripgut grass	Low	4	High	-
Cirsium arvense	Canada thistle	Low	5	High	-
Festuca arundinacea	tall fescue	Low	9	High	-
Hypericum perforatum	St. John's wort	Low	2	High	-
Lepidium draba	hoary cress	Low	53	Moderate	Low
Cirsium vulgare	bull thistle	Low	93	Low	Low

5.3.3.2 IEV Control Methods, Including Targeted Use of Exclusion Fencing

The Renewal Corporation will implement two (2) primary strategies for IEV treatment: eradication and containment. Species to be contained are those that are ubiquitous on the landscape, those in close proximity to all restoration areas, and those that cannot be realistically eradicated or contained for long periods, including cheatgrass (*Bromus tectorum*), medusahead (*Elymus caput-medusae*), and yellow star thistle (*Centaurea solstitialis*). The strategies were determined for each species and were based on abundance on the landscape and the cost-effectiveness of treatments. Treatments will be adaptively managed through a robust quantitative monitoring program.

While IEV treatments will often require a combination of methods, the Renewal Corporation will use mechanical removal techniques (i.e., grubbing and mowing) as the primary treatment method for all IEV species known to occur within the Limits of Work (Table 5-15). Chemical treatments will be minimized and used only on species that are not effectively treated mechanically.

IEV identified in the Limits of Work were individually evaluated to determine effective control methods using federal, state, and local recommendations (i.e., California Invasive Plant Council Management guidelines). The following control methods are proposed to be used for IEV control:

1. Grubbing (hand pulling) is effective for controlling small IEV infestations, emerging infestations, or infestations at the fringes of a large patch. Grubbing (hand pulling) is typically more effective on annual species and species that are not rhizomatous but can be used for perennial species if the populations are small and/or young. Grubbing will be done by hand or with hand tools such as Pulaskis, shovels, or other digging tools. Efforts will be made to minimize soil disturbance when possible. Large patches of *Rubus armeniacus* may be grubbed using large equipment (e.g., excavators) during construction activities when possible. If the species being grubbed is in seed, the grubbed plants will be bagged and removed from the site. The Renewal Corporation expects to primarily use grubbing as an IEV control method from May through July.

2. Mowing or cutting (using weed trimmers and mowers) for invasive annuals will be employed as a containment strategy to reduce production in biennials and perennials, exhaust the nutrient reserves, and reduce plant vigor, as well as decrease the buildup of thatch. Mowing is considered an effective containment strategy for the most abundant IEV species (*Bromus tectorum, Centaurea solstitialis, Dipsacus follunum,* and *Elymus caput-medusae*) (DiTomaso et al., 2013) and will only be employed in areas with extensive, near-monoculture stands of IEV to avoid mowing native species. To be effective, mowing must be repeated two (2) to three (3) times during the growing season for three (3) or more years (DiTomaso et al., 2013). A buffer of 50 to 100 ft mowed regularly should prevent seed dispersal into the Reservoir Areas after drawdown because these species all disperse seed short distances in the wind (DiTomaso et al., 2013). The Renewal Corporation expects to primarily use mowing as an IEV control method from April through July. In accordance with Cal-Fire, Oregon Fire and PacifiCorp recommendations, mowing will cease when fire danger is high.

    a. Mowing will primarily be accomplished with string trimmers. Large rocks, steep terrain, and other features on the landscape preclude the effective use of tractor-based mowers. Trimmers can handle the terrain better and presents less risk of sparking wildfire. Trimmers will also allow for the preservation of important native species such as *Lupinus albifrons* and woody shrubs within the mowed area, providing residual vegetation capable of seeding into the mowed areas.

3. Herbicides will be used for species that are not suited to mechanical removal techniques. Only herbicides that have been approved for use by the BLM, CDFW, the Oregon

Department of Agriculture, North Coast RWQCB, USFWS and NMFS in both California and Oregon, and the Renewal Corporation and Native American Tribes, will be considered. The Renewal Corporation expects to primarily apply herbicides in the spring from March through June and in the fall from September through November. Herbicides will be rotated when possible to reduce herbicide resistance. The Renewal Corporation will implement the BMPs set forth in Appendix C that relate to herbicide application and will comply with any additional requirements related to herbicides set forth in NMFS's Biological Opinion. In addition, the Renewal Corporation will follow guidelines to protect pollinator species, including USDA's Agronomy Technical Note No. 9 (USDA 2014). Spot spraying, the primary method the Renewal Corporation will employ on the Lower Klamath Project, is used for species-specific control. All herbicides used will be applied according to label specifications by a California Licensed Qualified Applicator in California, by an Oregon Licensed Qualified Applicator in Oregon and approved by the U.S. Environmental Protection Agency (EPA). Application timing and locations will be designed to minimize chemical contamination of waterways. When necessary, populations that are close to water will be treated with herbicides approved by the EPA and designed for use in aquatic environments.

Herbicides recommended for treatment include the following:

a. Glyphosate (AquaNeat®, Rodeo®)[5]
b. Aminopyralid (Milestone®)
c. Triclopyr (Garlon 3A®, Element3A®)
d. Imazapyr (Polaris®, Habitat®)[5]
e. Clopyralid (Transline®)

The above list is not comprehensive. As new information becomes available on recommended treatment, additional herbicides may be added. Any new herbicides and/or surfactants proposed will be provided to the pertinent agencies prior to use. Glyphosate is generally only effective for the season that it is applied for perennial or woody species, and it is non-selective, affecting all vegetation in the area of treatment. This can create significant bare ground for new weeds to colonize. Application of this herbicide will be formulated to minimize impacts to native plants and will be mostly employed as a spot treatment for small populations. Bare ground that is created by herbicide use will be seeded and/or planted with native species within a year.

4. Solarization will be used only in areas where there are small patches of invasive vegetation. Solarization will be accomplished using thick, non-translucent black plastic capable of smothering a population and blocking all sunlight. The Renewal Corporation expects to primarily install the plastic for solarization during June and July.

[5] Habitat® and Rodeo® will only be used on BLM land to conform with the Klamath Falls Resource Area, Pesticide Use Proposal.

5. Tilling and disking is an agricultural weed eradication method used in solid stands of invasive species to disrupt and bury the plant or to separate the root from the plant. This method will be employed only in heavily infested areas, which are level and where erosion is not a concern and culturally significant resources are not expected. If used, seeding of pioneer and native species will follow the tilling and disking event to promote native growth to outcompete the invasive species.

Proposed treatments for the 52 identified IEV species are provided in Table 5-15.

Table 5-15. Proposed Treatments for Identified IEV Species

SCIENTIFIC NAME	COMMON NAME	PRIORITY	PRIMARY	SECONDARY	ADDITIONAL
Onopordum acanthium	Scotch thistle	High	Grub	Clopyralid	Aminopyralid
Centaurea diffusa	diffuse knapweed	High	Grub	Clopyralid	Aminopyralid
Acroptilon repens	Russian knapweed	High	Grub	Clopyralid	Aminopyralid
Linaria dalmatica	Dalmatian toadflax	High	Grub	Imazapyr	Glyphosate
Isatis tinctoria	dyer's woad	Medium	Grub	Glyphosate	-
Bromus madritensis ssp. *rubens*	foxtail brome	Medium	Grub/Mow	Glyphosate	Aminopyralid
Foeniculum vulgare	fennel	Medium	Chop	Glyphosate	-
Xanthium spinosum	spiny clotbur	Medium	Grub	Will not use herbicide	
Rubus americanus	Himalayan blackberry	Medium	Mow/Grub	Triclopyr	Glyphosate
Bromus tectorum	cheatgrass	Medium	Mow	Glyphosate	Aminopyralid
Centaurea solstitialis	yellow star thistle	Medium	Mow	Clopyralid	Aminopyralid
Dipascus fullonum	teasel	Medium	Mow	Imazapyr	Aminopyralid
Elymus caput-med	medusahead	Medium	Mow	Glyphosate	Aminopyralid
Phalaris arundinacea	reed canarygrass	Medium	Mow	Glyphosate	Imazapyr
Conium maculatum	poison hemlock	Medium	Mow/Grub	Clopyralid	Glyphosate
Brassica nigra	Black mustard	Low	Mow/Grub	Will not use herbicide	
Bromus diandrus	ripgut grass	Low	Mow/Grub	Glyphosate	Aminopyralid
Cirsium arvense	Canada thistle	Low	Mow/Grub	Clopyralid	Aminopyralid
Festuca arundinacea	tall fescue	Low	Mow/Grub	Glyphosate	Imazapyr
Hypericum perforatum	St. John's wort	Low	Mow/Grub	Aminopyralid	Glyphosate
Lepidium draba	hoary cress	Low	Mow/Grub	Glyphosate	-

SCIENTIFIC NAME	COMMON NAME	PRIORITY	PRIMARY	SECONDARY	ADDITIONAL
Cirsium vulgare	bull thistle	Low	Mow/Grub	Will not use herbicide	
	WATCH LIST				
Centaurea virgata ssp. *squarrosa*	Squarrose knapweed	High	Mow/Grub	Clopyralid	Aminopyralid
Euphorbia esula (or Euphorbia virgata)	Leafy spurge	High	Mow/Grub	Glyphosate	-
Onopordum tauricum	Taurian thistle	High	Mow/Grub	Aminopyralid	Glyphosate
Carduus acanthoides	Spiny plumeless thistle	High	Mow/Grub	Will not use herbicide	
Carduus nutans	Nodding plumeless thistle	High	Mow/Grub	Will not use herbicide	
Centaurea stoebe ssp. *micranthos*	Spotted knapweed	High	Mow/Grub	Clopyralid	Aminopyralid
Cytisus scoparius	Scotch broom	High	Mow/Grub	Will not use herbicide	
Lepidium latifolium	Perennial pepperweed	High	Mow/Grub	Glyphosate	Imazapyr
Lythrum salicaria	Purple loosestrife	High	Mow/Grub	Triclopyr	-
Fallopia japonica	Japanese knotweed	High	Mow/Grub	Imazapyr	Glyphosate
Sonchus arvensis	Perennial sow thistle	High	Mow/Grub	Glyphosate	-
Tamarix parviflora	Tamarisk	High	Mow/Grub	Imazapyr	Triclopyr
Anchusa officinalis	Alkanet	Medium	Mow/Grub	TBD	-
Cirsium ochrocentrum	Beaumont thistle	Medium	Mow/Grub	Will not use herbicide	
Convolvulus arvensis	Field bindweed	Medium	Mow/Grub	Glyphosate	Imazapyr
Crupina vulgaris	Bearded creeper	Medium	Mow/Grub	Will not use herbicide	
Halogeton glomeratus	Halogeton	Medium	Mow/Grub	Will not use herbicide	
Linaria vulgaris	Butter and eggs	Medium	Mow/Grub	Imazapyr	Glyphosate
Salvia aethiopis	Mediterranean sage	Medium	Mow/Grub	Glyphosate	Aminopyralid
Tribulus terrestris	Puncture vine	Medium	Mow/Grub	Imazapyr	Glyphosate
Aegilops cylindrica	Jointed goatgrass	Low	Mow/Grub	Will not use herbicide	

SCIENTIFIC NAME	COMMON NAME	PRIORITY	PRIMARY	SECONDARY	ADDITIONAL
Avena barbata	Slim oat	Low	Mow/Grub	Will not use herbicide	
Hirschfeldia incana	Mustard	Low	Mow/Grub	Will not use herbicide	
Hordeum murinum	Foxtail barley	Low	Mow/Grub	Will not use herbicide	
Leucanthemum vulgare	Oxe eye daisy	Low	Mow/Grub	Will not use herbicide	
Marrubium vulgare	White horehound	Low	Mow/Grub	Will not use herbicide	
Mentha pulegium	Pennyroyal	Low	Mow/Grub	Will not use herbicide	
Persicaria wallichii	Himalayan knotweed	Low	Mow/Grub	Will not use herbicide	

IEV treatment will require a multi-year approach to ensure that containment or eradication goals are achieved. Treatment will begin during pre-drawdown site preparation activities, will continue through drawdown, and will extend into the monitoring period. Although total eradication or prevention of IEV in the reservoirs is not possible, the goal will be to minimize IEV presence during the crucial native plant establishment phase, thereby providing desirable native vegetation a competitive advantage for several years.

The strategies for controlling IEV will differ for each revegetation period. Prior to dam removal, restoration staff will work at the watershed scale to eradicate and contain established populations to limit the opportunity for propagules to disperse into the dewatered reservoirs (Von Holle and Simberloff, 2005). The highest priority sites for IEV control will be the future access points and staging areas. The Renewal Corporation will establish a 50- to 100-foot buffer around all future staging areas. This buffer will be eradicated of all IEV species and will be maintained IEV-free during the lifespan of these temporary access sites. During drawdown, work at the watershed scale will continue, but the priority will shift to evaluating and eradicating pioneering populations of IEV in the newly exposed Reservoir Areas. Eradicating pioneering populations within the Reservoir Areas will be the highest priority during and after drawdown (Moody and Mack, 1988). Preventing inadvertent introductions of IEV can be achieved by focusing management on roads and access points to the Reservoir Areas. New trails and roads established in the dewatered Reservoir Areas will be major pathways for moving invasive plants (seeds and roots). Therefore, we will maintain a 50-foot buffer free of IEV around access trails and roads during and after drawdown.

After drawdown, the Renewal Corporation will work to prevent introductions of IEV by initiating an Early Detection and Rapid Response (EDRR) program in the Reservoir Areas. Wildlife will disperse seed long distances from the unmanaged areas into fenced and unfenced exposed Reservoir Areas by tracking seed on their hooves and paws. The EDRR program will be designed to eradicate IEV populations originating from seed tracked into the area. EDRR elements include the following:

1. Crews will be trained to identify IEV species in their seedling forms.

2. Reservoir Areas will be thoroughly surveyed annually on the ground using Geographic Information System (GIS) portable units.
3. Patterns of infestations will be assessed to inform adaptive management.
4. Seed sources outside of the Limits of Work may need additional control efforts before plants are flowering and/or seeds are mature based on infestation patterns.
5. Populations will be removed mechanically while seedlings are small.
6. All staff will be educated and trained, including dam removal contractors, fisheries biologists, etc.
7. A public awareness campaign will be implemented using educational flyers highlighting priority IEV species.
8. Disposal units (i.e., garbage cans) for mechanically removed IEV will be well labeled and placed at all staging areas to facilitate and encourage removal by all Lower Klamath Project staff.

The Renewal Corporation will remove IEV in accordance with federal, state, and local laws.

The Renewal Corporation will employ the following BMPs to limit the spread of invasive species to the extent practicable during removal efforts (see Appendix C for a complete list of BMPs):

1. Maintain 50-foot-wide buffer free of IEV species around access roads and trails.
2. Thoroughly clean clothing and gear following site visits.
3. Check clothing and gear for soil, seeds, and plant materials.
4. Inspect and clean equipment upon entering and exiting the Limits of Work.
5. Inspect and clean vehicles upon entering and exiting the Limits of Work.
6. Train staff, including contractors, on weed identification and methods to avoid the unintentional spread of invasive plants.
7. Manage vegetation using methods that reduce the spread of invasive species and encourage desirable vegetation.

The Renewal Corporation will closely monitor movement of people and equipment conducting restoration in an effort to ensure that human activities do not introduce IEV seed. IEV cleaning stations at each staging area will include vehicle washing and boot cleaning facilities. While fencing can prevent seed from entering the High Priority Tributary Work Areas from cattle movements, the Renewal Corporation does expect wildlife capable of jumping over fencing to move seed into the High Priority Tributary Work Areas.

5.4 J.C. Boyle Site-Specific Restoration

This section describes restoration activities that are unique to J.C. Boyle Reservoir. It expands upon the activities described in Section 5.2, Adaptive Design and Implementation. Spencer Creek is the only High Priority Tributary at J.C. Boyle Reservoir. Figure 5-7 provides an overview map of the Reservoir Area and identifies the High Priority Tributary Work Area for Spencer Creek. The map also indicates the probable post-removal location of the Klamath River and water inundation limits for the anticipated 2-year and 100-year flood events.

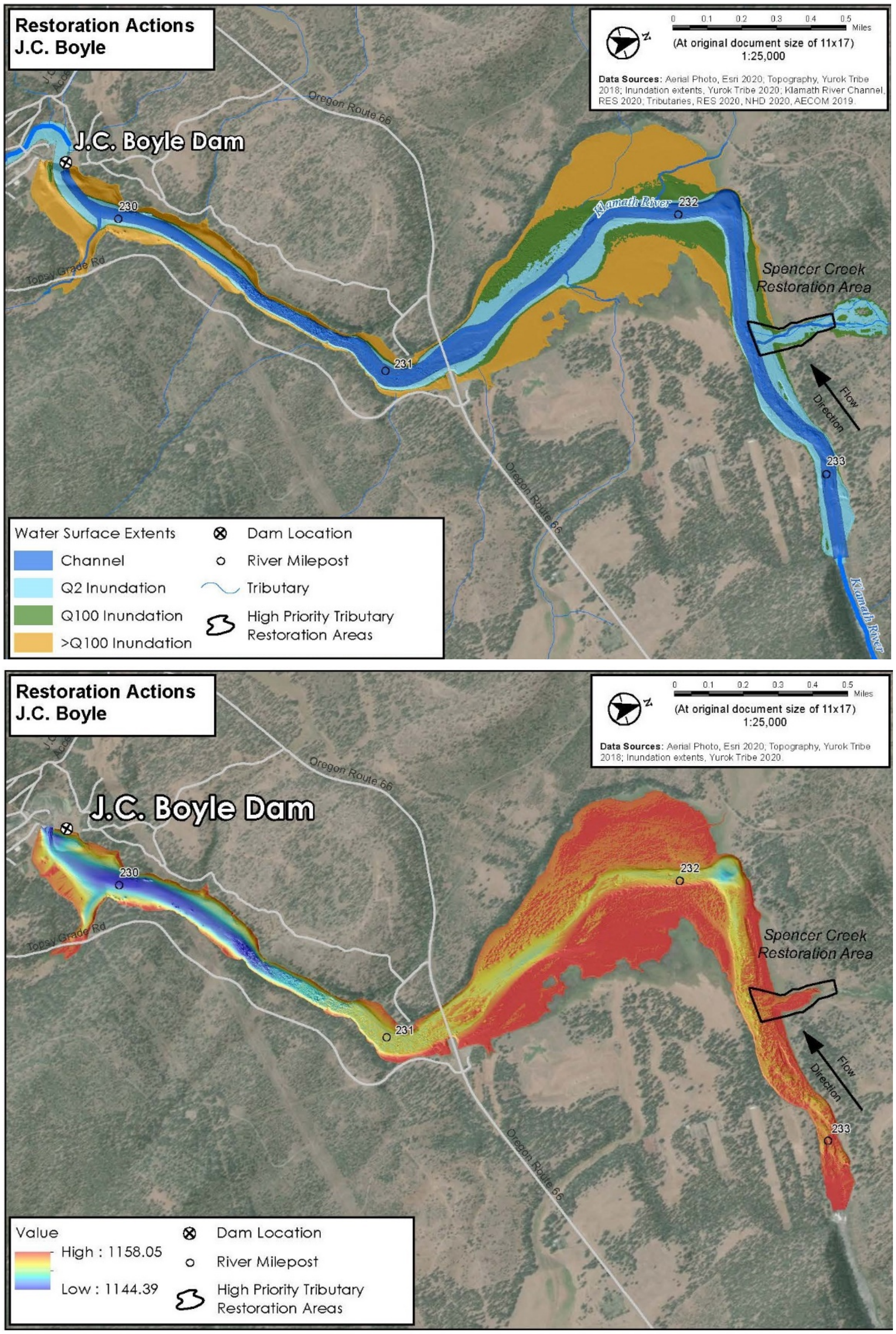


Figure 5-7. Maps of Estimated Klamath River Centerline, Tributaries, and Locations of Potential Restoration Actions in J.C. Boyle

J.C. Boyle Reservoir Area topography with flood inundation extents for the 2-year (Q2) and 100-year (Q100) floods are shown for context (Yurok Tribe 2020 estimation).

5.4.1 Assisted Sediment Evacuation

The Renewal Corporation does not propose assisted sediment evacuation activities at the J.C. Boyle Facility.

5.4.2 Major Tributaries

5.4.2.1 Spencer Creek

The Renewal Corporation will limit restoration of Spencer Creek to minor profile adjustment at or near its confluence with the Klamath River. Since sediment composition at the confluence is expected to be coarser than other locations throughout the Spencer Creek restoration reach, it is plausible that mechanical means of sediment removal may be necessary during a low-flow year. During normal water years, sediment might be self-evacuated by flow in Spencer Creek. Design considerations for Spencer Creek will focus on removing observed fish passage barriers and providing a restored channel with stable planform, profile, and cross-section while promoting frequent floodplain access commensurate with the geomorphometry of the portion of Spencer Creek just upstream of the Reservoir Area. Revegetation of the Spencer Creek area is expected to include both riparian planting and upland planting (see Figure 5-6, Reservoir Planting Zones).

5.4.3 Selective Grading

The Renewal Corporation does not expect to perform selective grading in the vicinity of Spencer Creek given the shallow residual sediment depths within the J.C. Boyle reservoir.

5.4.4 Tributary Connectivity, Bank Stability, and Channel Fringe Complexity

The Renewal Corporation will undertake restoration construction at Spencer Creek, a High Priority Tributary. The proposed measures will be designed to maintain tributary connectivity and bank stability and incorporate channel fringe complexity and habitat enhancement into the design approach as described in Section 5.2, Adaptive Design and Implementation. The Renewal Corporation will utilize grading within the High Priority Tributary Work Area to remove remaining reservoir sediments and create channels with connected floodplains to spread flow and reduce in-channel stream power. In addition, grading will be used to minimize incision potential post-restoration construction to maintain volitional passage (see Section 5.2.3, Tributary Connectivity).

5.4.5 Wetlands, Floodplains, and Off-Channel Habitat Features

The Renewal Corporation will undertake restoration actions at Spencer Creek to reconnect floodplains, improve off-channel habitat features, and enhance wetlands (see Section 5.2.5, Wetlands, Floodplains, and Off-Channel Habitat Features). Pre-dam photographs and adjacent topography suggest that there is the potential for the conversion of floodplains to wetlands over time through the continued influence of riverine hydrology and the establishment of wetland plants. The Renewal Corporation will install floodplain roughness features (see Section 5.2.5, Wetlands, Floodplains, and Off-Channel Habitat Features) along Spencer Creek within the High Priority Tributary Work Area.

5.4.6 Revegetation and Initial IEV Management

Surveys of J.C. Boyle in 2009 and 2010 (KRRC, 2018) found that J.C. Boyle reservoir banks were largely dominated by conifers, especially along the river-right side of the main reservoir (wider portion north of the Highway 66) while the river-left bank was populated with large stands of wetland species such as reed canarygrass and rushes (note, river-right and river-left designations are in reference to looking in the downstream direction) (USBR, 2011a). Confluences of tributaries in the Upper Reach primarily supported grassy meadows with many wetland constituents. Between the Highway 66 Bridge and the dam, the reservoir narrows considerably and is surrounded by steep, rocky banks largely populated with woody shrubs. Grasses were common in the understory of conifer stands, intermixed with woody shrubs and wetland species. A few willows and sages were observed, primary in the southern section. Large stands of reed canarygrass were observed along the eastern shoreline of the northern section of the reservoir (USBR, 2011a). Based on field observations by the Yurok Tribe and other biologists, the five (5) most common IEV species are, in order of total acreage, cheatgrass, teasel, reed canarygrass, medusa head, and yellow star thistle. The Renewal Corporation will manage these IEV species primarily through mowing and secondarily through herbicides (see Section 5.3.2.2, IEV Control Methods, Including Targeted Use of Exclusion Fencing), while employing other monitoring and adaptive management, as described in Section 6.0, Monitoring and Adaptive Management.

The Renewal Corporation will use the following revegetation methods for J.C. Boyle:

- Seeding approximately 197 acres with upland pioneer mix
- Seeding approximately 52 acres with riparian pioneer mix
- Seeding approximately 197 acres with upland diversity mix
- Seeding approximately 52 acres with riparian/wetland diversity mix
- Wetland herbaceous plugs (approximately 4,460 individuals)
- Salvaged wetland transplant (approximately 0.52 acre)
- Bare root herbaceous (approximately 4,460 individuals)
- Cuttings (approximately 5,270 individuals)
- Pole cuttings (approximately 120 individuals)
- Bare root shrubs (approximately 29,029 individuals)
- Bare root trees (approximately 4,700 individuals)

Seeding and planting at J.C. Boyle will follow methods outlined in Section 5.3.2, Planting Strategies and Species, and Section 5.3.3, Invasive Exotic Vegetation (IEV) Management. The Renewal Corporation will select a suitable planting palette for the J.C. Boyle site, including native species that occur in the vicinity. The proposed palette is provided in Tables 5-16 and 5-17. Additional species may be considered based on reference site data collected.

Table 5-4. Riparian Species Suitable for Planting in the J.C. Boyle Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Calocedrus decurrens	Tree	Bare root
Cornus sericea	Shrub	Bare root, live-stake
Fraxinus latifolia	Tree	Bare root
Philadelphus lewisii	Shrub	Bare root
Pinus ponderosa	Tree	Bare root
Prunus virginiana	Shrub	Bare root
Pseudotsuga menziesii	Tree	Bare root
Rosa woodsia	Shrub	Bare root
Salix exigua	Shrub	Live-stake
Salix lasiolepis	Shrub	Live-stake
Salix lucida ssp. lasiandra	Shrub	Live-stake
Spiraea douglasii	Shrub	Bare root, live-stake
Symphoricarpos albus	Shrub	Bare root, live-stake

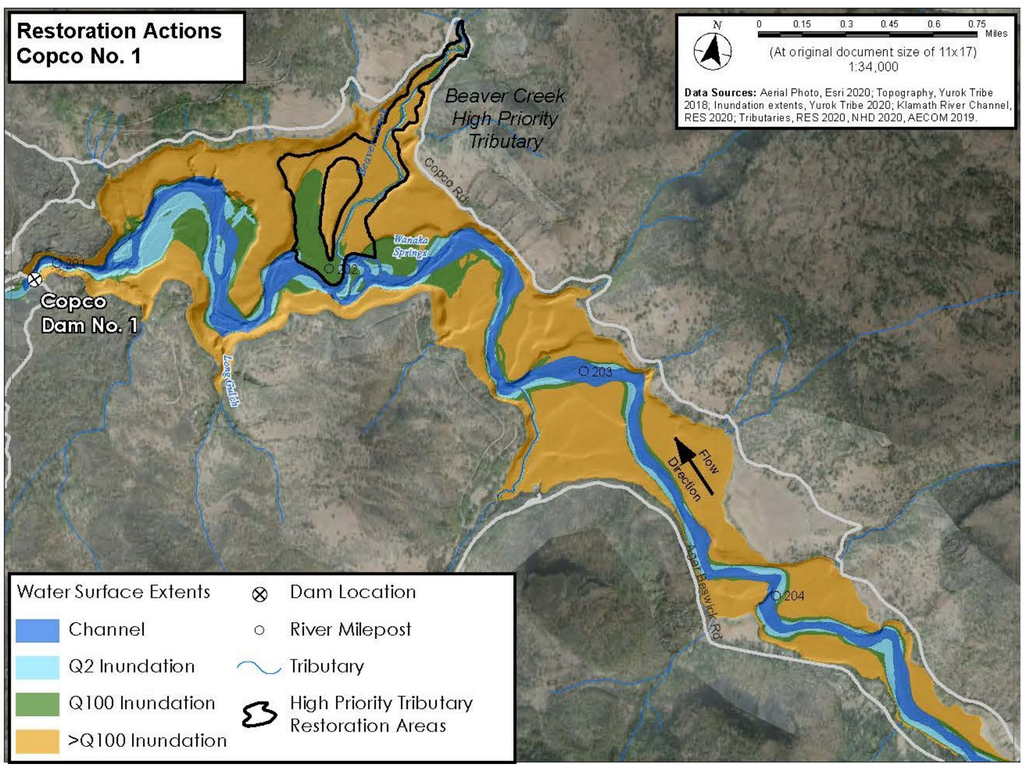
Table 5-5. Upland Native Woody Species Suitable for Planting in the J.C. Boyle Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Abies concolor	Tree	Bare root
Amelanchier alnifolia	Shrub	Bare root
Artemisia tridentata	Shrub	Bare root
Berberis aquifolium	Shrub	Bare root
Calocedrus decurrens	Tree	Bare root
Cercocarpus betuloides	Shrub	Bare root
Ericameria bloomeri	Shrub	Bare root, Seed
Ericameria nauseosa	Shrub	Bare root, Seed
Philadelphus lewisii	Shrub	Bare root
Pinus contorta var latifolia	Tree	Bare root
Pinus lambertiana	Tree	Bare root
Pinus ponderosa	Tree	Bare root
Prunus subcordata	Shrub	Bare root
Prunus virginiana	Shrub	Bare root
Pseudotsuga menziesii	Tree	Bare root
Purshia tridentata	Shrub	Bare root
Ribes cerneum	Shrub	Bare root
Ribes velutinum	Shrub	Bare root
Sambucus nigra	Shrub	Bare root
Symphoricarpos albus	Shrub	Bare root

The Renewal Corporation does not expect to employ irrigation at J.C. Boyle. Approximately 2,300 linear feet of fencing will be installed, primarily at the High Priority Tributary Work Area for Spencer Creek (Figure 5-7).

5.5 Copco No. 1 Reservoir Site-Specific Restoration

This section describes restoration activities that are unique to Copco No. 1 Reservoir. It expands upon the activities described in Section 5.2, Adaptive Design and Implementation. Beaver Creek is the only High Priority Tributary at Copco No. 1 Reservoir. Most of the length of Long Prairie Creek is unreachable for anadromous fish due to a steep reach that is likely to be a natural passage barrier at RM 0.2. Based on this analysis, Long Prairie Creek is not considered a High Priority Tributary. Figure 5-8 provides an overview map of the Reservoir Area and identifies the High Priority Tributary Work Area for Beaver Creek. The map also indicates the probable post-removal location of the Klamath River and water inundation limits for the anticipated 2-year and 100-year flood events.



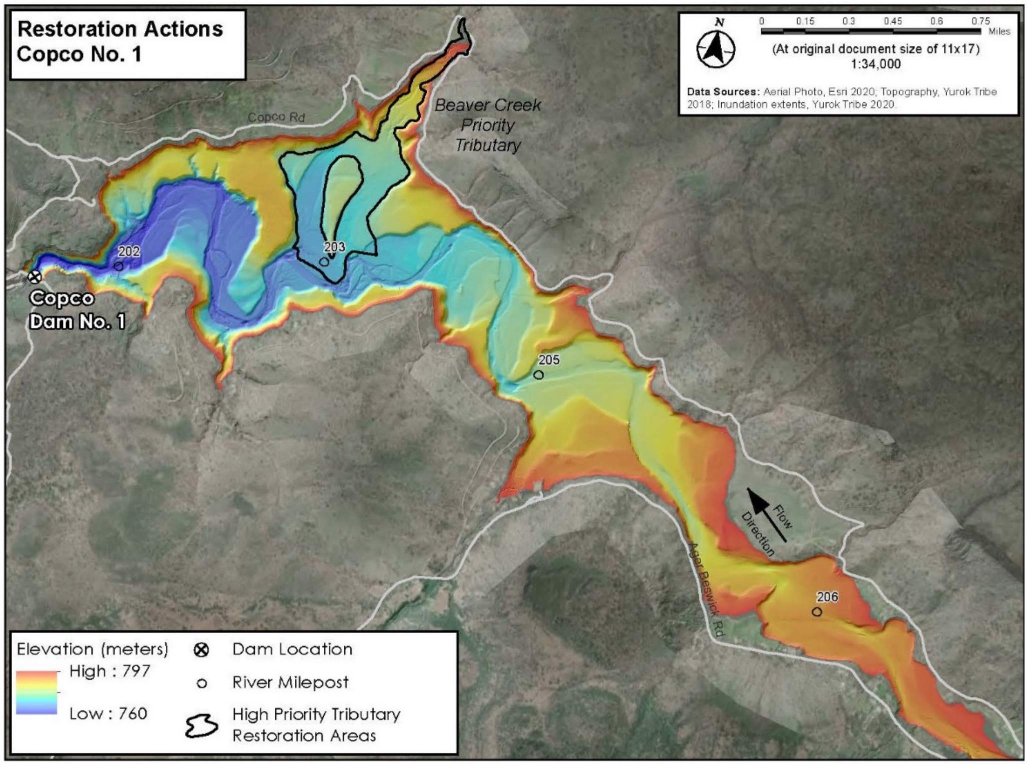


Figure 5-8. Maps (upper and lower) of Estimated Klamath River Centerline, Tributaries, and Locations of Potential Restoration Actions in Copco No. 1 Reservoir

Copco No. 1 Reservoir Area topography with flood inundation extents for the 2-year (Q2) and 100-year (Q100) floods are shown for context (Yurok Tribe 2020 estimation).

5.5.1 Assisted Sediment Evacuation

Following drawdown, the Renewal Corporation will perform assisted sediment evacuation activities to promote removal of stored reservoir sediments within the Copco No. 1 Reservoir Area as described in Section 5.2.1, Assisted Sediment Evacuation. In addition to tributary sites within the Reservoir Area, side channel complexes throughout the Reservoir Area will be the focus of assisted sediment evacuation (Figure 5-8).

5.5.2 Major Tributaries

5.5.2.1 Beaver Creek

As with other primary tributaries, the restoration work on Beaver Creek will focus on preserving fish passage from the confluence with the Klamath River upstream beyond the limits of the Reservoir Area. Historical topographic information suggests that the alignment of Beaver Creek has occupied one (1) segment or the other of an abandoned Klamath River meander. The Renewal Corporation will allow geomorphic processes to create the preferred pathway for Beaver Creek. Once the preferred pathway is created, the Renewal Corporation will monitor the pathway and intervene to preserve fish passage as needed. The lower extents of Beaver Creek may comprise single or multiple threads.

5.5.3 Selective Grading

The High Priority Tributary Work Area at Beaver Creek will likely require additional selective grading to promote natural process-based restoration and recovery of the tributary.

5.5.4 Tributary Connectivity, Bank Stability, and Channel Fringe Complexity

The Renewal Corporation will undertake restoration construction at Beaver Creek, a High Priority Tributary, that maintains tributary connectivity and bank stability and incorporates channel fringe complexity and habitat enhancement into the design approach as described in Section 5.2, Adaptive Design and Implementation. Grading will be used at the High Priority Tributary Work Area to remove remaining reservoir sediments and create channels with connected floodplains to spread flow and reduce in-channel stream power. In addition, grading will be used to minimize incision potential post-restoration construction to maintain volitional passage (see Section 5.2.3, Tributary Connectivity).

5.5.5 Wetlands, Floodplains, and Off-channel Habitat Features

In addition to the restoration work at Beaver Creek, the Renewal Corporation will undertake restoration actions at the spring-fed floodplain/wetland complex in the Copco No. 1 Reservoir Area to reconnect floodplains, improve off-channel habitat features and enhance wetlands (see Section 5.2.5, Wetlands, Floodplains, and Off-Channel Habitat Features).

5.5.6 Revegetation and Initial IEV Management

Based on vegetation surveys of Copco No.1 and Copco No.2 Reservoirs in 2009 and 2010 (KRRC, 2018), the Renewal Corporation found that oak trees and scrub were very common amongst the shoreline vegetation, occurring more sparsely on drier, southern-facing slopes. Ponderosa pine was scattered fairly uniformly. Other native shrubs and grasses were often observed in the oak and conifer understory as well as in the dry uplands and erosion areas and mixed in with stands of wetland vegetation. Eroded banks were sparsely vegetated, primarily with weedy forbs. Willows and conifers were scattered along the shoreline, somewhat clustered in certain areas at the northwest end of the reservoir at tributary confluence, along with reed canarygrass and rushes to a lesser extent. Yellow star thistle was observed growing on the northern side of the reservoir, appearing to be a near monoculture on dry slopes (USBR, 2011a). Based on field observations by the Yurok Tribe and other biologists, the warmer, drier conditions and surrounding land uses at the Copco No. 1 Reservoir support a different proportion of IEV species than J.C. Boyle, with the top five (5) being, in order of acreage, yellow star thistle, medusa head, Himalayan blackberry, reed canarygrass, and teasel. The Renewal Corporation proposes to manage these species in accordance with methods outlined in Section 5.3.3.2 (IEV Control Methods, Including Targeted Use of Exclusion Fencing), while employing monitoring and adaptive management as described in Chapter 6.0 (Monitoring and Adaptive Management).

Proposed revegetation methods for Copco include the following:

- Seeding approximately 702 acres with upland pioneer mix

- Seeding approximately 143 acres with riparian pioneer mix
- Seeding approximately 702 acres with upland diversity mix
- Seeding approximately 143 acres with riparian/wetland diversity mix
- Wetland herbaceous plugs (approximately 3,560 individuals)
- Salvaged wetland transplant (approximately 0.04 acre)
- Bare root herbaceous (approximately 5,890 individuals)
- Cuttings (approximately 8,600 individuals)
- Pole cuttings (approximately 1,770 individuals)
- Bare root shrubs (approximately 99,300 individuals)
- Bare root trees (approximately 5,780 individuals)

The seeding and planting at Copco No.1 Reservoir will follow methods outlined in Section 5.3.2, Planting Strategies and Species, and Section 5.3.3, Invasive Exotic Vegetation (IEV) Management. The planting palette at Copco No.1 Reservoir will be selected to be suitable for the site, including native species that occur in the vicinity. The proposed palette is provided in Tables 5-18 and 5-19. Additional species may be considered based on reference site data collected.

Table 5-18. Riparian Woody Species Suitable to Planting in the Copco Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Acer macrophyllum	Tree	Bare root
Alnus rhombifolia	Tree	Bare root
Amelanchier utahensis	Shrub	Bare root
Berberis aquifolium	Shrub	Bare root
Cornus glabrata	Shrub	Bare root, live-stake
Cornus sericea	Shrub	Bare root, live-stake
Fraxinus latifolia	Tree	Bare root
Holodiscus discolor	Shrub	Bare root
Lonicera interrupta	Shrub	Bare root
Philadelphus lewisii	Shrub	Bare root
Physocarpus capitatus	Shrub	Bare root
Pinus ponderosa	Tree	Bare root
Prunus virginiana	Shrub	Bare root
Pseudotsuga menziesii	Tree	Bare root
Rosa woodsia	Shrub	Bare root
Salix exigua	Shrub	Live-stake
Salix lasiolepis	Shrub	Live-stake
Salix lucida ssp. lasiandra	Shrub	Live-stake

SPECIES	TYPE	PROPAGULE
Spiraea douglasii	Shrub	Bare root, live-stake
Symphoricarpos albus	Shrub	Bare root, live-stake

Table 5-19. Upland Native Woody Species Suitable for Planting in the Copco Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Amelanchier utahensis	Shrub	Bare root
Berberis aquifolium	Shrub	Bare root
Calocedrus decurrens	Tree	Bare root
Ceanothus cuneatus	Shrub	Bare root
Ceanothus integerrimus	Shrub	Bare root
Cercocarpus betuloides	Shrub	Bare root
Ericameria nauseosa	Shrub	Bare root, Seed
Holodiscus discolor	Shrub	Bare root
Lonicera interrupta	Shrub	Bare root
Philadelphus lewisii	Shrub	Bare root
Pinus ponderosa	Tree	Bare root
Prunus subcordata	Shrub	Bare root
Pseudotsuga menziesii	Tree	Bare root
Purshia tridentata	Shrub	Bare root
Quercus garryana	Tree	Container, acorn
Quercus kelloggii	Tree	Container, acorn
Rhus aromatica	Shrub	Bare root
Ribes velutinum	Shrub	Bare root
Sambucus nigra	Shrub	Bare root

The Renewal Corporation anticipates mid-channel islands within the Klamath River in the Copco No. 1 reach based on review of historical mapping and high-resolution bathymetric data. The Renewal Corporation will seed these islands with either the upland or wetland/riparian mix depending upon elevation above channel. Additional planting may be added where access is possible.

The Renewal Corporation may utilize irrigation to promote success of newly established riparian areas, covering approximately 98 acres. Approximately 14,600 linear feet of fencing will be installed.

5.6 Iron Gate Site-Specific Restoration Activities

This section describes restoration activities that are unique to Iron Gate Reservoir. It expands upon the activities described in Section 5.2 (Adaptive Design and Implementation). Jenny Creek, Camp Creek and Scotch Creek are the only High Priority Tributaries at Iron Gate Reservoir. Figure 5-9 provides an overview map of the Reservoir Area and identifies the High Priority Tributary Work Areas for Jenny Creek, Camp Creek and Scotch Creek. The map also indicates the probable post-removal location of the Klamath River and water inundation limits for the anticipated 2-year and 100-year flood events.

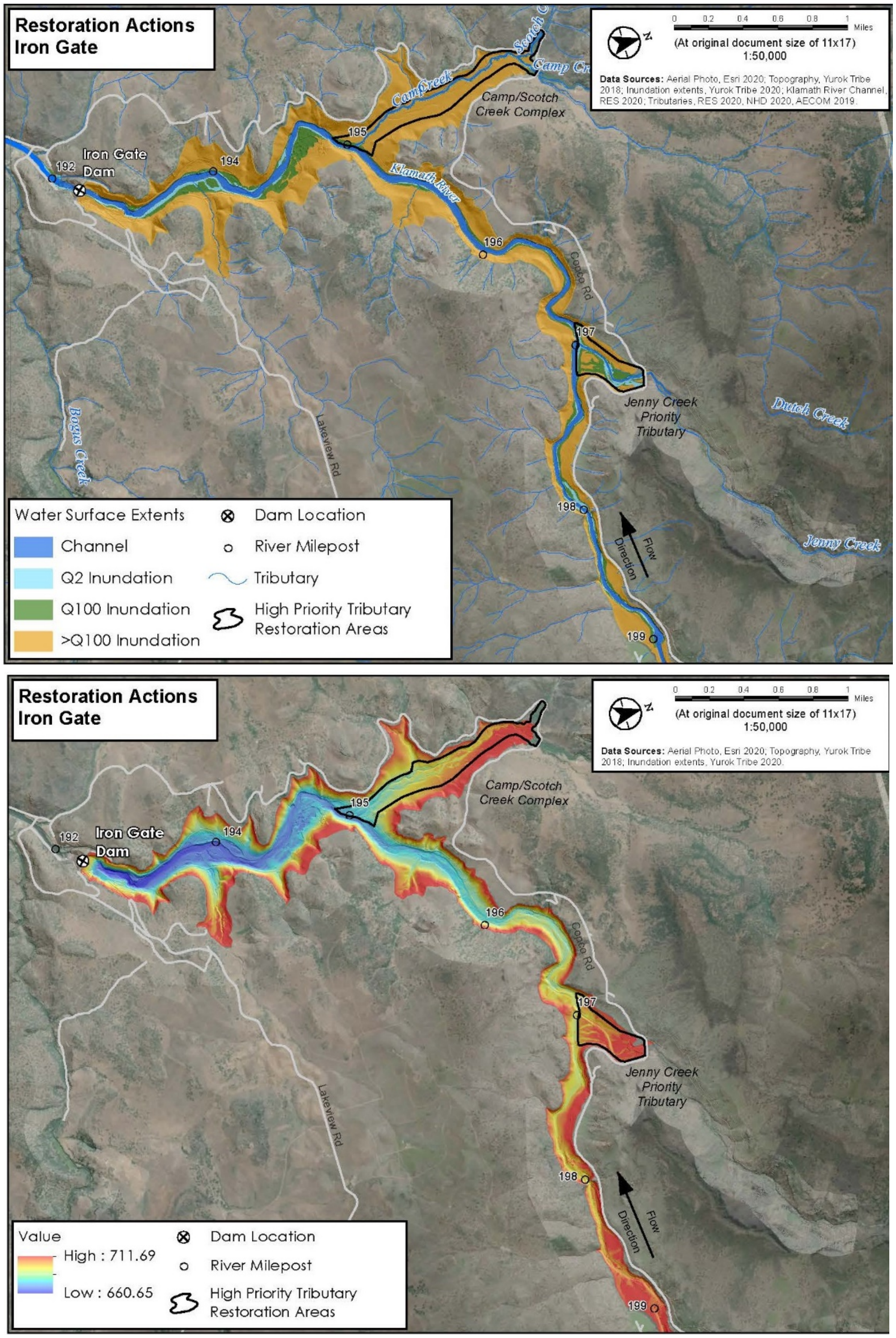


Figure 5-9. Maps (upper and lower) of Estimated Klamath River Centerline, Tributaries, and Locations of Potential Restoration Actions in Iron Gate Reservoir

Iron Gate Reservoir Area topography with flood inundation extents for the 2-year (Q2) and 100-year (Q100) floods are shown for context (Yurok Tribe 2020 estimation)

5.6.1 Assisted Sediment Evacuation

Following drawdown, the Renewal Corporation will perform assisted sediment evacuation activities to promote removal of stored reservoir sediments within the Iron Gate Reservoir Area as described in Section 5.2.1, Assisted Sediment Evacuation.

5.6.2 Major Tributaries

5.6.2.1 Jenny Creek

Restoration activities for Jenny Creek are expected to address volitional fish passage through deltaic sediments at the upstream limits of the Reservoir Area as well as passage continuity through reservoir sediments at the confluence with the Klamath River. While adaptive design strategy will follow the procedure described in Section 6.2 (Geomorphology Management), there is a high likelihood that physical manipulation of sediments will be required in the upstream section of the reach.

5.6.2.2 Camp Creek

Restoration for Camp Creek will be similar to the approach outlined for Jenny Creek. Sediments that do not evacuate during drawdown will be physically removed during Year 3 as part of the restoration activities. In Camp Creek, there is a potential for multi-thread channel at the downstream end based on bathymetric mapping. The channels will be monitored as described in Section 6.2 (Geomorphology Management), and restoration activities will focus on establishing and maintaining volitional fish passage as described in Chapter 3.0 (Restoration Goals and Objectives).

5.6.2.3 Scotch Creek

Restoration for Scotch Creek will be similar to the approach outlined for Jenny Creek. Sediments that do not evacuate during drawdown will be physically removed during Year 3 as part of the restoration activities. At Scotch Creek it will be important to promote confluence stability with Camp Creek. The channels will be monitored as described in Section 6.2 (Geomorphology Management), and restoration activities will focus on establishing and maintaining volitional fish passage as described in Chapter 3.0 (Restoration Goals and Objectives).

5.6.2.4 Long Gulch

Though not listed as a High Priority Tributary, Long Gulch will require targeted work following dam removal. Several culverts believed to have been placed during original dam construction are submerged in Long Gulch. Restoration activities along Long Gulch will consist of the removal of these culverts, reconstruction of the banks to approximate adjacent contours, and revegetation.

5.6.3 Selective Grading

The High Priority Tributary Work Areas at Camp, Scotch and Jenny Creeks will likely require additional selective grading to remove sediments making up the deltas.

5.6.4 Tributary Connectivity, Bank Stability, and Channel Fringe Complexity

The Renewal Corporation will undertake restoration construction at Jenny Creek, Camp Creek and Scotch Creek (all of which are High Priority Tributaries) that maintains tributary connectivity and bank stability and incorporates channel fringe complexity and habitat enhancement into the design approach as described in Section 5.2, Adaptive Design and Implementation. The Renewal Corporation will use grading at the High Priority Tributary Work Areas to remove remaining reservoir sediments and create channels with connected floodplains to spread flow and reduce in-channel stream power and to minimize incision potential post-restoration construction to maintain volitional passage (see Section 5.2.3, Tributary Connectivity).

5.6.5 Wetlands, Floodplains, and Off-channel Habitat Features

In addition to the restoration construction at Jenny Creek, Camp Creek and Scotch Creek, the Renewal Corporation will undertake restoration actions at Wanaka Springs in the Iron Gate Reservoir Area to reconnect floodplains, improve off-channel habitat features, and enhance wetlands (see Section 5.2.5, Wetlands, Floodplains, and Off-Channel Habitat Features).

5.6.6 Revegetation and Initial IEV Management

Based on surveys of Iron Gate in 2009 and 2010 (KRRC, 2018), the Renewal Corporation found native grasses and shrubs commonly occurring along the shoreline area of Iron Gate, in some of the wetland areas and as understory species in the wooded communities (USBR, 2011a). Willows and rushes were observed to dominate the river-right side of the reservoir at tributary inlets, with willows to a lesser degree at the main river inlet on the river-left (looking downstream) side. Upland slopes were dominated by yellow star thistle and smaller populations of grasses and sagebrush. Oaks were observed on the shadier northern facing slopes, occasionally scattered closer to the shoreline. Conifers and sagebrush did not appear to be associated with specific slope or moisture regimes. Yellow star thistle at Iron Gate was primary observed on southern-facing slopes with rushes being common at the wet perimeter of slopes, primarily at stream confluences (USBR, 2011a). The Iron Gate area is the restoration area most affected by yellow star thistle with nearly one hundred acres impacted. Based on field observations by the Yurok Tribe and other biologists, the top five (5) IEV species at Iron Gate include: yellow star thistle, medusa head, teasel, cheatgrass, and Himalayan blackberry. These areas will likely be best managed by mowing (in accordance with methods outlined in Section 5.3.3.2 (IEV Control Methods, Including Targeted Use of Exclusion Fencing), with monitoring and adaptive management employed, as described in Chapter 6.0, Monitoring and Adaptive Management.

The Renewal Corporation will use the following revegetation methods for Iron Gate:

- Seeding approximately 715 acres with pioneer upland mix

- Seeding approximately 122 acres with riparian pioneer mix
- Seeding approximately 715 acres with upland diversity mix
- Seeding approximately 122 acres with riparian/wetland diversity mix
- Wetland herbaceous plugs (approximately 3,560 individuals)
- Salvaged wetland transplant (approximately 0.08 acre)
- Bare root herbaceous (approximately 3,560 individuals)
- Cuttings (approximately 11,880 individuals)
- Pole cuttings (approximately 410 individuals)
- Bare root shrubs (approximately 99,859 individuals)
- Bare root trees (approximately 5,740 individuals)

In seeding and planting at Iron Gate Reservoir, the Renewal Corporation will follow methods outlined in Section 5.3.2, Planting Strategies and Species.

The Renewal Corporation will select a suitable planting palette for Iron Gate Reservoir, including native species that occur in the vicinity. The proposed palette is provided in Tables 5-20 and 5-21. Additional species may be considered based on reference site data collected.

Table 5-20. Riparian Woody Species Suitable to Planting in the Iron Gate Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Acer macrophyllum	Tree	Bare root
Alnus rhombifolia	Tree	Bare root
Amelanchier utahensis	Shrub	Bare root
Berberis aquifolium	Shrub	Bare root
Cornus glabrata	Shrub	Bare root, live-stake
Cornus sericea	Shrub	Bare root, live-stake
Fraxinus latifolia	Tree	Bare root
Philadelphus lewisii	Shrub	Bare root
Physocarpus capitatus	Shrub	Bare root
Pinus ponderosa	Tree	Bare root
Prunus virginiana	Shrub	Bare root
Pseudotsuga menziesii	Tree	Bare root
Rosa woodsia	Shrub	Bare root
Salix exigua	Shrub	Live-stake
Salix lasiolepis	Shrub	Live-stake
Salix lucida ssp. lasiandra	Shrub	Live-stake
Spiraea douglasii	Shrub	Bare root, live-stake
Symphoricarpos albus	Shrub	Bare root, live-stake

Table 5-21. Upland Native Woody Species Suitable for Planting in the Iron Gate Reservoir Post-Dam Removal

SPECIES	TYPE	PROPAGULE
Amelanchier utahensis	Shrub	Bare root
Berberis aquifolium	Shrub	Bare root
Ceanothus cuneatus	Shrub	Bare root
Ceanothus integerrimus	Shrub	Bare root
Cercocarpus betuloides	Shrub	Bare root
Ericameria nauseosa	Shrub	Bare root, Seed
Lonicera interrupta	Shrub	Bare root
Philadelphus lewisii	Shrub	Bare root
Pinus ponderosa	Tree	Bare root
Prunus subcordata	Shrub	Bare root
Purshia tridentata	Shrub	Bare root
Quercus garryana	Tree	Container, acorn
Quercus kelloggii	Tree	Container, acorn
Rhus aromatica	Shrub	Bare root
Ribes velutinum	Shrub	Bare root
Rosa woodsia	Shrub	Bare root
Sambucus nigra	Shrub	Bare root

The Renewal Corporation may use irrigation to promote success of newly established riparian areas, covering approximately 109 acres of restored habitat. Approximately 14,600 linear feet of fencing will be installed in the vicinity of the High Priority Tributary Work Areas for Jenny Creek, Camp Creek and Scotch Creek (Figure 5-9).

5.7 Schedule of Construction and Restoration

This section summarizes the schedule for construction and restoration activities based on current design reports. Tables 5-22 through 5-25 summarize the work activity schedules for each of the reservoirs and related work areas based on the Renewal Corporation's current implementation schedule. In general, the pre-drawdown dam removal activities are expected to occur in mid- to late Year 1 with drawdown commencing in Year 2. The remainder of the deconstruction activities are expected to occur in Year 2, with volitional fish passage targeted for November of Year 2. Active restoration (i.e., tributary connectivity, recontouring, creating habitat complexity and flood plain connection, and revegetation) is expected to begin in Year 2 as the reservoir levels lower and continue to the end of Year 3.

While the dam and infrastructure removal schedules are based on the current 100 percent design (Kiewit 2020), the restoration and fish passage monitoring schedules are based on the current reservoir restoration 60 percent design (RES 2020). The reservoir restoration design will be updated from 60 to 90 percent and final design after the Reservoir Areas respond and evolve under post-drawdown conditions during Year 2. The Renewal Corporation may adjust the schedule for restoration and monitoring work set forth in Tables 5-22 through 5-25 and elsewhere in the Reservoir Area Management Plan as appropriate in response to changed conditions, subject to regulatory approvals.

Table 5-22. J.C. Boyle Work Activities

DESCRIPTION	EXPECTED START	EXPECTED FINISH
Pre-Drawdown Work	Oct Year 1	Nov Year 1
Drawdown	Jan Year 2	Jan Year 2
Transmission / Distribution Work	Apr Year 2	May Year 2
Power Canal Removal	Apr Year 2	Aug Year 2
Powerhouse and Penstock Removal	Apr Year 2	Sept Year 2
Intake Structure Removal	May Year 2	Oct Year 2
Embankment Removal	May Year 2	Oct Year 2
Embankment Breach	Sept Year 2	Sept Year 2
Volitional Fish Passage	Sept Year 2	Sept Year 2
Restoration	Jan Year 2	Sept Year 3

Table 5-23. Copco No. 1 Work Activities

DESCRIPTION	EXPECTED START	EXPECTED FINISH
Construction Access	May Year 1	Oct Year 1
Pre-Drawdown Work	May Year 1	Nov Year 1
Drawdown	Jan Year 2	June Year 2
Transmission / Distribution Work	Apr Year 2	May Year 2
Dam Removal	Apr Year 2	Oct Year 2
Powerhouse and Penstock Removal	Apr Year 2	May Year 2
Volitional Fish Passage	Oct Year 2	Oct Year 2
Restoration	Jan Year 2	Sep Year 3

Table 5-24. Copco No. 2 Work Activities

DESCRIPTION	EXPECTED START	EXPECTED FINISH
Construction Access	May Year 1	Aug Year 1

DESCRIPTION	EXPECTED START	EXPECTED FINISH
Initial Dam Removal	Jul Year 1	Sep Year 1
Dam Removal	Aug Year 1	Oct Year 1
Transmission / Distribution Work	Jun Year 2	May Year 2
Powerhouse and Penstock Removal	June Year 2	July Year 2
Wood-Stave Penstock Removal	Apr Year 2	May Year 2
Volitional Fish Passage	Oct Year 2	Oct Year 2
Restoration	Jan Year 2	Sep Year 3

Table 5-25. Iron Gate Work Activities

DESCRIPTION	EXPECTED START	EXPECTED FINISH
Construction Access	May Year 1	Aug Year 1
Pre-Drawdown Modifications	Aug Year 1	Nov Year 1
Drawdown	Jan Year 2	June Year 2
Transmission / Distribution Work	Apr Year 2	May Year 2
Powerhouse / Penstock / Fish Facility Removal	June Year 2	Aug Year 2
Embankment Removal	Apr Year 2	Nov Year 2
Embankment Breach	Oct Year 2	Nov Year 2
Volitional Fish Passage	Nov Year 2	Nov Year 2
Restoration	Jan Year 2	Sep Year 3

6.0 Monitoring, Performance Criteria and Adaptive Management

Chapter 6.0 describes the qualitative and quantitative metrics that will be monitored by the Renewal Corporation, the performance criteria for the restoration goals described in the Reservoir Area Management Plan, and the Renewal Corporation's approach to adaptive management. The Renewal Corporation will implement the measures set forth in this Chapter 6.0 as part of the Proposed Action.

Ecosystems, including riverine ecosystems, are inherently complex and will evolve and change during restoration efforts. During restoration, the Renewal Corporation will monitor both geomorphological and vegetative criteria, as described in more detail below. The purpose of this monitoring is to determine if the restored Reservoir Areas and High Priority Tributaries are on a trajectory to achieve the performance criteria. While the restored Reservoir Areas will continue to evolve after restoration is complete, the performance criteria represent the point in time where natural processes are driving continued Reservoir Area ecological recovery without intervention by the Renewal Corporation.

If the monitoring results indicate that the restored Reservoir Areas are not on a trajectory to timely achieve the performance criteria, the Renewal Corporation will undertake adaptive management. This process of design, implementation monitoring and adaptive management is illustrated in the CDFW adaptive management diagram in Figure 6-1.

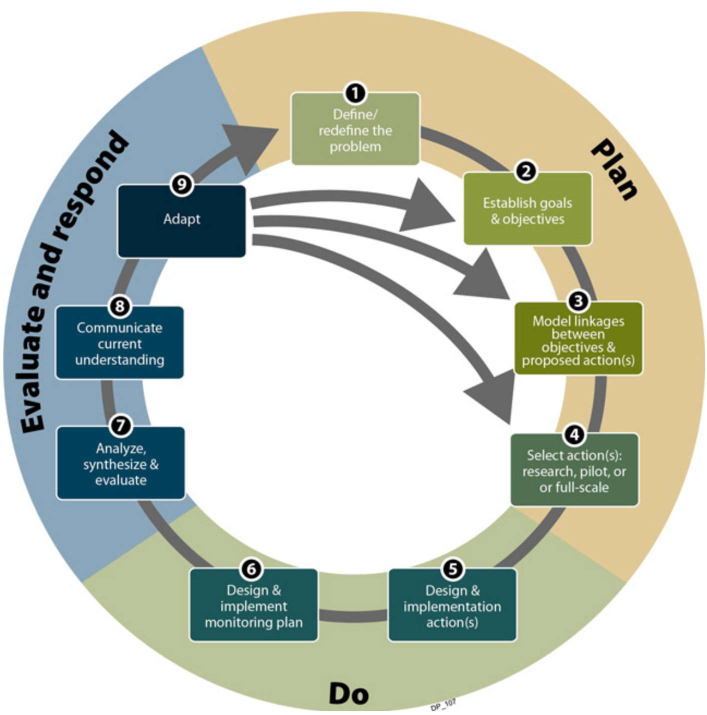


Figure 6-1. CDFW Adaptive Management Diagram

Source: CDFW, 2012 as cited in KRRC, 2018).

The adaptive management provisions described below provide a framework for making decisions and taking actions based on monitoring results, as generally described in Table 6-1.

Table 6-1. Monitoring Decision Pathway

CONCLUSION CATEGORIES	DECISIONS AND ACTIONS
Conclusion 1 – Proposed Action is meeting performance criteria based on qualitative and/or quantitative monitoring metrics.	• Evaluate the monitoring program (continue, reduce or eliminate some metrics)
Conclusion 2 – Proposed Action is trending towards meeting the performance criteria based on qualitative and/or quantitative monitoring metrics.	• Evaluate the monitoring program (continue, reduce or eliminate some metrics)
Conclusion 3 – Proposed Action is not meeting (or trending away from meeting) the performance criteria based on qualitative and/or quantitative monitoring metrics.	• Evaluate causes through additional, focused quantitative monitoring • Assess the monitoring program, in consultation with the HRG, to evaluate whether appropriate data are being collected to assess and evaluate causes • Evaluate, in consultation with the HRG, whether performance criteria metrics are measuring the intended outcomes and propose new criteria as necessary • Evaluate, in consultation with the HRG, whether additional adaptive management measures are necessary • Develop a plan to address problems • Implement the plan and monitor results

Section 6.1 describes the interplay between monitoring, performance criteria and adaptive management, and it provides an overview of the Renewal Corporation's approach to monitoring and a summary of the applicable performance criteria. Section 6.2 provides detail on monitoring, performance criteria and adaptive management with respect to the key tributaries and portions of the mainstem Klamath River covered by this Reservoir Area Management Plan (Geomorphology Management). Section 6.3 provides detail on monitoring, performance criteria and adaptive management with respect to the revegetation of the Reservoir Areas and the associated restoration (Revegetation Management).

6.1 Adaptive Management Overview

Geomorphological monitoring metrics and performance criteria are primarily associated with Reservoir Area restoration and sediment stabilization, High Priority Tributary restoration and fish passage, Klamath River fish passage, and dam footprint fish passage. Revegetation monitoring metrics and performance criteria are primarily associated with riparian and upland revegetation, IEV management, and Reservoir Area restoration and sediment stabilization.

Table 6-2 provides an overview of the restoration goals described in this Reservoir Area Management Plan, what restoration measures will be used, and the key monitoring metrics used to determine if the restoration goals have been achieved.

Restoration measures vary depending on the restoration goals. For instance, restoration of the five (5) High Priority Tributaries involves assisted sediment evacuation, run-of-the-river operation, and restoration plan implementation followed by monitoring and adaptive management. Timely achievement of this restoration goal requires construction interventions at the High Priority Tributary Work Areas to advance the stream evolutionary clock to achieve favorable site conditions following initial establishment without having to wait for natural processes to stabilize the High Priority Tributary Work Areas over a longer period of time. That said, natural processes will impact the Reservoir Areas immediately following drawdown, during restoration, and also following the achievement of the performance criteria. The restoration design, including adaptive management, depends on these natural processes to achieve the performance criteria (referred to as natural process or a natural process-based approach). The dam footprint rehabilitation, on the other hand, will rely primarily on construction interventions to create threshold channels that are designed to support fish passage and be stable over the range of flows anticipated at the site. These sites should, therefore, involve a lower level of ongoing intervention and adaptive management.

Table 6-2. Restoration Approach and Key Monitoring Metrics

RESERVOIR AREA MANAGEMENT PLAN GOAL	RESTORATION APPROACH	MONITORING METRICS
Riparian and Upland Revegetation	Revegetation	Native Vegetation
IEV Management	Removal/control of IEV	% IEV Vegetation
Reservoir Areas Sediment Stabilization	Revegetation Residual reservoir sediment stabilization	Sediment Stability

RESERVOIR AREA MANAGEMENT PLAN GOAL	RESTORATION APPROACH	MONITORING METRICS
High Priority Tributary Restoration and Fish Passage	Revegetation Restoration construction to reconnect floodplains, spread energy and achieve favorable conditions, including fish passage, followed by monitoring and adaptive management to achieve favorable post-dam removal outcomes based on natural process-based restoration and stream evolution	Fish Passage Bank Stability Floodplain Connectivity Floodplain Roughness Channel Fringe Complexity
Klamath River Fish Passage	Revegetation Natural process based restoration supported by other restoration measures	Fish Passage
Dam Footprint Fish Passage	Threshold channel construction following drawdown	Fish Passage

6.1.1 Monitoring and Management Approach

Monitoring associated with restoration of the Reservoir Areas is designed to measure progress toward achieving the performance criteria described in this Reservoir Area Management Plan, inform potential adaptive management needs, and provide insight into river and Reservoir Area conditions. Certain physical site characteristics have been identified by the Renewal Corporation as appropriate monitoring metrics to produce data compatible with standard protocols derived from previously developed dam removal monitoring and adaptive management plans, as described in the following sections.

6.1.2 Baseline Monitoring Conditions and Data Gathering

Following drawdown and aerial exposure of the Reservoir Areas, the Renewal Corporation will use a combination of survey techniques, including photo points, ground based survey, and aerial topographic data capture, to establish baseline conditions as well as finalize restoration designs. Table 6-3 sets forth the initial measures that will be taken over the two year restoration period (i.e., Year 2 and Year 3) with respect to each Reservoir Area Management Plan goal in order to establish baseline monitoring conditions for monitoring and adaptive management.

Table 6-3. Initial Establishment Measures to Set Baseline Monitoring Conditions

RESERVOIR AREA MANAGEMENT PLAN GOALS	INITIAL ESTABLISHMENT ACTIONS			
	YEAR 2		YEAR 3	
Riparian and Upland Revegetation[1]	DD[2]	Native Seed, Bare Root, Live Stakes, Plugs	Run of the River[3]	Native Seed, Bare Root, Live Stakes, Plugs
IEV Management[4]	DD	Mechanical and Chemical Treatment and Fencing	Run of the River	Mechanical and Chemical Treatment and Fencing
Reservoir Areas Sediment Stabilization	DD	Native Seed, Bare Root, Live Stakes, Plugs	Run of the River	Native Seed, Bare Root, Live Stakes, Plugs
High Priority Tributary Restoration and Fish Passage	DD	Assisted sediment evacuation	Run of the River	Restoration Construction if needed at sites following Geomorphic Assessment
Klamath River Fish Passage	DD	Residual Reservoir Sediment management to maintain volitional fish passage	Run of the River	Residual Reservoir Sediment management to maintain volitional fish passage
Dam Footprint Fish Passage	DD	Dam removal and channel construction	Run of the River	Management to maintain volitional fish passage

Notes:
1. Initial establishment of riparian and upland vegetation will occur during Year 2 and Year 3.
2. DD refers to the drawdown of the Lower Klamath Project reach reservoirs to facilitate dam removal and restoration activities.
3. Run of the River refers to the post-dam removal operation condition of the Hydroelectric Reach unimpeded by dam structures that impound the river and create reservoirs. Run-of-the-river operation is used as a process-based restoration tool to facilitate residual reservoir sediment evacuation and begin the conversion from lotic to lentic and riparian environments.
4. IEV Management activities begin pre-drawdown.

Table 6-4 provides an overview of the data gathering methods for High Priority Tributary restoration design development and monitoring during the drawdown and run-of-the-river time periods. Data gathering is incremental because the Reservoir Areas will remain underwater until the drawdown is completed. The reservoir restoration design will be updated from 60 to 90 percent and final design after the Reservoir Areas respond and evolve under post-drawdown conditions during Year 2. Following drawdown and assisted sediment evacuation at the High Priority Tributary Work Areas, the Renewal Corporation will use aerial data capture methods and ground-based survey to inform design progression. The scale and intensity of construction and/or continuation of passive process-based restoration will be based on post-dam removal site conditions.

Table 6-4. Data Gathering Methods for Design and Monitoring

DATA GATHERING	YEAR 2			YEAR 3	
	DRAWDOWN	DAM REMOVAL	RUN OF THE RIVER/VOLITIONAL FISH PASSAGE		
Design	Aerial Topographic Data Capture to update baseline surface data	Aerial Topographic Data Capture supplemented with ground-based survey for High Priority Tributary Work Areas	Restoration Design Completion where appropriate and/or natural process-based restoration, monitoring and adaptive management	Continued Aerial Topographic Data Capture and ground-based survey to support Design and Construction at High Priority Tributary Work Areas	Continuation of natural process-based Restoration Monitoring and Adaptive Management where indicated
Monitoring	Aerial and Ground-Based Photography to record post-drawdown condition	Establish revegetation monitoring plots for native plant establishment and IEV control. Establish Permanent Ground Photo Points	Aerial and Ground-Based Photography to record post-drawdown condition evolution and revegetation success	Continue data collection at permanent Ground Photo Points	Aerial Topographic Data Capture and monitoring profiles and cross-sections for High Priority Tributary restoration construction As-Builts

The Renewal Corporation will complete additional data gathering following run of the river operation and High Priority Tributary restoration construction completion to confirm the as-built restoration condition and to set the baseline for monitoring and adaptive management. Pre-drawdown topographic data for the Proposed Action is based on the 2018 baseline bathymetry, which is stored at www.opentopography.org. The open topography website is open to the public and will serve as the baseline data hub for topography and bathymetry. Baseline data can be downloaded at https://opentopography.org/news/klamath-river-renewal-project-data-access-through-opentopography and https://doi.org/10.5069/G9DN436N.

6.1.3 Monitoring Timeline

Reservoir Area Management Plan goals, monitoring metrics, monitoring timeline, and performance criteria are summarized in Table 6-5. The monitoring timeline for all monitoring metrics is anticipated to be five (5) years, as described below in Table 6-5. If a performance criteria has not been achieved with respect to a particular reservoir by the end of the applicable 5-year period set forth in Table 6-5, the Renewal Corporation will continue monitoring in that reservoir with respect to the unachieved performance criteria until such time as the performance criteria is met.

Table 6-5. Monitoring Timeline and Performance Criteria Achievement

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRICS	MONITORING TIMELINE[1]	PERFORMANCE CRITERIA[2]
Riparian and Upland Revegetation	Native Vegetation	Two (2) years of implementation period monitoring (Years 2-3) followed by five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
IEV Management	% IEV Vegetation	Two (2) years of implementation period monitoring ((Years 2-3) followed by five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
Reservoir Areas Sediment Stabilization	Sediment Stability	Five (5)-year term (Years 2-7)	(1) After five years of monitoring or (2) end-of-monitoring performance criteria is achieved, whichever is later
High Priority Tributary Restoration and Fish Passage	Fish Passage	Five (5)-year term (Years 2-7)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
	Bank Stability	Five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
	Floodplain Connectivity	Five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
	Floodplain Roughness	Five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRICS	MONITORING TIMELINE[1]	PERFORMANCE CRITERIA[2]
	Channel Fringe Complexity	Five (5)-year term (Years 4-8)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
Klamath River Fish Passage	Fish Passage	Five (5)-year term (Years 2-7)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later
Dam Footprint Fish Passage	Fish Passage	Five (5)-year term (Years 2-7)	(1) After five years of monitoring or (2) performance criteria is achieved, whichever is later

Notes:
1. Monitoring metrics that begin immediately following drawdown (e.g., fish passage and sediment stability) are estimated to begin in July of Year 2 and end in July of Year 7. Fish passage at dam footprints will be evaluated immediately following completion of dam removal and channel construction activities. High Priority Tributary monitoring will be delayed until October of Year 3 to allow for design and construction activities to be completed and will end in October of Year 8. Riparian and upland revegetation establishment will begin as soon as practicable following drawdown for a 2-year period (Years 2-3) with monitoring beginning in Year 4 and ending in Year 8. IEV management will begin pre-drawdown (Year 0 and Year 1) and continue through the dam removal and restoration phase (Years 2-3) followed by a 5-year monitoring period ending in Year 8.
2. If the final year performance criteria has been achieved (Table 6-6) within an individual reservoir at the end of the monitoring timeline set forth in Table 6-5, the Renewal Corporation will notify the applicable regulatory agencies that the performance criteria has been met and request that the Renewal Corporation be permitted to discontinue monitoring with respect to the performance criteria. The Renewal Corporation will provide documentation to the applicable regulatory agencies that demonstrates that the performance criteria has been achieved. Once the applicable regulatory agencies approve the request, the Renewal Corporation will no longer be required to conduct any monitoring with respect to such performance criteria within the applicable reservoir. With respect to IEV Management and Riparian and Upland Revegetation monitoring, achievement of performance criteria will be determined separately for each habitat type within an individual reservoir.

6.1.4 Performance Criteria

As described above, the performance criteria are separated into geomorphic and revegetation performance criteria and are discussed in additional detail in Sections 6.2 and 6.3, respectively. Table 6-6 provides an overview of the performance criteria associated with each Reservoir Area Management Plan goal and monitoring metric. For additional information regarding each performance criteria, see the sections/appendices referenced in the footnotes of Table 6-6.

Table 6-6. Performance Criteria

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRIC	PERFORMANCE CRITERIA
Riparian and Upland Revegetation	Native Vegetation	Species richness, tree and shrub density and vegetation cover[1]
IEV Management	% IEV Vegetation	Non-native relative frequency[2]
Reservoir Areas Sediment Stabilization	Sediment Stability	Residual reservoir sediments exhibit stability as demonstrated by digital terrain model comparisons[3]
High Priority Tributary Restoration and Fish Passage	Fish Passage	Water surface elevation drops caused by discontinuity in residual reservoir sediments do not preclude fish passage[4]
	Bank Stability	Constructed banks of restored High Priority Tributaries are stable and meeting expected conditions[5]
	Floodplain Connectivity	Floodplain connectivity of restored High Priority Tributaries is achieved and meeting expected conditions[5]
	Floodplain Roughness	Revegetation of floodplain surface along with large wood elements and willow baffles are producing roughness and meeting expected conditions[5]
	Channel Fringe Complexity	Channel fringe complexity features (i.e., pools, large wood, overhanging banks) are present and accessible to species, meetings expected conditions[5]
Klamath River Fish Passage	Fish Passage	Water surface elevation drops caused by discontinuity in residual reservoir sediments do not preclude fish passage[4]

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRIC	PERFORMANCE CRITERIA
Dam Footprint Fish Passage	Fish Passage	Threshold channel design is passable to target fish species and conforms to the current 100 percent design (Kiewit 2020)

1. Performance Criteria targets for species richness, tree and shrub density and vegetation cover are set forth in Section 6.3.1.
2. Performance Criteria targets for non-native relative frequency are set forth in Section 6.3.1.4.
3. Performance criteria for sediment stability are described in Section 6.2.8.1.
4. Performance criteria for Klamath River and High Priority Tributary fish passage evaluated using protocols described in Sections 6.2.6 and 6.2.7.
5. Performance criteria for bank stability, floodplain connectivity, floodplain roughness and channel fringe evaluated based on expected conditions as measured using the RGA described in Section 6.2.8 and Appendix G-2.

6.2 Geomorphology Management

Section 6.2 focuses on the proposed geomorphology management of the Reservoir Areas and High Priority Tributaries. Geomorphology refers to the study of landforms, their processes, form, and sediments, and how interactions with erosive forces like water, wind, and ice change landforms. Critically important to the success of the Proposed Action is the role of vegetation in stabilizing sediments, riverbanks, and streambanks, and in adding roughness to floodplain surfaces. Tracking the evolutionary trajectory of the reservoir landscape as the Proposed Action progresses through initial establishment and into monitoring and adaptive management requires a common language to communicate channel evolution as well as qualitative and quantitative monitoring measures.

6.2.1 Geomorphological Communication

The Renewal Corporation has adopted the Stream Evolution Triangle (SET) (Figure 6-2) developed by Castro and Thorne (Castro and Thorne, 2019) as the conceptual model for riverine geomorphology for the Lower Klamath Project. The Castro and Thorne report can be found in Appendix G-1. The SET will be used by the Renewal Corporation to communicate the geomorphic state of areas being restored based on stream evolution by indicating site condition relative to dominant process which include hydrology, geology, and biology. Geomorphic site condition will then be tracked over time during subsequent phases noting trends during monitoring activities to plot stream evolution trajectories over time. If the trend at a site is diverging from desirable outcomes, the Renewal Corporation will consider adaptive measures. This approach is illustrated in Figure 6-3 for the Camp/Scotch Creek Complex, which is a High Priority Tributary.

The Camp/Scotch Creek Complex streams are expected to exhibit a Stage 6 channel form following drawdown with reservoir sediments occupying the pre-dam channel as indicated by the yellow #1 circle in Figure 6-3. Following assisted sediment evacuation and run of the river operation, sediment will be evacuated and the stream is expected to move to a Stage 3 channel with incision as indicated by the yellow #2 circle on Figure 6-3. The yellow #3 circle in Figure 6-3 represents the post-restoration construction trajectory and a positive endpoint for this High Priority Tributary. Following construction, the biological components, namely native vegetation, will not be fully established. The site will therefore be trending towards position #3 but will require successful revegetation. Critical to putting the channel on the path towards Stage 8 is correcting the incision that will be present once reservoir sediments are evacuated. The Renewal Corporation will accomplish this by constructing channels connected to floodplains that are capable of transmitting flow and sediment without further incision. For the Camp/Scotch Creek example, the Renewal Corporation will use monitoring and adaptive management to achieve the relevant performance criteria.

Monitoring use of the SET is demonstrated with a real-world example in Figure 6- where the Wychus Creek Stage 0 restoration is depicted. In the Wychus Creek example, the pre-construction stage was geology dominated with an incised channel, little vegetative interaction, and insufficient hydrology to inundate floodplains and promote channel evolution (Figure 6-4(a)). During construction, the incised channel was filled, large wood was used to spread energy and inhibit a single thread channel from reforming, and the site was revegetated. This construction intervention moved the channel from a geology dominated Stage 2 to a hydrology dominated Stage 6 (Figure 6-4(b)). Rapid revegetation success over the first-year post-construction moved the site towards a biology dominated Stage 0 (Figure 6-4(c)). In cases where the trajectory is not trending as anticipated or desired, a conceptual analysis using the SET, as in the example presented for the Camp /Scotch Creek Complex, will be applied. Based on the SET analysis and an evaluation of the quantitative monitoring measures, the Renewal Corporation will evaluate causes and determine corrective actions.

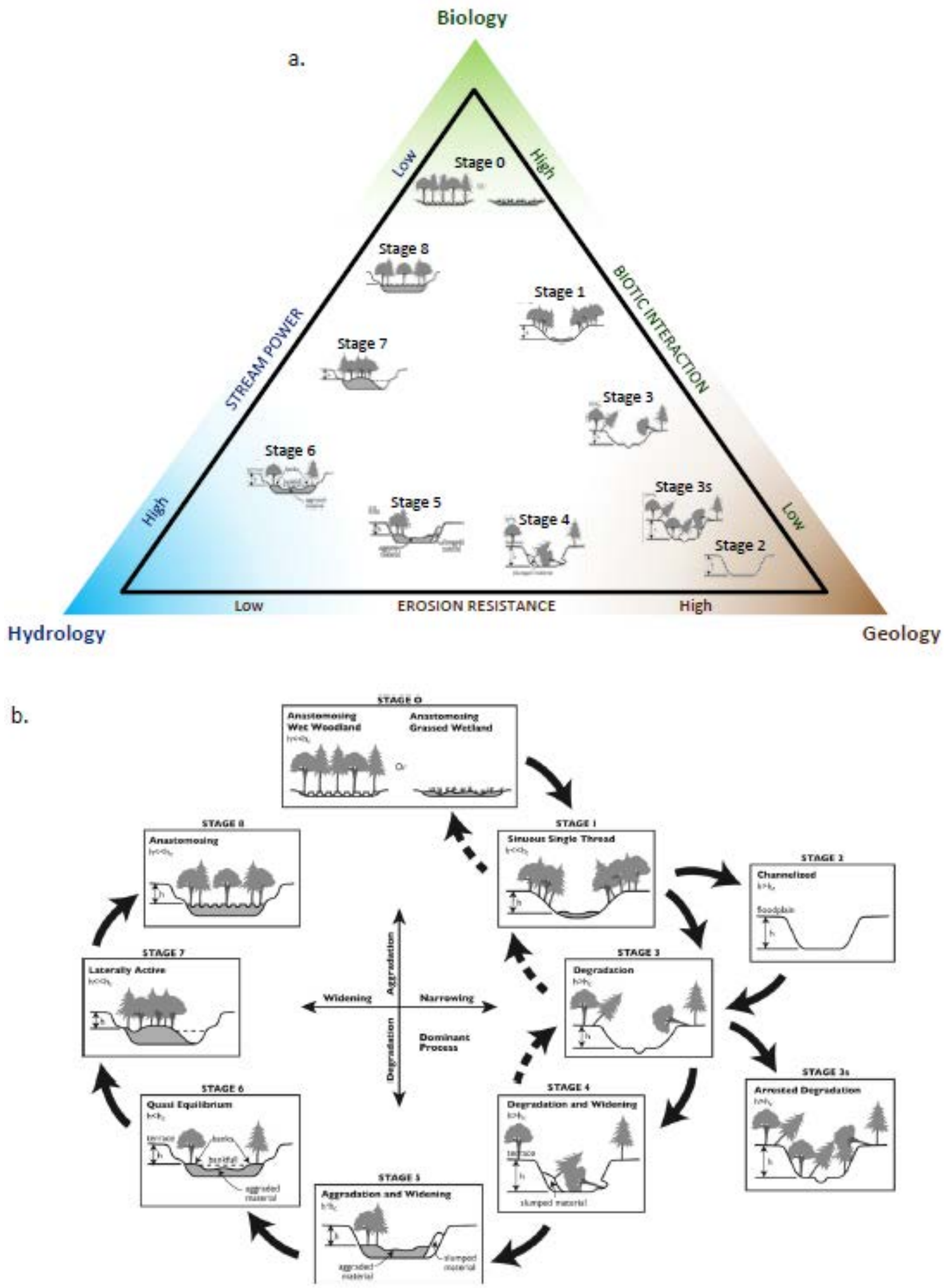


Figure 6-2. Stream Evolution Triangle
(a) SET with Stages of Stream Evolution (Cluer and Thorne, 2013), (b) Stream Evolution Model (Cluer and Thorne, 2014)

Source: Castro and Thorne, 2019

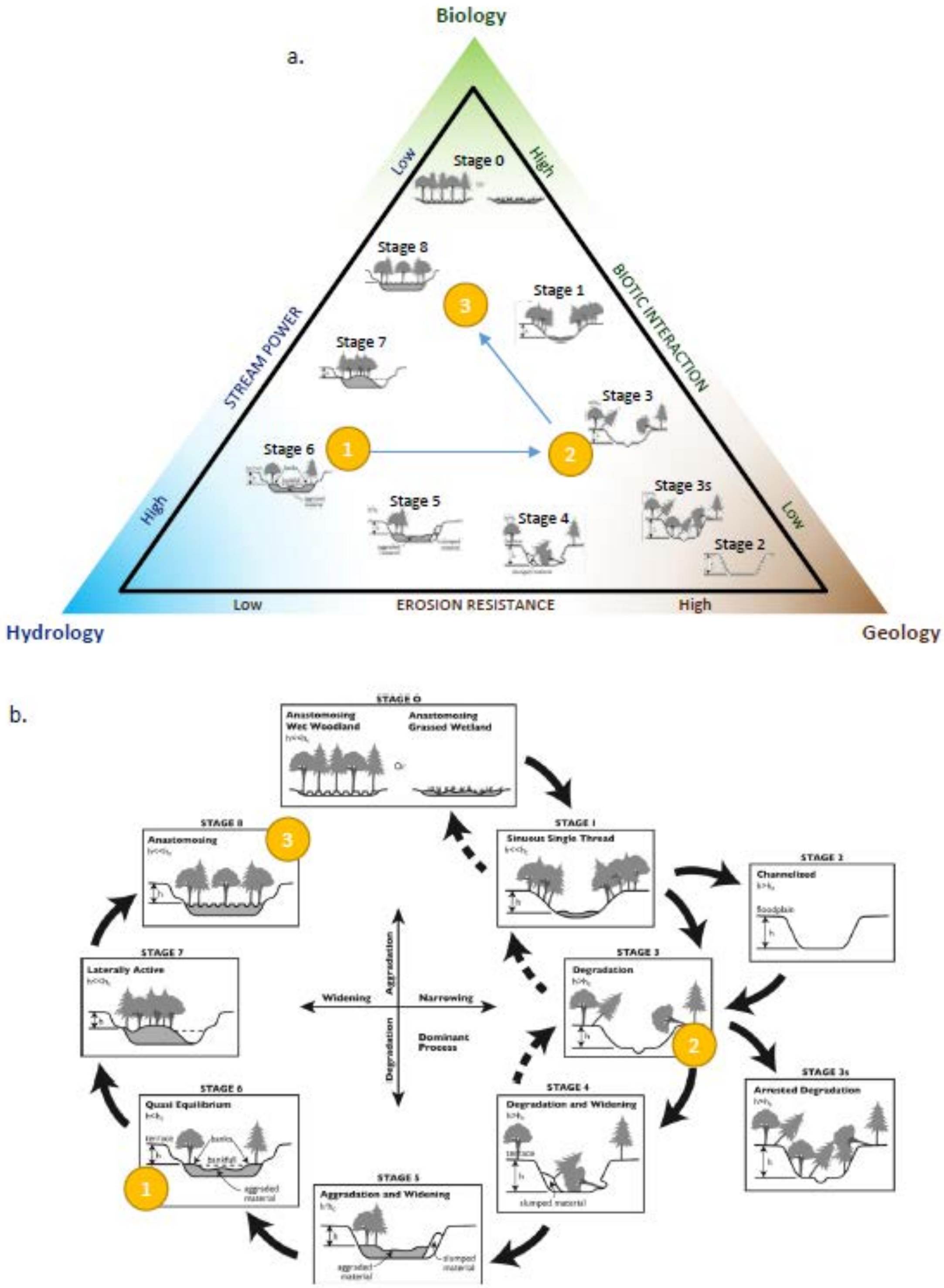


Figure 6-3. Stream Evolution Triangle Example for Camp/ Scotch Creek Complex Starting with Post-Drawdown (1), Following Assisted Sediment Evacuation and Run-of-the-River Operation (2), and Post -Construction Implementation (3)

Source: Castro and Thorne, 2019

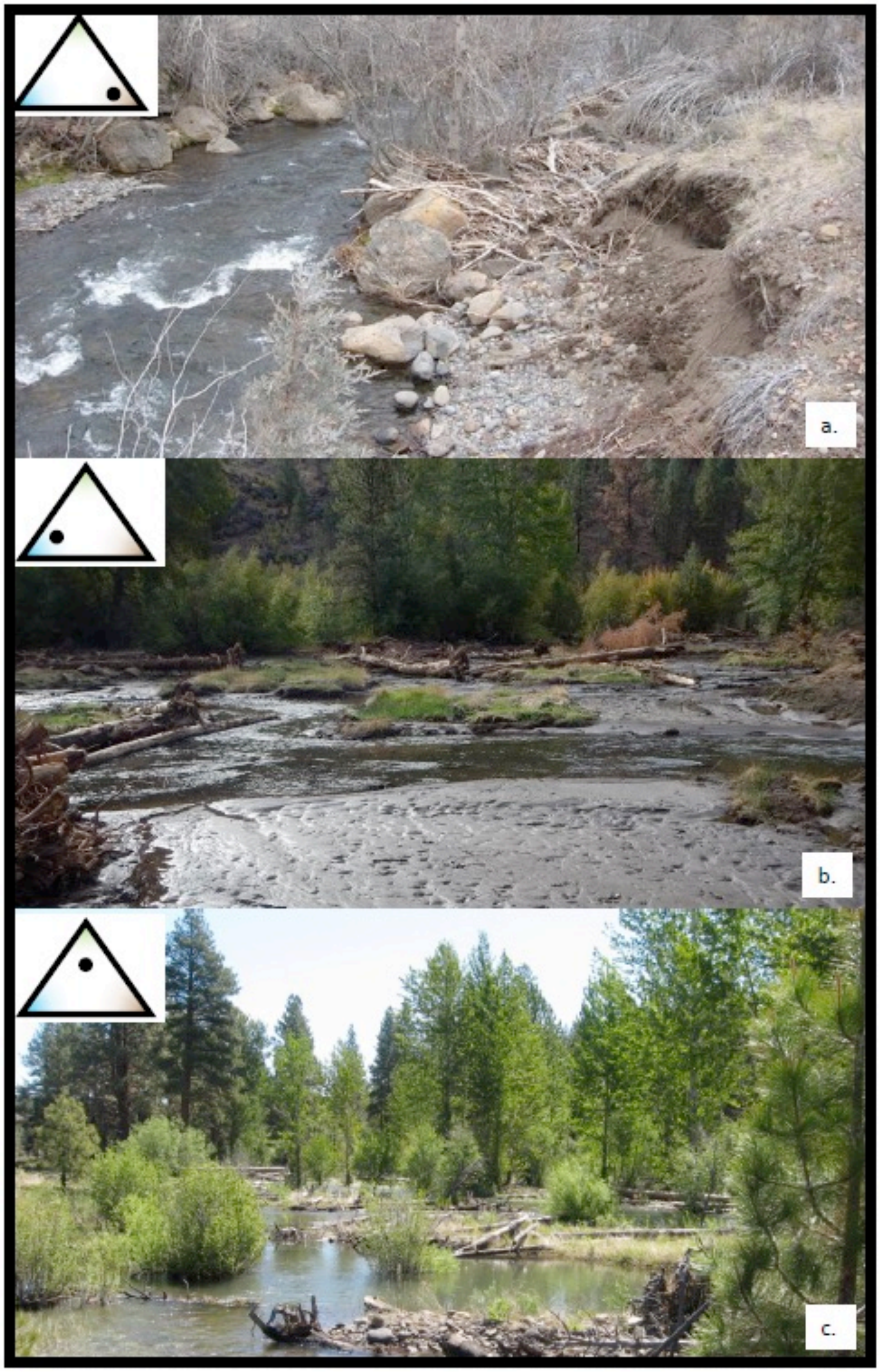


Figure 6-4. Stream Evolution Triangle Example
(a) Representing Pre-Implementation, (b) Immediately Following Restoration Construction, and (c) One (1)-Year Following Construction

Source: Castro and Thorne, 2019

6.2.2 Performance Criteria

Geomorphic performance criteria for monitoring metrics are described for each Reservoir Area Management Plan goal and monitoring metric in Table 6-6. The following Reservoir Area Management Plan goals have geomorphic performance criteria: Reservoir Areas sediment stabilization, High Priority Tributary restoration and fish passage, Klamath River fish passage, and dam footprint fish passage.

6.2.3 Monitoring Methods

Reservoir Area Management Plan geomorphology monitoring methods are focused on fish passage, headcut migration, and residual reservoir sediment stability as described in Sections 6.2.4 through 6.2.8.

6.2.4 Fish Passage Monitoring

Fish passage monitoring for the Proposed Action is described in Section 6.2.5 (Reservoir Area Management Plan Fish Passage Monitoring Area) and Section 6.2.6 (Fish Passage Monitoring Schedule). Fish passage monitoring is also described in the TMCP for the Tributary Mainstem Connectivity Pan Fish Passage Monitoring Area. Figure 6-5 provides a graphical depiction of fish passage monitoring requirements for the Proposed Action. Both the Reservoir Area Management Plan and the TMCP are focused on fish passage impediments caused by anthropogenic debris, as defined in Section 6.2.6.2 (Anthropogenic Debris). In addition, both the Reservoir Area Management Plan and the TMCP rely on the monitoring methods described in Section 6.2.7 (Headcut Migration Monitoring) for potential fish passage barrier identification and evaluation.

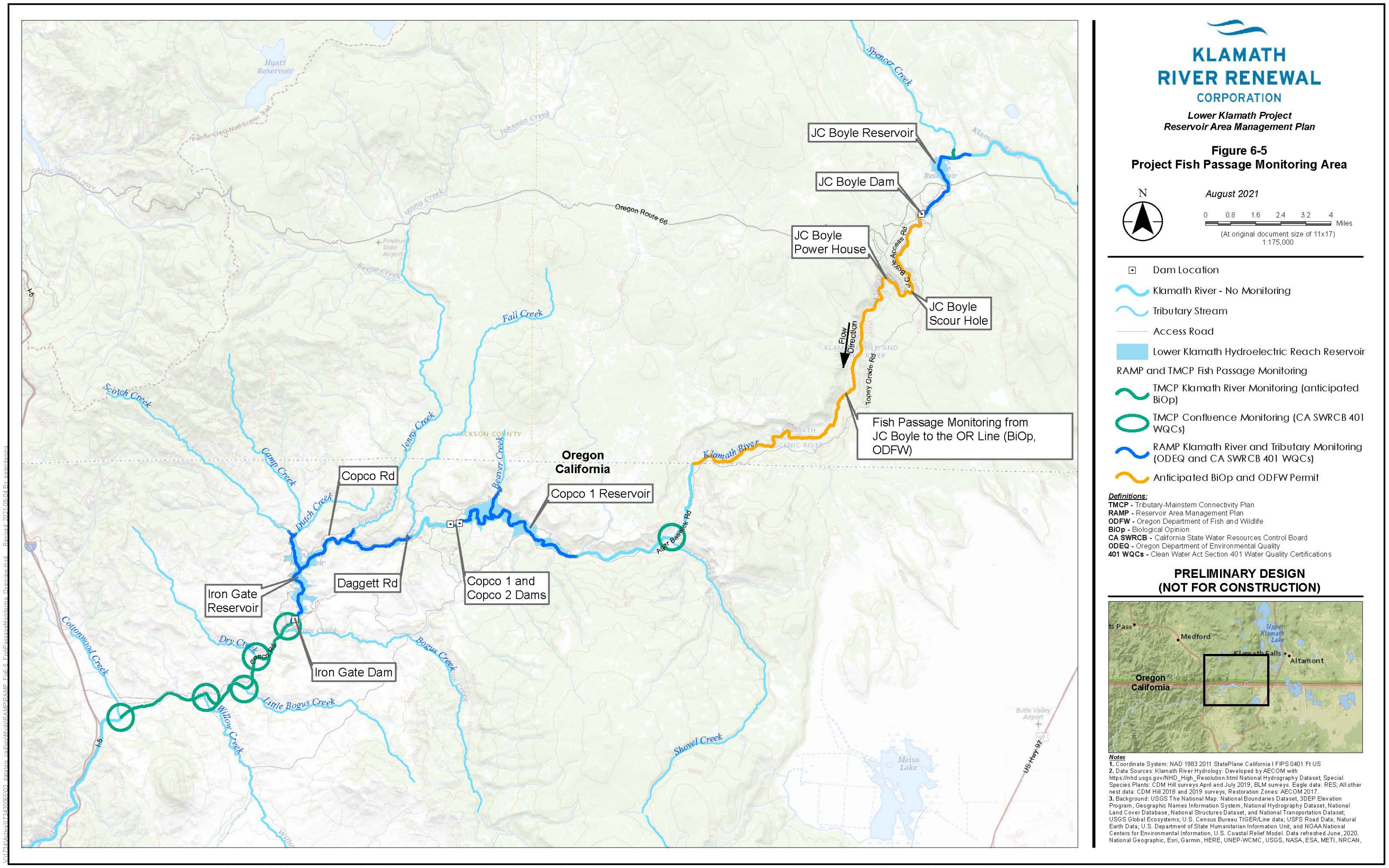


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Figure 6-5. Lower Klamath Project Fish Passage Monitoring Area

6.2.5 Reservoir Area Management Plan Fish Passage Monitoring Area

The Reservoir Area Management Plan Fish Passage Monitoring Area (Figure 6-6) is within the Hydroelectric Reach and includes the J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate Reservoir Areas and dam footprints. Fish passage monitoring under the Reservoir Area Management Plan will be conducted by the Renewal Corporation on the following sections of the mainstem Klamath River:

- In the Hydroelectric Reach (i.e., within the former J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate Reservoir Areas)
- At and immediately downstream of the former dam footprints of J.C. Boyle Dam, Copco No. 1 Dam, and Iron Gate Dam (i.e., restored channel footprint)
- At any temporary and/or permanent road stream crossings associated with dam removal activities within the Reservoir Area Management Plan Fish Passage Monitoring Area

Additionally, the Renewal Corporation will monitor fish-bearing streams (i.e., fish-bearing tributaries) upstream of the former Iron Gate Dam. These tributaries were selected based on having historical or potential habitat for adult salmonids (Huntington, 2006). These include the following:

- The lower reach of Spencer Creek near the confluence of Spencer Creek and the Klamath River
- Approximately 1.1 miles of lower Beaver Creek, from Copco Road to the confluence of Beaver Creek and the Klamath River
- The lower 400 feet of Fall Creek, from Daggett Road to the confluence of Fall Creek and the Klamath River
- Approximately 0.5 mile of lower Jenny Creek, from approximately 500 feet upstream of Copco Road to the confluence of Jenny Creek and the Klamath River
- Approximately 1.25 miles of the lower Camp/Scotch Creek Complex, from Copco Road to the confluence of Camp/Dutch Creek and the Klamath River

Collectively, the areas referenced above are the Reservoir Area Management Plan Fish Passage Monitoring Area (Figure 6-6).

Fish passage monitoring under the TMCP will be conducted from the downstream side of the Iron Gate Dam footprint to Cottonwood Creek (including five (5) tributary confluences) and at the confluence of Shovel Creek and the Klamath River. In addition, the Klamath River downstream from J.C. Boyle Dam to the Oregon State Line will be surveyed in accordance with the anticipated conditions of NMFS's Biological Opinion (Figure 6-5). The Klamath River downstream from the upper end of the former footprint of the J.C. Boyle Reservoir to the Oregon State Line will also be surveyed in accordance with anticipated conditions of ODFW's Fish Passage Permit (Figure 6-5).

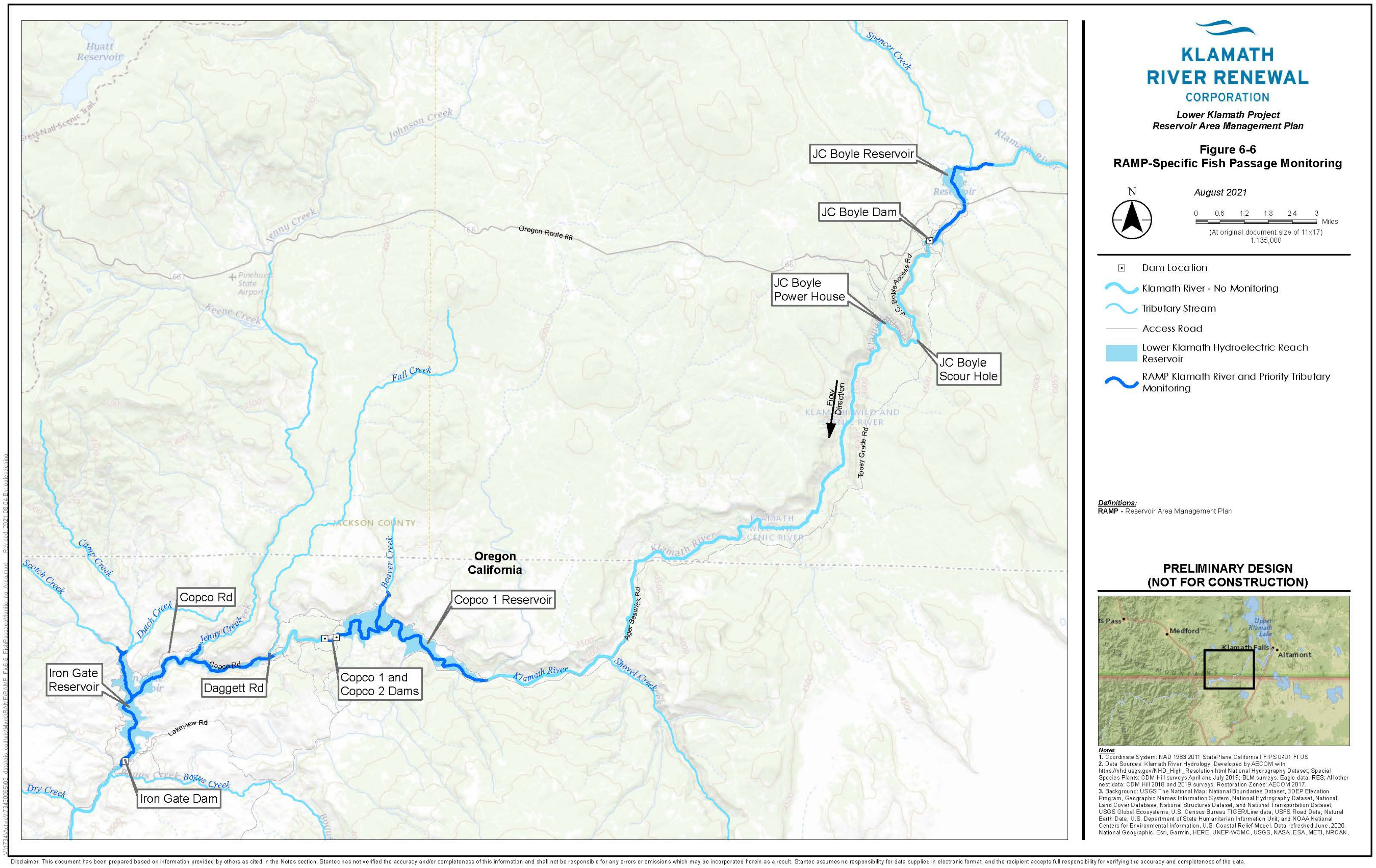


Figure 6-6. Reservoir Area Management Plan-Specific Fish Passage Monitoring Area

6.2.6 Fish Passage Monitoring Schedule

For ease of reference, fish passage monitoring schedules for both the Reservoir Area Management Plan and TMCP are presented in Table 6-7. During Year 2 and Year 3, the Renewal Corporation will monitor the Reservoir Area Management Plan Fish Passage Monitoring Area twice, once in June/July after the rainy season and again in early fall. For the remainder of the fish passage monitoring period (i.e., Years 4-7) the Renewal Corporation will monitor the Reservoir Area Management Plan Fish Passage Monitoring Area annually, after the rainy season. The Renewal Corporation will conduct additional monitoring following the first 5-year or greater flow event to occur following drawdown if the flow event occurs within 5 years of drawdown. The additional monitoring will occur within one month of the 5-year flow event unless it is unsafe for field crews, in which case the monitoring will occur as soon thereafter as it can safely be conducted.

Table 6-7. Post-Dam Removal Fish Passage Monitoring

YEAR	SURVEY PERIOD	LOCATION	MANAGEMENT PLAN RESPONSIBILITY
Year 2 (i.e., the drawdown year)	Spring	TMCP Fish Passage Monitoring Area[1] and Spencer Creek	TMCP
	Post-Final Drawdown	Reservoir Area Management Plan Fish Passage Monitoring Area[2] and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP
	Post-Final Drawdown	Upper end of the former footprint of the J.C. Boyle Reservoir to the Oregon State Line	NMFS's Biological Opinion and ODFW's Fish Passage Permit[3]
	Fall	Reservoir Area Management Plan Fish Passage Monitoring Area and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP
All Fish Passage Monitoring Years	Additional monitoring event will be conducted following the first 5-year or greater flow event to occur following drawdown if such event occurs within 5 years of drawdown.[4]	Reservoir Area Management Plan Fish Passage Monitoring Area and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP
Year 3	After rainy season[5]	Reservoir Area Management Plan Fish Passage Monitoring Area and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP

YEAR	SURVEY PERIOD	LOCATION	MANAGEMENT PLAN RESPONSIBILITY
	Fall	Reservoir Area Management Plan Fish Passage Monitoring Area and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP
Year 4	After rainy season	Reservoir Area Management Plan Fish Passage Monitoring Area and TMCP Monitoring Area	Reservoir Area Management Plan and TMCP
Year 5	After rainy season	Reservoir Area Management Plan Fish Passage Monitoring Area	Reservoir Area Management Plan
Year 6	After rainy season	Reservoir Area Management Plan Fish Passage Monitoring Area	Reservoir Area Management Plan
Year 7	After rainy season	Reservoir Area Management Plan Fish Passage Monitoring Area	Reservoir Area Management Plan

Notes:
1. TMCP Fish Passage Monitoring Area = The 8-mile reach from Iron Gate Dam (RM 193.1) to Cottonwood Creek (RM 185.1), five tributary confluences within the reach, and Shovel Creek Confluence (RM 210.4)
2. Reservoir Area Management Plan Fish Passage Monitoring Area – Defined in Section 6.2.5
3. The schedule will be revised as necessary to reflect the final conditions set forth in the Biological Opinion issued by NMFS and the Fish Passage Permit issued by ODFW.
4. 5-year Flow Event of 10,908 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (#11516530)
5. Monitoring during the survey period "after rainy season" is anticipated to occur between June 15 and July 31. The exact dates will be determined based on the 14-day weather forecast to avoid significant storms forecast to cause 0.25 or more inches of rain. During this period, the monthly flow on the mainstem of the Klamath River should be approximately 1,050 to 1,280 cfs, some of the lowest monthly average flow periods for the mainstem.

6.2.6.1 Desktop versus Field Survey, Agency Notification, and Reporting

The Renewal Corporation will undertake fish passage monitoring through a combination of desktop and field review processes as described in Section 6.2.7, Headcut Migration Monitoring. The reference to survey period in Table 6-7 refers to a scheduled desktop evaluation. If the desktop evaluation of a potential fish passage barrier is inconclusive or if a potential barrier is identified by desktop methods or field personnel, the Renewal Corporation will conduct a field investigation. If the Renewal Corporation determines that a field-based fish passage barrier evaluation is required, the Renewal Corporation will notify the HRG approximately two (2) weeks prior (or at least 48 hours in the case of an emergency) to the field investigation to allow staff the opportunity to participate in the monitoring effort. The field evaluation will be led by a fisheries biologist or geomorphologist who will assess barriers to volitional fish passage.

6.2.6.2 Anthropogenic Debris

During the period from drawdown until completion of the final survey in Year 7 (Table 6-5), the Renewal Corporation will remove human-made structures and natural debris barriers caused by dam removal activities within the Reservoir Area Management Plan Fish Passage Monitoring Area if such barriers are visible within channel beds and present as potential fish passage barriers. Human-made structures and debris present potential fish passage barriers if they cause greater than a six (6) inch discontinuity in water surface elevation (WSE) in Oregon or greater than a 12-inch discontinuity in WSE in California.

6.2.6.3 Natural Barriers

The Renewal Corporation will not remove any natural barriers consisting of non-residual reservoir sediments, bedrock, or other pre-dam channel elements, such as woody debris and boulders. However, if a natural barrier materially and unexpectedly restricts fish passage within the Reservoir Area Management Plan Fish Passage Monitoring Area, the Renewal Corporation will determine, in consultation with the HRG, whether the natural barrier should be removed or manipulated to permit fish passage.

6.2.7 Headcut Migration Monitoring

Discontinuities in the channel bed due to uneven evacuation of sediments may lead to temporary headcuts that could act as a barrier to fish migration. Depending on the nature of the residual sediment and subsequent flows experienced, such headcuts may be short-lived and/or unlikely to pose a sustained threat to fish passage or long-term habitat function. The Renewal Corporation will apply the following methods for evaluating and removing residual reservoir sediment headcuts that result in WSE drops of six (6) inches in Oregon and 12 inches in California.

6.2.7.1 Qualitative/Desktop Monitoring Methods

The Renewal Corporation will begin qualitative desktop monitoring immediately after drawdown and will continue such monitoring for 5 years. The Renewal Corporation’s qualitative desktop monitoring will be conducted by qualified professional staff and will include the monitoring and evaluation of all headcut features within the Reservoir Area Management Plan Fish Passage Monitoring Area using topographic data and aerial imagery as described in Section 6.2.7.2, Identification. The Renewal Corporation’s qualitative desktop monitoring will allow for in-season adaptive management of headcut features and communication of potential fish passage issues. The Renewal Corporation’s qualitative desktop monitoring assessment will include the identification of headcuts that are potential barriers to fish passage and the evaluation of substrate, stability, and upstream fish presence. In addition, the Renewal Corporation will use the aerial imagery to identify smaller non-spawning tributaries that are not within the Reservoir Area Management Plan Fish Passage Monitoring Area but provide salmonids with thermal refugia and/or habitat for non-natal rearing. The location of these smaller tributaries will be identified in the Annual Compliance Report that the Renewal Corporation will prepare and submit in accordance with Section 7.0.

6.2.7.2 Identification

Given the spatial scale of the Reservoir Area Management Plan Fish Passage Monitoring Area, the Renewal Corporation will implement aerial data collection technologies to identify and evaluate potential fish passage barriers. Aerial data collection may include the following within the Reservoir Area Management Plan Fish Passage Monitoring Area:

- Low-elevation, geolocated oblique aerial video along the mainstem of the Klamath River and tributaries where fish passage monitoring is required. Video will be taken at a low elevation from downstream to upstream so that headcuts generating a change in WSE greater than six (6) inches in Oregon and 12 inches in California can be remotely identified.
- High-resolution orthorectified aerial imagery.
- Bare earth digital terrain model developed from aerial topographic data collection technologies.

The Renewal Corporation will collect aerial data for the Reservoir Area Management Plan Fish Passage Monitoring Area according to the schedule outlined in Table 6-7. All three data sets will be collected concurrently so that headcuts can be cross-identified between data sources. If the results of the desktop evaluation are inconclusive, the Renewal Corporation will conduct a site investigation, if required. The Renewal Corporation's desktop and field (if required) programs will include the evaluation of physical and biological components and will be completed by a multi-disciplinary team of qualified personnel. A fluvial geomorphologist or stream restoration engineer with experience in evaluating headcut migration will evaluate the physical components of the headcuts. An ecologist or fisheries biologist with experience in evaluating fish passage barriers will evaluate the biological components of the headcuts.

The first step in the mapping process is to review aerial data to identify and map the locations of headcuts within the Reservoir Area Management Plan Fish Passage Monitoring Area that have the potential to meet the following criteria:

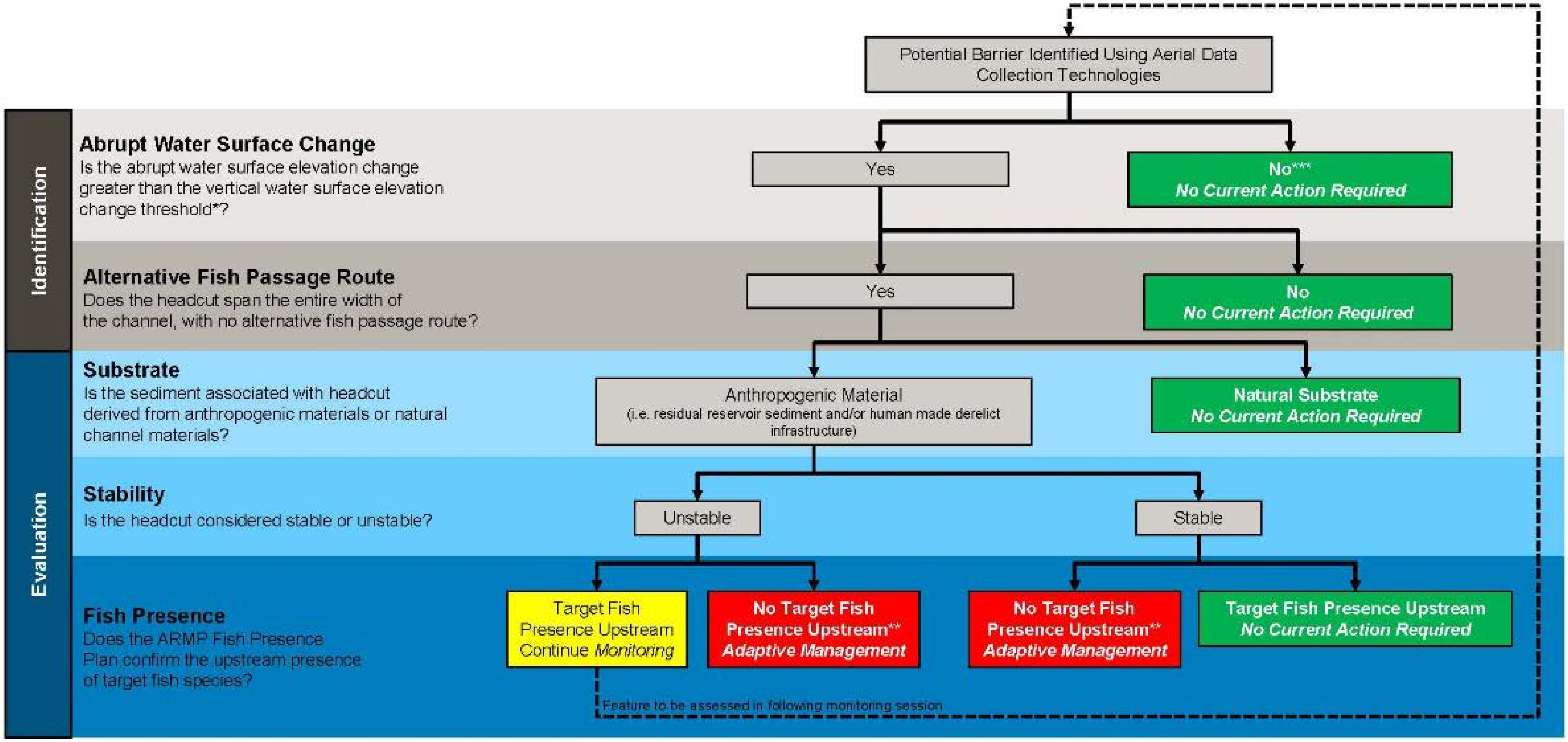
- Abrupt WSE changes greater than twelve (12) inches (California) and six (6) inches (Oregon); and
- Span the width of the channel, with no alternative fish passage route.

Upon the Renewal Corporation's completion of feature identification, each identified headcut will be assigned a unique identifier so that its location and morphology can be monitored over time. Furthermore, a detailed desktop evaluation will be completed by the Renewal Corporation for each identified headcut feature as described below. Features that do not meet both the WSE change and channel width spanning criteria will not undergo further evaluation, as outlined in the identification component of the headcut evaluation framework in Figure 6-7.

To further facilitate the identification process, the Renewal Corporation's field staff will be asked during training to promptly notify their supervisor if they observe any potential fish passage barriers while in the field.

6.2.7.3 Evaluation

The Renewal Corporation will evaluate identified headcuts that are potential barriers to fish passage to determine the need for future monitoring and/or adaptive management. Utilization of the headcut evaluation framework in Figure 6-7 will provide a systematic and repeatable evaluation of each potential headcut barrier. The evaluation component of the framework separates potential barriers into those resulting from residual reservoir sediments and those arising from natural processes. The Renewal Corporation will undertake further evaluation if the barrier is anthropogenic in origin to assess whether it is stable or unstable over time. In general, the Renewal Corporation will not correct natural barriers (i.e., barriers (1) composed of materials other than residual reservoir sediments, human made structures, and large human-made debris and (2) primarily created by something other than dam removal activities). The Renewal Corporation will evaluate potential anthropogenic barriers for adaptive management interventions as described in Section 6.2.9, Adaptive Management whether they are stable or unstable if there is no fish presence above the potential barrier or if fish presence upstream of the potential barrier is unconfirmed. The Renewal Corporation will reassess potential anthropogenic barriers that are determined to be unstable during the following monitoring year if fish presence above them is confirmed.



* Abrupt water surface elevation changes greater than six inches in the Oregon portion of monitoring area and twelve inches in the California portion of the monitoring area.

** Adaptive management will be required if target fish presence/absence upstream is unconfirmed. Project adaptive management begins with a field-based review of the potential barrier and coordination with the RTWG to determine next steps (see Section 6.2.9).

***If the evaluation indicates that no further action is needed at the current time, the headcut will be monitored again during the next monitoring period as necessary.

Figure 6-7. Headcut Evaluation Framework

6.2.7.4 Substrate

The fish passage monitoring and associated adaptive management activities in the Reservoir Area Management Plan are focused on fish passage impediments caused by anthropogenic debris, as defined in Section 6.2.6.2 (Anthropogenic Debris). The Renewal Corporation will undertake a substrate evaluation to evaluate whether the potential fish passage barrier is caused by anthropogenic debris or is a natural barrier, as defined in Section 6.2.6.3 (Natural Barriers).

Anthropogenic debris includes the following:

- Human-made structures
- Large human-made debris (such as abandoned cars and boats)
- Natural debris barriers primarily caused by dam removal activities within the Reservoir Area Management Plan Fish Passage Monitoring Area

Natural barriers include but are not limited to the following:

- Channel substrate with a gradation consistent with the pre-dam channel substrate, excluding imported or placed material
- Colluvial and/or alluvial material supplied to the Reservoir Area Management Plan area from natural process occurring within the upstream watershed during the period of monitoring
- Beaver dams
- Woody debris supplied to the Reservoir Area Management Plan area from the upstream watershed

The desktop analysis will include a comparison of the headcut substrate composition to the composition of natural and anthropogenic materials. To support the categorization of substrate as anthropogenic or natural, it may be necessary to compare the existing channel elevation to the pre-dam channel elevation. If the headcut is founded on natural channel materials, no further monitoring will occur, as indicated in Figure 6-7.

6.2.7.5 Stability

Following dam removal, downcutting and headcut migration is expected and desired to evacuate residual reservoir sediments within the Reservoir Area. In general, the rates of reservoir sediment erosion and headcut migration are expected to decay exponentially over time until the pre-dam surface is reached (USBR, 2016). While there may be instances where headcut migration is arrested due to an incision intersecting erosion resistant material (e.g., large woody debris, firm reservoir deposits, remnant infrastructure), time and/or increased river flow may reinitiate headcut migration. The headcut migration process described above can be expected to occur within the mainstem of the Klamath River as well as tributary channels that enter the reservoir and flow through residual reservoir sediments.

The Renewal Corporation's headcut stability monitoring will include the following steps to evaluate potential effects of headcuts on fish passage within the Reservoir Area Management Plan Fish Passage Monitoring Area:

- Estimate annual migration distance based on relative position; and
- Review the flow record on the mainstem of the Klamath to evaluate the number of flow events exceeding the bankfull[6] discharge within the monitoring year.

The headcut is considered stable for the purpose of this monitoring protocol if both of the following statements are true:

- Planform position has remained stationary relative to previous two (2) monitoring years
- The hydrologic record indicates that the headcut has twice endured a discharge equal to or larger than the bankfull discharge within the previous two (2) monitoring years

If either of the above statements is false, the feature will be deemed unstable (see Figure 6-7).

6.2.7.6 Fish Presence

Headcut migration has the potential to act as an impediment to fish migration. Because of multiple variables, including flow regime, channel morphology, sediment transport, and fish migration timing, fish presence upstream is still possible despite the presence of an apparent barrier. Therefore, whether the Renewal Corporation's fisheries investigations (see ARMP Fish Presence Monitoring Plan) confirm or do not confirm upstream target fish presence will inform adaptive management.

6.2.7.7 Quantitative / Field Monitoring Methods

If the desktop monitoring process is inconclusive, the barrier assessment approach will shift to field monitoring methods to complete the headcut evaluation. The Renewal Corporation's field monitoring methods may include the following:

[6] **Bankfull Definition** From a traditional geomorphic perspective, bankfull is defined as the point of incipient flooding whereby flow accesses its floodplain in alluvial channels. It is generally observable in the field as break in slope as the bank transitions to a flatter surface at the floodplain as one moves away from the stream centerline. However, in actively incising, adjusting, or non-alluvial channels this break in slope can be difficult to perceive, and bankfull may be difficult to discern based on physical characteristics of the channel so it must be determined based on other characteristics. As many of the tributaries to the Klamath River within the reservoir areas are expected to undergo cycles of adjustment as residual sediments are mobilized and transported downstream, this circumstance is likely to apply, and thus, other means may be required to determine if bankfull flows have occurred. For the primary tributaries, the determination of whether or not flow has exceeded the bankfull discharge will be based first on bankfull indicators where present. In the absence of bankfull indicators, RES will consult bankfull indicators that can be observed on the channel upstream of the Reservoir Area, and if flow exceeds the threshold signified by those indicators, it will be assumed that the bankfull discharge was exceeded within the tributary as well.

- Longitudinal survey of the water surface profile to confirm magnitude of the drop.
- Field assessment to confirm whether headcuts span the width of the channel, leaving no alternative fish passage path
- Substrate characterization using visual observations, Wolman pebble count, or grab samples where appropriate
- Additional fish presence/absence surveys upstream of the headcut

If field-based data gathering is required to support the headcut evaluation, the relevant sections of the following references will be used by the Renewal Corporation to guide the effort:

- **Wadeable Streams:** A watercourse is considered wadable if it is less than one (1) meter deep for at least half the length of the site. Site investigations for wadeable streams will adhere to Section 3 (Initial Site Procedures) and Section 8 (Physical Habitat Characterization) of the EPA Field Operations Manual for Wadeable Streams (EPA, 2013a).
- **Non-Wadeable Streams**: Site investigations for non-wadeable streams will adhere to Section 3 (Initial Site Procedures) and Section 8 (Physical Habitat Characterization) of the EPA Field Operations Manual for Non-Wadeable Streams (EPA, 2013b).

6.2.7.8 Summary of Headcut Monitoring Methods

Headcut migration monitoring is meant to assess potential impacts to volitional fish passage within the Reservoir Area Management Plan Fish Passage Monitoring Area. The Renewal Corporation's monitoring program is designed to inform the fish passage monitoring metric and is summarized in Table 6-8.

Table 6-8. Summary of Desktop and Field Fish Passage Evaluation Components

HEADCUT EVALUATION STAGE	DESKTOP EVALUATION COMPONENTS	FIELD EVALUATION COMPONENTS *
Identification	• Identify headcuts (1) generating a change in WSE greater than six (6) inches in Oregon and 12 inches in California and (2) spanning the width of the channel, leaving no alternative fish passage path • Assign each potential barrier a unique identifier	• Longitudinal profile survey to confirm if WSE change exceeds six (6) inches in Oregon and 12 inches in California • Field confirmation that the barrier spans the width of the channel, leaving no alternative fish passage path
Substrate	• Characterization of headcut substrate to confirm if it is consistent with the residual reservoir sediment, restored reach substrate, or with natural channel substrate • Confirm the presence of remnant anthropogenic structures	• Field characterization of headcut substrate (e.g., visual observation, pebble count, grab sample)
Stability	• Estimate annual migration distance based on relative position • Review flow record to evaluate the number of flow events exceeding the bankfull discharge within the monitoring year	• Field observations by a qualified river scientist to confirm stability of the headcut
Fish Presence	• Refer to findings of fisheries investigation to evaluate the presence/absence of fish upstream of the headcut	• Complete additional fisheries investigations to evaluate the presence or absence of fish upstream of the headcut

Notes:
* Implementation of a field evaluation component is only required if the results of the desktop evaluation are inconclusive.

6.2.7.9 Subsequent Measures

Upon completion of the evaluation, the Renewal Corporation will determine whether to implement adaptive management. If a site requires adaptive management intervention, including field-based data gathering, notification will be provided to HRG approximately (2) weeks prior to scheduled field work activities or 48 hours in advance of emergency interventions.

6.2.8 Geomorphological and Residual Reservoir Sediment Stability Monitoring

The Renewal Corporation will annually have qualified professional(s) monitor geomorphological and residual reservoir sediment stability to assess the stability of the High Priority Tributaries and the residual reservoir sediments within the Reservoir Areas using the monitoring methods discussed in the following sections. Additionally, the Renewal Corporation will review the monitoring observations annually to estimate patterns and trends of geomorphological adjustment. The results of this interpretation will be used by the Renewal Corporation to evaluate each High Priority Tributary's position within the SET (Section 6.2.1, Geomorphological Communication). Positioning each site within the SET will provide context to any adaptive management decisions and facilitate consistent geomorphological communication.

6.2.8.1 Monitoring Methods

This section describes the Renewal Corporation's monitoring methods to assess High Priority Tributary restoration success and residual reservoir sediment stability. The monitoring methods for High Priority Tributary Work Areas are intended to compare the post-construction stream condition to the final design of the tributaries. If monitoring indicates that conditions are materially deviating from the restoration design, adaptive management may be required. Monitoring will be completed by the Renewal Corporation following the rainy season and shall include the following:

- **Rapid Geomorphological Assessment**: Rapid geomorphological assessment (RGA) of the High Priority Tributary restoration reaches includes an evaluation of bed morphology, substrate composition, riparian vegetation, bank stability, channel fringe complexity, floodplain roughness, floodplain connectivity, and geomorphological stability (i.e., aggradation and degradation). In order to provide a systematic and repeatable evaluation of each site, field forms were developed to support the RGA (Appendix G-2). Following the development of the final restoration designs for the High Priority Tributary Work Areas, the RGA will be used, in consultation with the HRG, to estimate the post-construction condition and 5-year post-construction condition of the reaches to be restored. During monitoring events, the observed condition of the restored reaches will be compared to the estimated 5-year post-construction condition to evaluate whether the sites are progressing toward the expected 5-year post-construction condition. If monitoring indicates that sites are not progressing toward the expected 5-year post-construction condition, or away from it, adaptive management might be required. The RGA also includes collecting photographs to document the channel morphology, floodplain condition, and vegetation establishment. Attempts will be made to collect photographs from the same location and looking in the same direction during subsequent monitoring visits so that photographic comparisons can be made over time.

  *Monitoring metric(s) supported***:** bank stability, floodplain connectivity, floodplain roughness, and channel fringe complexity.

- **Longitudinal Profile:** Longitudinal profile refers to the elevations of the thalweg of the watercourse. The longitudinal profile will consist of thalweg, water surface, and bankfull indicators where appropriate. The Renewal Corporation's comparison of the channel profile between monitoring years will support the Renewal Corporation's evaluation of channel change over time. Natural watercourses may demonstrate slight vertical adjustments over time, but there should be no significant channel bottom lowering (degradation) or raising (aggradation). The Renewal Corporation's longitudinal profile surveys will support the assessment of the bank stability and floodplain connectivity monitoring metrics. The survey will also support the assessment of drop heights in support of the fish passage monitoring metric, if required.

  Monitoring metric(s) supported: bank stability (if required), floodplain connectivity (if required), fish passage (if required)

- **Dimension**: The Renewal Corporation will monitor channel dimension through monumented annual cross-sectional surveys. The Renewal Corporation will survey geometry to monitor any changes in channel geometry (e.g., cross-sectional area, bankfull width, bankfull depth) and floodplain dimension. The Renewal Corporation's cross-sectional surveys will support bank stability and floodplain connectivity monitoring metrics.

  Monitoring metric(s) supported: bank stability, floodplain connectivity

- **Residual Reservoir Sediment Stability Assessment**: Residual reservoir sediment stability assessment includes the use of digital aerial data capture technologies and the creation of digital terrain models (DTM) that can be compared through surface subtraction to evaluate changes in residual reservoir sediments over time. Residual reservoir sediment surfaces are expected to change over time as the Reservoir Areas respond to natural hydrological processes. This could include streambank and riverbank erosion, re-formation of upland drainage features, and slope failures in residual reservoir sediment and pre-impoundment surface materials. No matter how successful, revegetation of the Reservoir Areas will not result in a static landscape. Adaptive management related to natural erosion processes such as those described above is outside the scope of the Reservoir Area Management Plan. Annual comparisons of topographic surface change will be used to inform adaptive management activities if the observed sediment instabilities can be attributed to insufficiencies in revegetation success. Other topographic changes are assumed to be the natural outcome of the process-based restoration approach of the Klamath River and Reservoir Areas.

  Monitoring metric(s) supported: residual reservoir sediment stability

When monitoring reveals issues with the success of restoration elements, follow-up monitoring and/or adaptive management will be triggered.

6.2.8.2 Field Protocols

In order to provide a systematic and repeatable quantitative evaluation of each site, the Renewal Corporation will adhere to the relevant sections of the EPA Field Operations Manual for Wadeable Streams (EPA, 2013a). Additionally, geomorphological processes and formations tend to be more visible immediately after large flow events before a river system has been able to re-establish equilibrium. Therefore, the Renewal Corporation will conduct assessments after high water has receded following a larger storm event to balance safety with ease of observation.

6.2.9 Adaptive Management

The adaptive management framework allows the Renewal Corporation to interpret the monitoring metrics and to take adaptive management actions when necessary to achieve the restoration goals described in this Reservoir Area Management Plan.

6.2.9.1 Triggers

Examples of monitoring results that may trigger the Renewal Corporation's adaptive management interventions are presented in Table 6-9 for Reservoir Area Management Plan goals and monitoring metrics. Table 6-9 also includes potential adaptive management measures that could be taken by the Renewal Corporation in response to the monitoring result example.

Table 6-9. Example Monitoring Results that Trigger Adaptive Management Frameworks

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRICS	EXAMPLE MONITORING RESULT	POTENTIAL ADAPTIVE MANAGEMENT MEASURES
Reservoir Areas Sediment Stabilization	Sediment Stability	Remaining reservoir sediments exhibit active erosion.	Revegetation maintenance and hand work to address water sources contributing to rill formation.
High Priority Tributary Restoration and Fish Passage	Fish Passage	WSE drop caused by discontinuity in residual reservoir sediments may preclude fish passage.	Conduct long profile survey, continue to monitor, assess severity, and/or evaluate need for physical interventions.
	Bank Stability	Constructed banks critical to restoration goals exhibit instability and erosion	Conduct long profile survey, continue to monitor, assess severity, and/or evaluate need for physical interventions.

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRICS	EXAMPLE MONITORING RESULT	POTENTIAL ADAPTIVE MANAGEMENT MEASURES
		indicators indicate evolution towards a negative outcome.	
	Floodplain Connectivity	Regular inundation of floodplains is not achieved. Excessive degradation is present in channel surface.	Conduct long profile survey, continue to monitor, assess severity, and/or evaluate need for physical interventions based on entrenchment ratio and SET trend.
	Floodplain Roughness	Revegetation of floodplain surface is not producing roughness in alignment with plan.	Revegetation maintenance and hand work to address roughness elements.
	Channel Fringe Complexity	Channel fringe complexity features are not present and/or are inaccessible to species.	Assess absent complexity features. May conduct long profile survey to assess incision processes.
Klamath River Fish Passage	Fish Passage	WSE drops caused by discontinuity in residual reservoir sediments may preclude fish passage.	Conduct long profile survey, continue to monitor, assess severity, and/or evaluate need for physical interventions.
Dam Footprint Fish Passage	Fish Passage	Threshold channel design is not functioning as intended and may not be passable to target fish species.	Revisit design and assess required adaptive management interventions to maintain threshold design and fish passage.

6.2.9.2 Example of Adaptive Management Measures

If volitional fish passage or geomorphological and residual reservoir sediment monitoring indicate that the performance criteria outlined in Section 6.1.4 (Performance Criteria) are not being met, the Renewal Corporation will determine, in consultation with the HRG, whether adaptive management is required. The following list provides illustrative examples of specific adaptive management measures that may be implemented by the Renewal Corporation:

- Bank stabilization using bioengineering, channel grading, and/or appropriately dimensioned stone
- Increase stability through targeted revegetation efforts
- Additional assessment and/or data collection (e.g., bathymetric survey)

- Channel bed stabilization using large wood and/or appropriately dimensioned stone
- Implementation of riparian plantings
- Supplementary sediment grading and stabilization

6.2.9.3 Adaptive Measures and Changing Circumstances

The Renewal Corporation will update the Reservoir Area Management Plan as appropriate to address unanticipated fish passage barriers if: (1) a natural disaster or other force majeure event (defined as events beyond the control of the Renewal Corporation, including without limitation flooding and drought) occurs, (2) sediment evacuation or other assumptions used by the Renewal Corporation are updated following dam removal, or (3) other unforeseen circumstances result in more fish passage barriers than anticipated (together, Unforeseen Circumstances). In the event Unforeseen Circumstances occur, the Reservoir Area Management Plan may be updated to adjust the monitoring measures the Renewal Corporation takes within the Reservoir Area Management Plan fish passage monitoring area during the survey periods set forth in Table 6-7 and/or the criteria the Renewal Corporation uses to determine if intervention is required. All updates to the Reservoir Area Management Plan will be submitted to SWRCB and ODEQ for approval and will be consistent with the purpose and goals of the Reservoir Area Management Plan. If an updated Reservoir Area Management Plan is approved by the SWRCB and ODEQ, the Renewal Corporation will file a report with the Commission within 14 calendar days, which shall include a copy of the updated Reservoir Area Management Plan, a description of the Unforeseen Circumstances, and documentation of consultation with the SWRCB and ODEQ.

6.2.9.4 Minor and Significant Fish Passage Barrier Intervention

As detailed in Table 6-10, adaptive management interventions may be minor or significant. If Unforeseen Circumstances require a revaluation of objectives, the Renewal Corporation will determine next steps in consultation with the HRG.

Table 6-10. Fish Passage Adaptive Management Interventions

RESERVOIR AREA MANAGEMENT PLAN GOALS	MONITORING METRIC	MINOR INTERVENTIONS	SIGNIFICANT INTERVENTIONS	REVALUATE OBJECTIVES
High Priority Tributary, Klamath River, Dam Footprint	Fish Passage	Maintenance Oriented - Hand Work – No Work Zone Isolation Required	Mobilization of Excavation Equipment – Work Zone Isolation May Be Required	Drought, Flooding, Unforeseen Circumstances

The Renewal Corporation will monitor volitional fish passage at variable frequencies depending on the season and year (see Table 6-7). The Renewal Corporation will remedy obstructions that limit fish passage through appropriate manual or mechanical means. Example removal methods include removing sediment using hand tools or hydraulic equipment. The Renewal Corporation will redistribute removed gravels and large woody debris within the channel in a manner that will both reduce the risk of future headcut formation and enhance the aquatic habitat. The Renewal Corporation will place removed fine sediments from removed fish passage barriers on the adjacent floodplain or uplands and stabilize such sediments using appropriate revegetation methods. See the Tributary Mainstem Connectivity Plan, a part of the ARMP, for additional information regarding adaptive management activities related to the adaptive removal of fish passage barriers.

Differentiation between minor and significant interventions is based on the scale of the issue encountered, the inherent risk to aquatic species, the need to mobilize powered excavation equipment to the site, the ability to remedy with less impactful hand approaches, and the need for work zone isolation measures (Table 6-10). The Renewal Corporation will consult with the HRG with respect to all significant barrier interventions.

In the event that data gathering is required to support significant interventions on the mainstem Klamath River, Section 3 (Initial Site Procedures) and Section 8 (Physical Habitat Characterization) of the EPA Field Operations Manual for Non-Wadeable Streams (EPA, 2013b) will be used by the Renewal Corporation to guide the effort. In the event that data gathering is required to support significant interventions on High Priority Tributaries, Section 3 (Initial Site Procedures) and Section 8 (Physical Habitat Characterization) of the EPA Field Operations Manual for Wadeable Streams (EPA, 2013a) will be used by the Renewal Corporation to guide the effort.

6.2.9.5 Communication Process for Significant Interventions

The Renewal Corporation will use the monitoring program to evaluate if adaptive management is required. In the event that a significant adaptive management intervention (Section 6.2.9.4, Minor and Significant Fish Passage Barrier Intervention) is required, the HRG will be notified and provided with the location of the issue, photographs, and characteristics, as well as assessed type and severity. Based on the type and severity of the issue, the Renewal Corporation will take the following actions during the monitoring period:

- The HRG will be notified of the need for corrective actions
- Hand tools will be used for minor interventions
- Mechanical equipment will be used for significant interventions
- Continued monitoring will potentially occur to evaluate if natural hydrology correction will occur, and no direct intervention will be required

Notifications will be provided to the HRG approximately two (2) weeks prior to field activities or 48 hours in advance of emergency interventions.

6.2.9.6 In-Water Work BMPs for Significant Interventions

Significant adaptive management interventions involve in-water work and the need for work zone isolation measures. The Renewal Corporation will implement the following BMPs for significant interventions that require in-water work (see Appendix C for a complete list of BMPs):

1. ARG will be notified a minimum of 48-hours before start of work.
2. Unless under the guidance of ARG, in-water construction will occur during the in-water work construction windows set forth in Appendix C.
3. A fisheries biologist will evaluate the in-water habitat to determine if salmonids or protected fish occur in the Limits of Work.
    a. If salmonid or protected fish are or are assumed to be present in the in-water work area, fish rescue, relocation, and exclusion will occur under the direction of a qualified fisheries biologist.
        i. General conditions for fish capture and relocation activities: Exclusion will include the use of block nets, or similar, to isolate the work area from fish access. The fisheries biologist will evaluate the upstream and downstream extent of the fish exclusion and relocation efforts, which will be based on the minimal amount of wetted channel where salmonids may experience potential injury or mortality from the in-water activity. Fish relocation will be performed using seine nets, dip nets, and/or electrofishing as determined appropriate and effective by the fisheries biologist. The duration and extent of fish relocation actions will be determined by the fisheries biologist. Once the work area is determined to be cleared of salmonids, in-water work activities will be cleared to begin.
            1. Electrofishing: All electrofishing will be conducted in accordance with the NMFS Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act (NOAA and NMFS, 2000).
            2. Salmonid Handling and Relocation: National Oceanic and Atmospheric Administration (NOAA) Restoration Center's Programmatic Approach to ESA/EFH Consultation Streamlining for Fisheries Habitat Restoration Projects (NOAA and NMFS, 2017), Section 2.4.1.E – Guidelines for Relocation of Salmonids, will guide relocation work.
    b. If no salmonids or protected fish occur in the work area, a biologist will monitor the in-water work actions to ensure that there is no change in conditions that would require fish exclusion or relocation. The biologist will document and report the completion of the in-water work activity to ARG as described below.
4. Disturbance to existing riparian vegetation and channel banks will be minimized to the extent feasible to complete the required restoration or maintenance action.
5. In the High Priority Tributary Work Areas, flow diversion around the work area will be used if channel bed adjustments are required.

6. The use or storage of petroleum-powered equipment shall be accomplished in a manner to prevent the potential release of petroleum materials into waters of the state.
7. Areas for fuel storage, refueling, and servicing of construction equipment will be located in an upland location.
8. Oil absorbent and spill containment materials will be on site when mechanical equipment is in operation within 100 ft of the proposed watercourse crossings. If a spill occurs, no additional work shall commence in-channel until the following occurs: (1) the mechanical equipment is inspected by the Renewal Corporation contractor, and the leak has been repaired; (2) the spill has been contained; and (3) the ARG is contacted and has evaluated the impacts of the spill.
9. To minimize potential transport of aquatic invasive species, restoration staff will comply with the relevant BMPs set forth in Appendix C (Best Management Practices).
10. Documentation and Reporting: Photographs of the in-water work location; summary of actions, including any fish relocation; and notification of completion of the in-water work will be provided to the ARG within one (1) week of the completion of in-water work.

6.3 Revegetation Management

The first two (2) years after dam removal are critical to vegetation establishment because plants that establish early have a strong impact on the trajectory of vegetation succession. Survival of established species will be highest during Year 2 and Year 3 due to the residual moisture left behind in the sediments after reservoir drawdown. Therefore, important species (e.g., oaks) will be introduced by the Renewal Corporation during this period. Establishment of native vegetation at the early stages of succession will also decrease the colonization and spread of IEV. The Renewal Corporation will quantitatively and qualitatively monitor vegetation establishment during Year 2 and Year 3 with implementation of adaptive management where appropriate. IEV management will be completed annually in early season and late season implementation phases, as necessary, to maximize IEV treatment effectiveness for specific plant species. A five (5)-year maintenance period (Years 4-8) will follow this two (2)-year vegetation establishment period. The Renewal Corporation will continue quantitative monitoring for the entire five (5)-year maintenance and monitoring period.

6.3.1 Performance Criteria

Performance criteria for the Proposed Action provide targets to evaluate the progression of vegetation development in the reservoirs with the goal of creating viable self-sustaining native plant communities in riparian and upland habitats. The Renewal Corporation's annual monitoring of the restoration areas will evaluate if revegetation is progressing along a trajectory compliant with the performance criteria. If revegetation is not adequately progressing by the end of Year 6, the Renewal Corporation will undertake adaptive management in consultation with the HRG to correct deficiencies in site performance.

The Renewal Corporation will use four (4) criteria to evaluate revegetation success in the former reservoirs after dam removal: (1) relative vegetation cover, (2) plant diversity, (3) number of surviving trees and shrubs per acre, and (4) invasive exotic vegetation cover. These criteria are standard practice for restoration projects. Dam removal revegetation is unique and differs in several ways from other restoration projects. To account for the unique conditions, the Renewal Corporation modified the criteria. These criteria are based on previous dam removal monitoring programs. The criteria establish targets for the following vegetation characteristics.

- Species richness
- Tree and shrub density
- Vegetation cover
- Non-native relative frequency

These criteria are separated into dry upland performance criteria and riparian/wetland performance criteria. While the proposed performance criteria for species richness, tree and shrub density, vegetation cover, and non-native relative frequency apply to both landforms, the performance targets themselves are often different. The revegetation performance criteria for both upland and riparian/wetland areas is based on a comparison between the monitoring results at a point in time and reference site conditions and is often determined as a percentage of the reference sites. For example, the upland species richness target in Year 4 is 50 percent of the species richness as measured in adjacent reference upland plant communities. The reference sites will be identified by the Renewal Corporation prior to drawdown in consultation with the HRG.

Individual performance criteria for each reservoir shall be separately analyzed by habitat to determine whether the criteria has been met. Analyses are aggregated by habitat within the three reservoirs. The Renewal Corporation will assess all of the performance criteria using quantitative monitoring methods. See Appendix H-3 (Data Analysis Protocols) for additional information regarding the performance criteria data analysis protocols relating to revegetation. The Renewal Corporation will establish randomly distributed permanent plots in all three (3) reservoirs and monitor annually beginning in Year 5 and re-survey annually until Year 8. The Renewal Corporation will evaluate the results of annual monitoring to determine if performance criteria are being met. If performance criteria are not being met or revegetation is not adequately progressing towards meeting the Year 8 performance criteria by the end of Year 6, the Renewal Corporation will undertake adaptive management in consultation with HRG to correct deficiencies in site performance.

The Renewal Corporation will not consider naturally occurring species separately in the data. All species present, planted, seeded, or natural will be treated equally for all performance criteria. The Renewal Corporation will make determinations of naturally recruited species versus planted by comparing data to plots located in control areas left unseeded and unplanted in the Reservoir Areas.

6.3.1.1 Species Richness

Species richness is an assessment of the number of species present in a given area. Species richness is preferable to the related species diversity metric because species diversity in early successional communities is very fleeting and not representative of the eventual community that will develop. Species richness is the number of species present in a given ecosystem. Species diversity combines the number of species with abundance measurements. Species richness provides a better measure of ecosystem resilience, which is not provided by diversity metrics. For restoration, particularly in light of climate change, ecosystem resilience is critical to a newly restored site. Species diversity in primary series tend to be low because early plant communities are often dominated by only a few species for a few years before giving way to longer-lived species. Ocular cover estimates, typically used to determine species diversity, are subjected to surveyor observation variability over time. Species richness records all species present, which is a less subjective metric that provides insight into the presence of important long-lived species that might be under-represented using diversity assessments. Species richness data are efficient and cost-effective to collect and can be used to determine abundance (diversity) on a landscape scale.

The Renewal Corporation's species richness criteria is based on the number (on a percentage basis) of species observed in a geographic area being monitored compared to the number of species present in reference target plant communities (Table 6-11). Over time, species richness will increase as a result of planting and natural recruitment. Moist riparian habitats are expected to develop more rapidly than drier upland habitats. Riparian habitats will be immediately connected to intact upstream riparian communities that provide moisture, seed, and vegetative propagules critical to habitat development.

For purposes of determining whether the performance criteria has been met, species richness shall include all species, including non-native species. For informational purposes only, species richness measurements for native species (i.e., excluding non-native species) will also be calculated and included in the Annual Compliance Report that will be prepared and submitted in accordance with Section 7.0.

Table 6-11. Species Richness Performance Criteria

HABITAT	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
Upland	50%	55%	60%	65%	70%
Riparian	50%	60%	70%	80%	85%

Note: The targets are a percent of the species richness observed in appropriate reference communities.

6.3.1.2 Tree and Shrub Density

Trees and shrubs provide important structural features in upland and riparian habitats. Target densities will be achieved by planting bare root plants, seeding and natural recruitment from surrounding seed sources. The Renewal Corporation's field botanists will not differentiate between natural and planted trees and shrubs. All woody plants present in the plots will be treated equally. The density data will allow the Renewal Corporation's field staff to assess species performance in the sediments and to focus maintenance activities on planting species that exhibit tolerance to the unique environmental conditions. This data will also provide a species richness and diversity metric for woody plants.

The Renewal Corporation will base tree and shrub density on a percentage of densities observed in target plant communities (Table 6-12). The Renewal Corporation expects that riparian areas will support densities close to reference conditions more quickly than in drier upland sites.

Table 6-12. Tree and Shrub Density Performance Criteria

HABITAT	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
Upland	50%	55%	60%	65%	70%
Riparian	50%	60%	70%	80%	85%

Note: The targets are a percent of the density of trees and shrubs observed in appropriate reference communities.

6.3.1.3 Vegetation Cover

The Renewal Corporation's criteria for vegetation cover is based on the percentage of vegetation cover observed in target plant communities (Table 6-13). Vegetation cover includes herbaceous and woody species and is calculated as the inverse of bare ground encountered along line-intercepts. In riparian/wetland areas, primary succession can result in rapid cover of vegetation, which can be accelerated by irrigation. The Renewal Corporation expects upland vegetation cover to be slow to reach targets because dry, primary successional surfaces devoid of vegetation take time to develop. For example, it is not anticipated that oak trees will develop significant cover in only seven (7) years. A progression of increasing cover is expected annually after Year 4.

Table 6-13. Vegetation Cover Performance Criteria

HABITAT	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
Upland	15%	25%	45%	60%	80%
Riparian	40%	50%	60%	70%	80%

Note: The targets are a percent of the vegetation cover observed in appropriate reference communities.

6.3.1.4 Non-Native Vegetation Relative Frequency

Typically, ocular cover data are used to assess abundance of non-native species. An alternative abundance measurement is frequency. Frequency is measured using presence/absence plots. Relative frequency calculates the percentage of all nonnative plants present relative to appropriate reference sites. This method is quicker and repeatable with low observer variability compared to ocular cover estimates. During monitoring events, vegetation frequency data collection will treat all non-native species equally (i.e., IEV will not be weighted differently - see Section 5.3.3 for discussion of non-native plants versus IEV).

While the Renewal Corporation's proposed seeding is designed to significantly reduce the abundance of non-native vegetation that initially establishes, the Renewal Corporation still expects a relatively slow increase in the frequency of non-native vegetation. Although this is not ideal, it is based on the conditions in the surrounding landscape, especially the fact that all three (3) reservoirs are surrounded by significant populations of non-native species. Non-native vegetation frequency performance criteria take this into account, with non-native vegetation frequency performance criteria increasing each year (Table 6-14).

Table 6-14. Non-Native Vegetation Frequency Performance Criteria

HABITAT	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
Upland	25%	40%	55%	70%	90%
Riparian	25%	40%	55%	70%	90%

Note: The targets are a percent of the total non-native vegetation frequency relative to the non-native vegetation frequency observed in appropriate reference communities. All IEV species occurrence will be included in non-native vegetation data collection; high priority IEV species will be eradicated upon observation, following occurrence frequency notation.

While the Renewal Corporation's IEV management strategy (as discussed in section 5.3.3) includes measures to contain highly invasive species, it does not focus on all non-native species. High-priority IEV will not be tolerated in the non-native vegetation frequency plots and will also be monitored separately outside the plots to contain occurrences within the Reservoir Areas. Randomly located, quantitative plots, such as those used to measure non-native vegetation frequency, are excellent at determining large-scale patterns of relative abundance but are not designed for effective early detection and rapid response to IEV.

6.3.2 Monitoring Methods

The Renewal Corporation will use the qualitative and quantitative monitoring methods discussed in this section.

6.3.2.1 Qualitative Monitoring Methods

The Renewal Corporation's qualitative monitoring will begin immediately after dam removal in Year 2 and will continue annually until monitoring is completed in accordance with the requirements set forth in Table 6-5. The Renewal Corporation's qualitative monitoring includes regular site inspections of all plantings and seeded areas conducted by professional botanists and ecologists. The Renewal Corporation's qualitative inspections allow for in-season adaptive management of vegetation and will inform project managers of the progress of vegetation development. The Renewal Corporation will promptly establish landscape-scale photo points following drawdown to represent the overall response of vegetation. During the maintenance and monitoring period, the Renewal Corporation will establish photo points at all monitoring plots that will be repeated annually.

6.3.2.2 Quantitative Monitoring Methods

The Renewal Corporation will monitor performance criteria using quantitative vegetation surveys in permanent plots randomly located within the Reservoir Areas and stratified by landform (riparian or upland) and treatment (i.e., seeded only, planted and seeded, or unmanaged). Each plot will survey for all four (4) performance criteria and will consist of a line-intercept and a 100-square-meter (approximately 1,076 square feet) plot. In uplands, the plots will be larger to ensure that tree and shrub densities are accurately measured. The final size and dimensions (shape) for these plots will be determined by reference sites in adjacent areas.

6.3.2.2.1 Quantitative Plot Monitoring Methods

Observational setup at each location shall consist of the following three (3) elements: a 20-meter line-intercept transect, a 160 square meter plot (smaller plots may be used in high density wetland/riparian areas) and multiple 80-square-centimeter plots. Bare ground, the cover of woody plants (to species, upper canopy only included), and the total cover of herbaceous plants (not identified to species, only noted where no woody cover overlaps) will be measured along the line-intercept transect. Within each 160 square meter plot, all plant species will be identified to species (for measure of species richness), and all trees and shrubs will be counted by species (for measure of tree and shrub density). Within each plot, a minimum of ten 80- square-centimeter quadrats (more may be needed in larger plots) will be located along either side of the line-intercept and sampled for rooted plant frequency (for measure of nonnative relative frequency).

There will be three types of plots surveyed for the Lower Klamath Project: reference plots, treatment plots and control plots. Reference plots are plots located in mature vegetation around the reservoirs and will be used to determine the baseline metrics for all performance criteria. Treatment plots are plots located within the dewatered reservoirs after dam removal that have received some form of revegetation treatment (i.e., seeded, planted, or seed and planted) that are the focus of revegetation efforts. Control plots are plots located within the dewatered reservoirs that have not been treated with a revegetation prescription.

The Renewal Corporation will survey plots during late spring/early summer to ensure that annual species are well represented in the data. Many native and nonnative annual species are prevalent in the surrounding plant communities, and these species senesce in the hot summers, when they are difficult to identify.

6.3.2.2.2 Reference Plots

Reference sites consist of plots located in the areas immediately surrounding the reservoirs and will be surveyed to determine the baseline metrics for all performance criteria. Plots will be stratified by habitat type and randomly located in areas surrounding the Reservoir Areas. The lands surrounding the Copco No.1 Reservoir are primarily owned by private landowners and will be difficult or impossible to access. The Iron Gate reference plots will therefore be used to determine the baseline metrics for the performance criteria related to the Copco Reservoir Areas since the Renewal Corporation considers the Iron Gate reference plots to be an adequate substitute due to the similar elevations and habitat conditions.

The reference sites will be identified by the Renewal Corporation prior to drawdown in coordination with HRG. The Renewal Corporation will survey the reference plots in adjacent upland and riparian sites in the spring and summer of Year 0 and Year 1 to establish a baseline for the performance criteria. The field monitoring team will sample multiple plant communities in the uplands around the reservoirs and locate appropriate tributary and mainstem riparian habitats for sampling. The Renewal Corporation will survey multiple reference plots (Table 6-15) and use the mean value for each vegetation characteristic to establish specific target numbers for all four (4) criteria to meet. For example, if the mean number of species identified in uplands is 32, 50 percent of 32 (16) will be the target species richness value for uplands in Year 6.

Reference plots will be surveyed by the Renewal Corporation during Years 4, 6 and 8. All performance criteria metrics will be surveyed at all reference sites. While woody stems are not expected in grassland areas (seeded only sites), they will be recorded if present.

Table 6-15. Vegetation Reference Plot Summary

LANDFORM	HABITAT TYPE	NUMBER OF PLOTS[1]	
		JC BOYLE	IRON GATE
Riparian	Riparian – mainstem	**6**	**9**
	Riparian – tributary	4	9
Upland	Oak woodland	0	11
	Chaparral[2]	6	11
	Grassland[2]	0	13
	Ponderosa pine woodlands	7	0
	Palustrine wetland	4	4
	TOTAL PLOTS	**27**	**47**

1. Plot numbers may be reduced if data analysis reveals no differences based on reservoir.
2. Chaparral and grassland habitats are anticipated to occupy the largest area within the reservoirs post-dam removal.

6.3.2.2.3 Treatment Plots

The treatment plots within the dewatered reservoirs will be stratified by landform, target type, treatment, and reservoir, as described below in Table 6-16. The data for each reservoir will be evaluated for each performance criterium for each habitat type and compared to data from reference plots. See Appendix H for additional information on performance criteria monitoring protocols and data analysis protocols.

Table 6-16. Numbers of Treatment Plots to Determine Performance Criteria Metrics

LANDFORM	HABITAT TYPE	TREATMENT	NUMBER OF PLOTS[1]		
			JC BOYLE	COPCO	IRON GATE
Riparian	Riparian – mainstem	Seeded & Planted	**5**	**8**	**8**
	Riparian – tributary	Seeded & Planted	4	7	6
	Control- riparian	No Treatment	6	9	9
Upland	Oak woodland	Seeded & Planted	0	4	8
	Chaparral[2]	Seeded & Planted	6	11	11
	Grassland[2]	Seeded Only	6	14	13
	Ponderosa pine woodlands	Seeded & Planted	6	4	0
	Palustrine wetland[3]	Seeded & Planted	4	4	4
	Control- upland	No Treatment	6	9	9
		TOTAL PLOTS: 181	**43**	**70**	**68**

Notes:
1. Plot numbers may be reduced if data analysis reveals no differences based on reservoir. For example, Copco and Iron Gate are very similar and may not require independent sampling. If that is proven in data analysis across all habitat types, plots will be reduced by randomly selecting a few to remain in each reservoir for future monitoring efforts.
2. Chaparral and grassland habitats are anticipated to occupy the largest area within the reservoirs post-dam removal.
3. Palustrine wetlands have the fewest plots because the total area anticipated to become palustrine wetlands is low.

The number of treatment plots was determined based on revegetation monitoring in the Elwha River (Prach et al. 2019; Chenoweth et al. 2021) and proportioned for the scale of the Lower Klamath Project and diversity of habitats. Primary successional plant communities differ by location (local flora) and disturbance (i.e., volcanic eruptions, glacier receding, and historical land use such as timber, row crop, and pasture). The Elwha Project has produced the only published data for a primary succession that was seeded and planted following large-scale dam removal. Monitoring for the Lower Klamath Project reflects elements of that monitoring plan to capture similar response variables. The total habitat acreage anticipated for each reservoir following dam removal is provided in Table 6-17.

The Renewal Corporation will survey treatment plots in the reservoirs annually for five years regardless of meeting performance criteria goals. However, many treatment plots will be established where possible in the reservoirs prior to the start of surveying for adaptive management purposes and to help develop the 5-year Maintenance Plan (see 6.3.2.2.4).

Table 6-17.Total Habitat Acreage Anticipated for Each Reservoir Post-Dam Removal

RESERVOIR	RIPARIAN-MAINSTEM (ACRES)	RIPARIAN-TRIBUTARY (ACRES)	DRY UPLANDS (ACRES)[1]	PALUSTRINE WETLAND (ACRES)	TOTAL (ACRES)
JC Boyle	40.6	15.1	197.1	5.8	258.6
Copco	82.4	53.0	719.5	7.5	862.4
Iron Gate	85.2	30.5	715.0	5.9	836.6
				TOTAL ACREAGE EXPOSED	1,957.6

1. Dry uplands include Oak woodland, Chaparral, Grassland and Ponderosa pine woodlands. The final distribution and acreages of these four cover types will be determined post-drawdown once final post-drawdown conditions become known.

6.3.2.2.4 Control Plots within the Reservoir Areas

The Renewal Corporation will leave areas within the Reservoir Areas unseeded and unplanted (control areas) to provide additional reference conditions to managed areas. Control areas will be small, limited to a few acres in areas away from residential viewpoints. The Renewal Corporation will treat these control sites for IEV. The Renewal Corporation will establish plots in the control areas to provide additional reference conditions and to adaptively manage the revegetation project and expectations. If necessary, the Renewal Corporation will use data from control areas to reassess the performance criteria in consultation with the HRG if traditional reference sites are not proving informative to vegetation development (see table 6-16 for number of control plots).

6.3.3 Adaptive Management for Vegetation

6.3.3.1 Maintenance Activities

If the monitoring data determined that the performance criteria outlined above are not being met, the Renewal Corporation will take the following actions:

1. Determine the cause of the problem. Appropriate staff, including but not limited to, restoration ecologists, botanists, soil scientists, hydrologists, and geomorphologists, will assess environmental conditions and submit a report to the Lower Klamath Project management team.
2. Performance criteria will be re-evaluated by comparing plot data to control sites. Results will be summarized and submitted to the HRG for review.
3. If necessary, proposed remedial measures based on problem determination will be submitted to the HRG for consultation prior to implementation.

Remedial actions implemented by the Renewal Corporation will be monitored to determine whether they are successful. The maintenance period will begin in Year 4. The Renewal Corporation will use data from the first two (2) years to develop the five (5) year maintenance plan. Maintenance will focus on meeting performance criteria and managing IEV species within the Reservoir Areas.

Several options are available to provide successful revegetation during the maintenance period including reseeding, plant replacement, irrigation, and IEV management. The Renewal Corporation's additional revegetation actions may include mulching, compost or other natural nutrient additives, and herbivore fencing.

6.3.3.1.1 Reseeding

The Renewal Corporation may reseed areas that are not performing up to standard (i.e., low cover, low richness or high IEV abundance) with species proven to succeed in the unique environmental conditions (fine sediments). The Renewal Corporation will use data from control plots and treatment plots to determine species patterns that are successful, and seed may be wild-collected to sow into trouble sites. New seed increase contracts or genetically appropriate native seed materials may be necessary to seed large areas during the maintenance period. The Renewal Corporation may use drill seeding to reseed certain areas as necessary.

6.3.3.1.2 Plant Replacement

The Renewal Corporation may replant if tree and stem densities do not meet the target numbers defined in the performance criteria. Species selected for replanting will be based on native species proven to tolerate the unique environmental conditions in the Reservoir Areas based on data collected in the first two (2) years.

6.3.3.1.3 Irrigation

Irrigation may be a remedial action at sites with facilitation patches of trees and shrubs. The Renewal Corporation will consider the location and irrigation methodology needed during the maintenance period.

6.3.3.1.4 IEV Management

The management of IEV species is critical to successful revegetation. Long term management will be dependent on how the sites evolve and will be based on data from a few years of monitoring. Adaptive IEV management is therefore likely to be re-assessed by the Renewal Corporation during Year 5 or Year 6.

7.0 Data Management and Reporting

The Renewal Corporation will manage compliance planning and documentation for the Reservoir Area Management Plan and the other management plans discussed in Section 2.2, Relationship to Other Management Plans.

The Renewal Corporation will prepare and submit an Annual Compliance Report within six (6) months of concluding drawdown activities, and annually thereafter for as long as the Renewal Corporation has performance obligations under the Reservoir Area Management Plan. For purposes of the Annual Compliance Report, drawdown activities will be considered concluded when the Klamath River lowers to, and permanently occupies, its original 100-year flood channel. The Annual Compliance Report will be submitted to the SWRCB and ODEQ, and copied to the HRG, by April 1. In addition, the Annual Compliance Report will be submitted to the Commission by April 15. The Annual Compliance Report will include the following:

1. Monitoring data, including graphical representations, as appropriate
2. Consultation record (Appendix A)
3. A narrative interpretation of the results of restoration
4. A summary of all significant interventions taken to remove fish passage barriers
5. Adaptive management recommendations and actions
6. A description of any tree removal activities performed in Ward’s Canyon
7. A summary of whether performance criteria is being met and/or whether restoration is on a trajectory to achieve the performance criteria

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Appendix A

Consultation Record

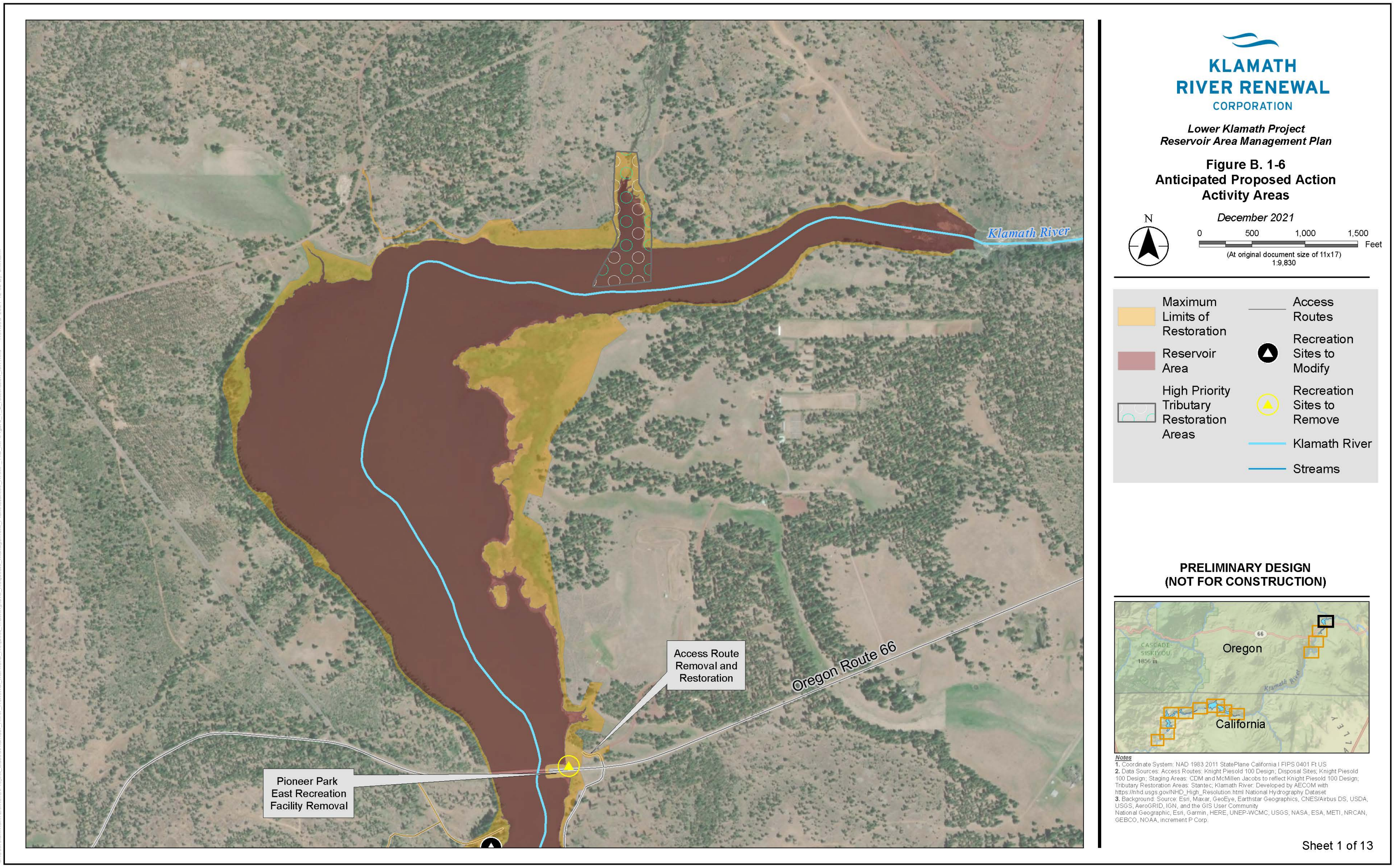
Consultation Record

Reservoir Area Management Plan		
Agency	**Date of Agency Plan Submittal**	**Agency Comments Received Date**
National Marine Fisheries Service	January 27, 2021 August 10, 2021	February 8, 2021 August 11, 2021
United Stated Fish and Wildlife Service	January 27, 2021 August 10, 2021	February 8, 2021 August 23, 2021
California State Water Resources Control Board	January 25, 2021 August 10, 2021	April 30, 2021 August 23, 2021
California Department of Water Resources	January 25, 2021 August 10, 2021	No Comments Received No Comments Received
California North Coast Regional Water Quality and Control Board	January 25, 2021 August 10, 2021	No Comments Received No Comments Received
California Department of Fish and Wildlife	January 25, 2021 August 10, 2021	February 8, 2021/ April 16, 2021 August 23, 2021
Karuk Tribe	January 25, 2021 August 10, 2021	No Comments Received No Comments Received
Yurok Tribe	January 25, 2021 August 10, 2021	No Comments Received No Comments Received
Klamath Tribes	August 10, 2021	No Comments Received
Oregon Department of Environmental Quality	January 25, 2021 August 10, 2021	No Comments Received August 30, 2021
Oregon Department of Fish and Wildlife	January 25, 2021 August 10, 2021	April 16, 2021 September 9, 2021

Reservoir Area Management Plan		
Agency	**Date of Agency Plan Submittal**	**Agency Comments Received Date**
Bureau of Land Management – Klamath Falls	February 12, 2021 August 10, 2021	April 15, 2021 No Comments Received
Bureau of Land Management – Redding	August 10, 2021	No Comments Received

Appendix B

Figures / Detailed Map Books



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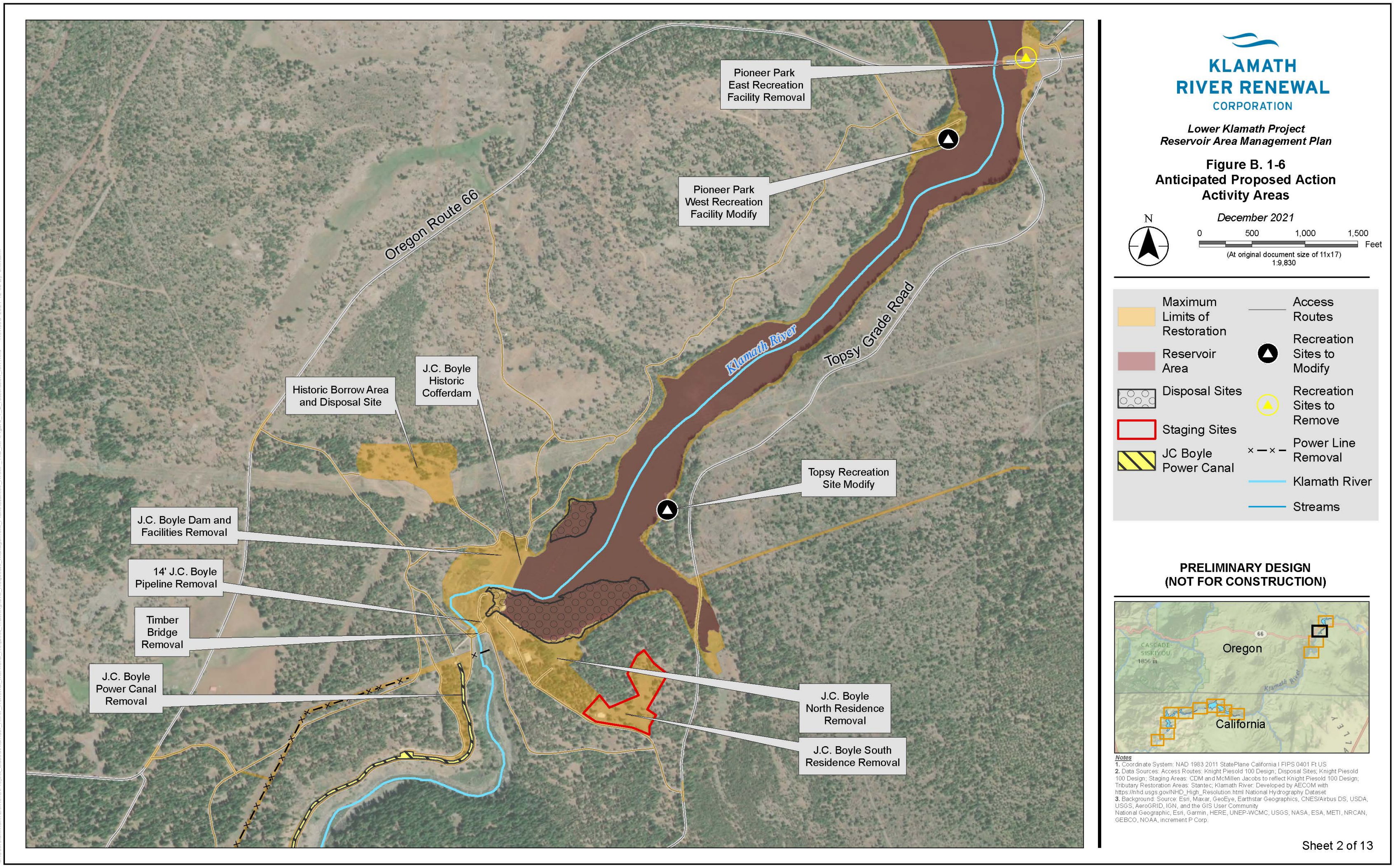

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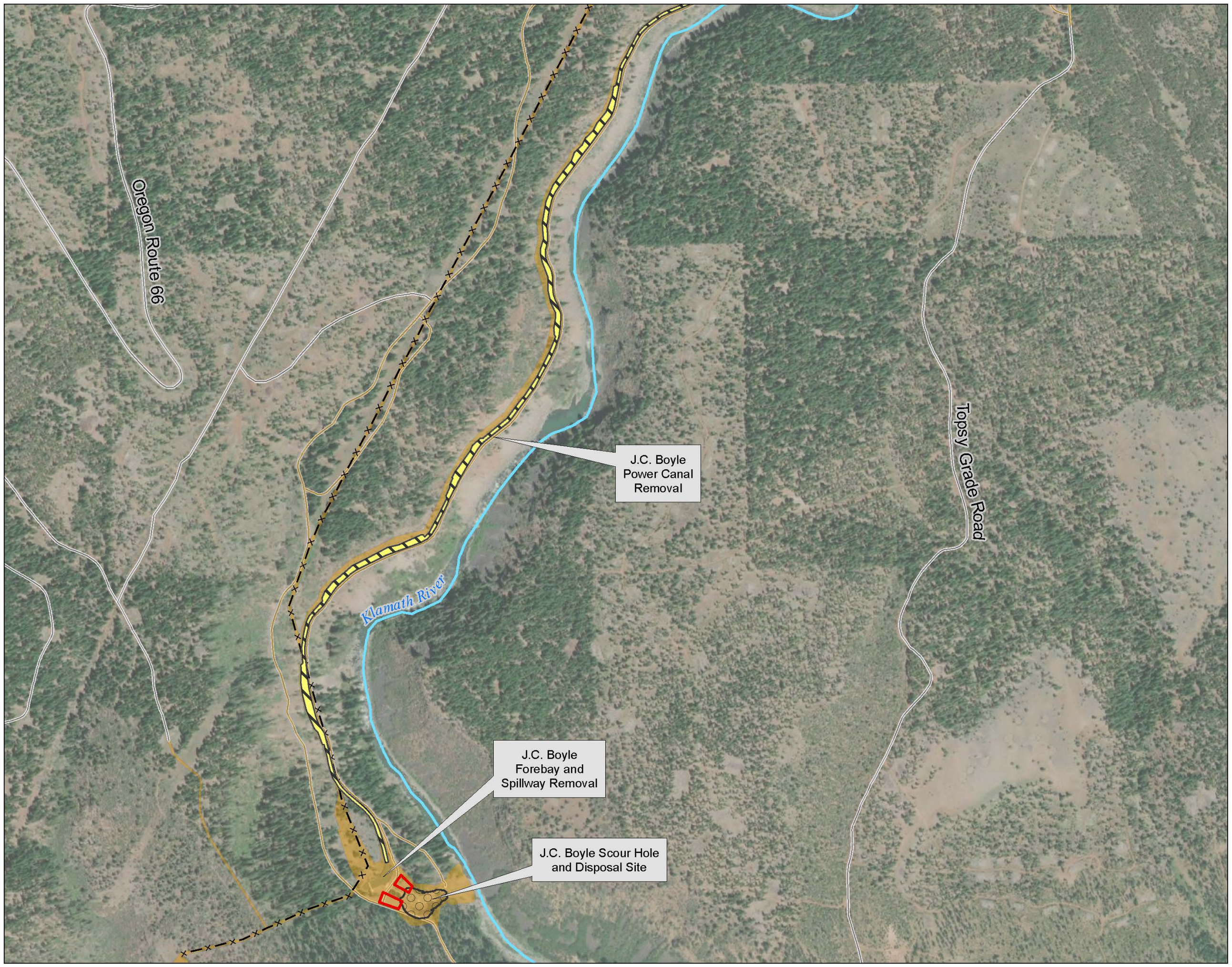


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

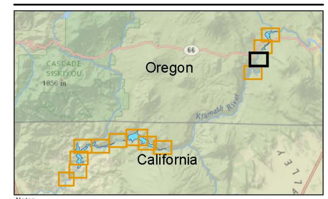
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

Maximum Limits of Restoration	Access Routes
Disposal Sites	Power Line Removal
Staging Sites	Klamath River
JC Boyle Power Canal	Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



Notes
1. Coordinate System: NAD 1983 2011 StatePlane California I FIPS 0401 Ft US
2. Data Sources: Access Routes: Knight Piesold 100 Design; Disposal Sites; Knight Piesold 100 Design; Staging Areas: CDM and McMillen Jacobs to reflect Knight Piesold 100 Design; Tributary Restoration Areas: Stantec; Klamath River: Developed by AECOM with https://nhd.usgs.gov/NHD_High_Resolution.html National Hydrography Dataset
3. Background: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Sheet 3 of 13

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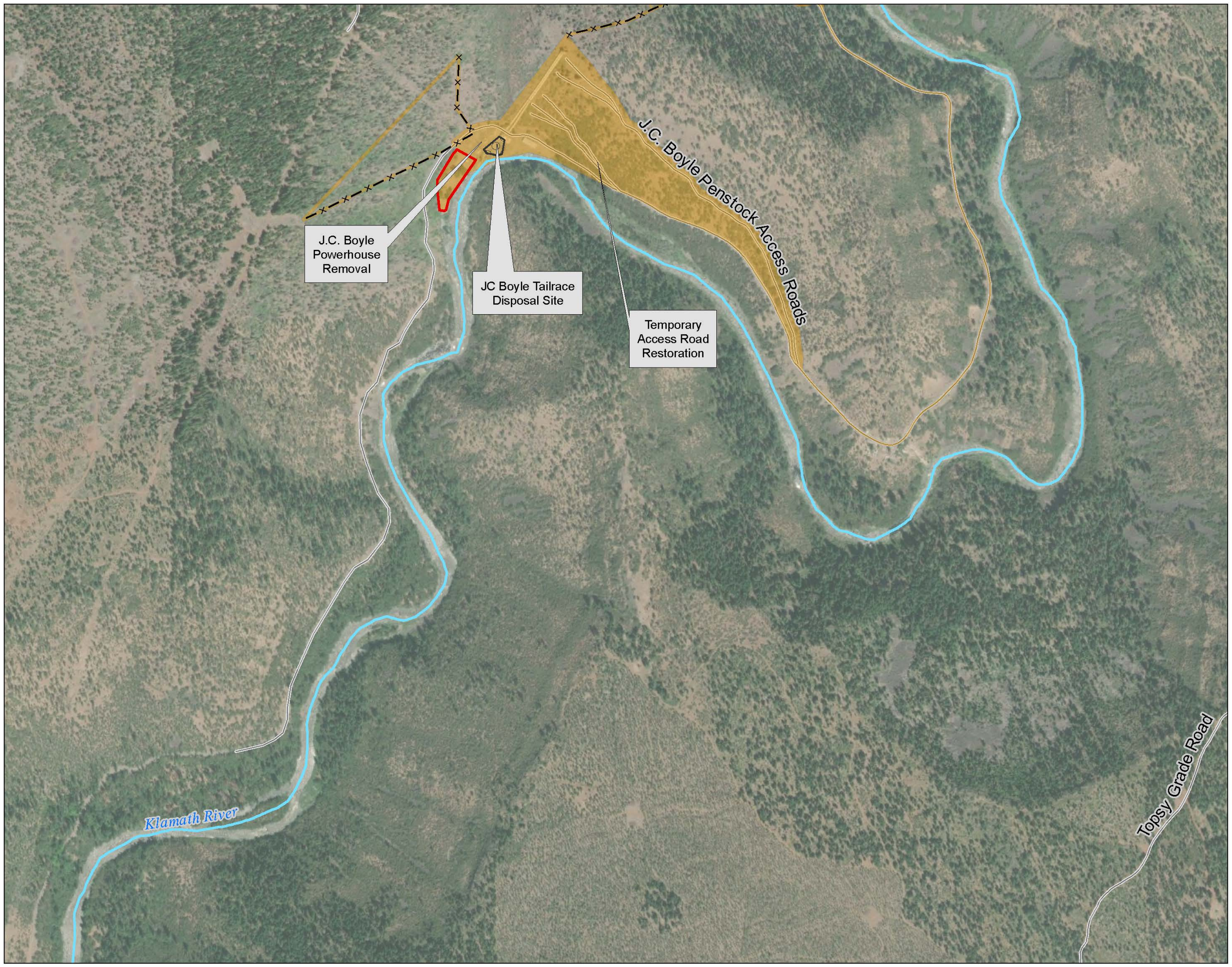


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

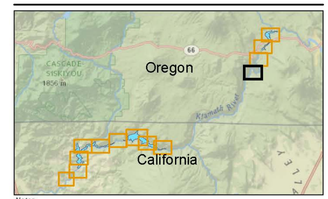
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

Maximum Limits of Restoration
Disposal Sites
Staging Sites
Access Routes
Power Line Removal
Klamath River
Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



Notes
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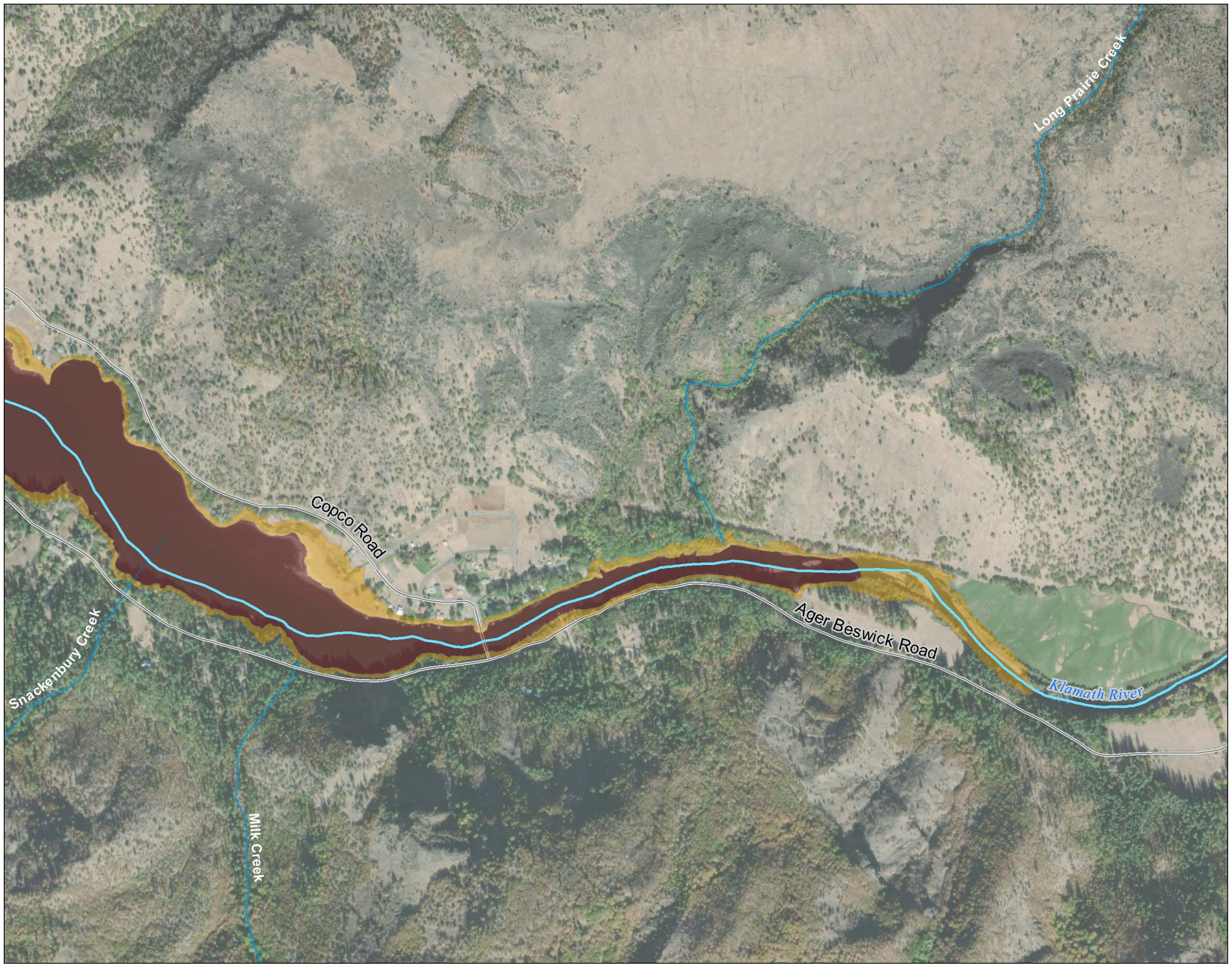


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

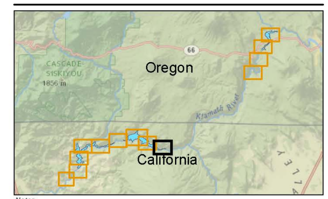
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

Legend	
Maximum Limits of Restoration	Access Routes
Reservoir Area	Klamath River
	Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



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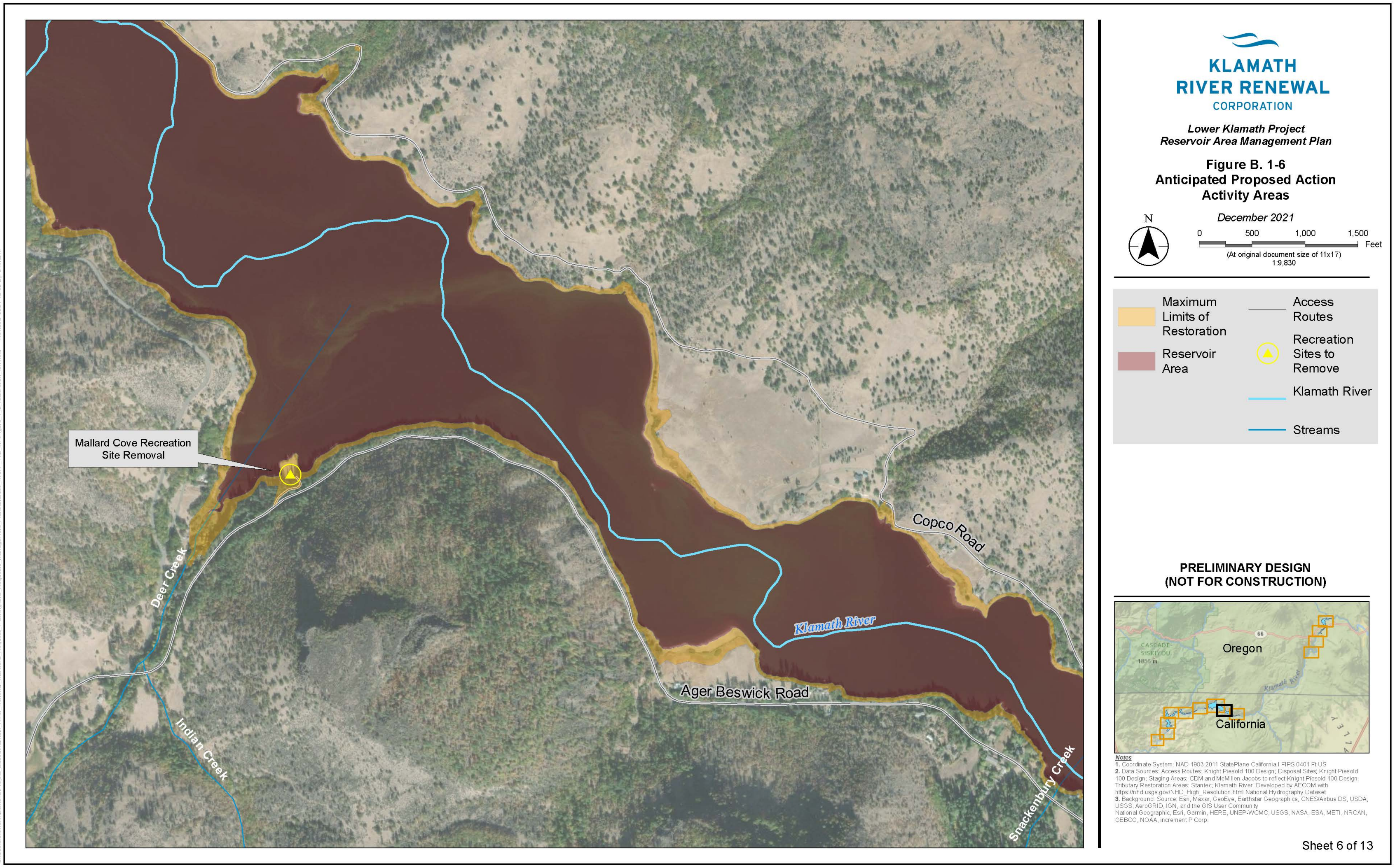

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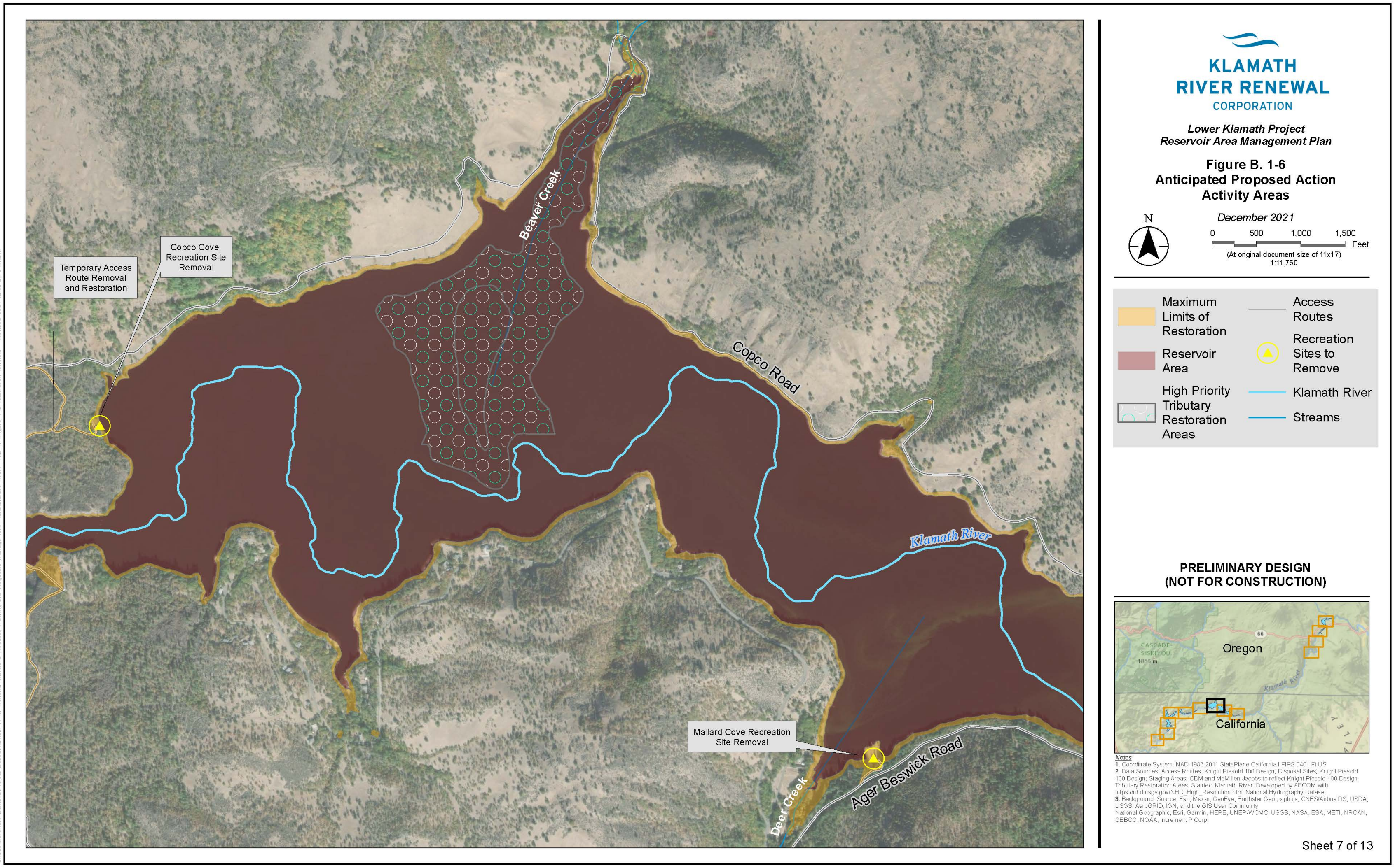

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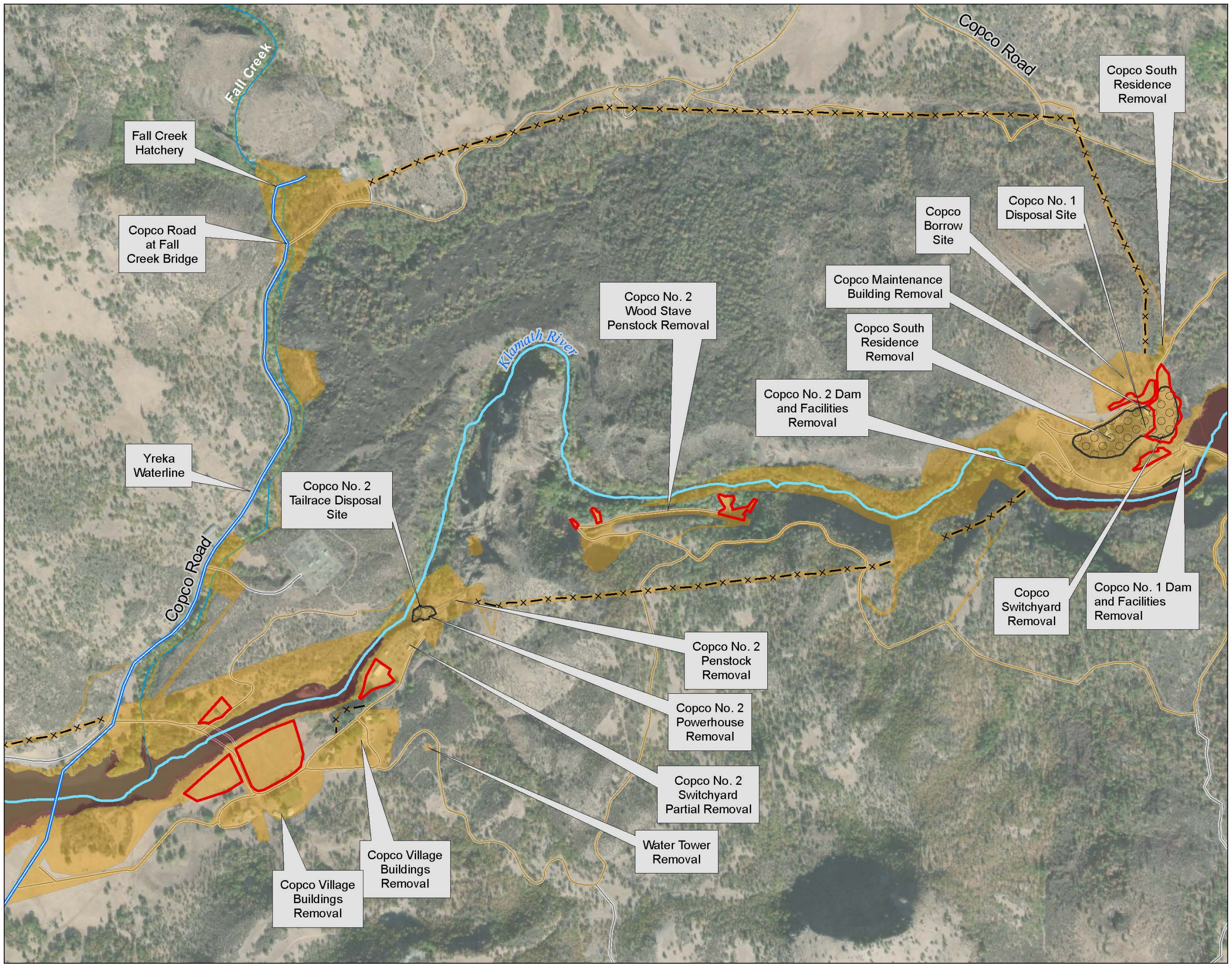


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

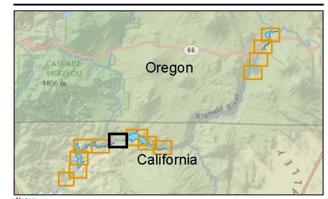
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

- Maximum Limits of Restoration
- Reservoir Area
- Disposal Sites
- Staging Sites
- Yreka Pipeline
- Access Routes
- Power Line Removal
- Klamath River
- Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



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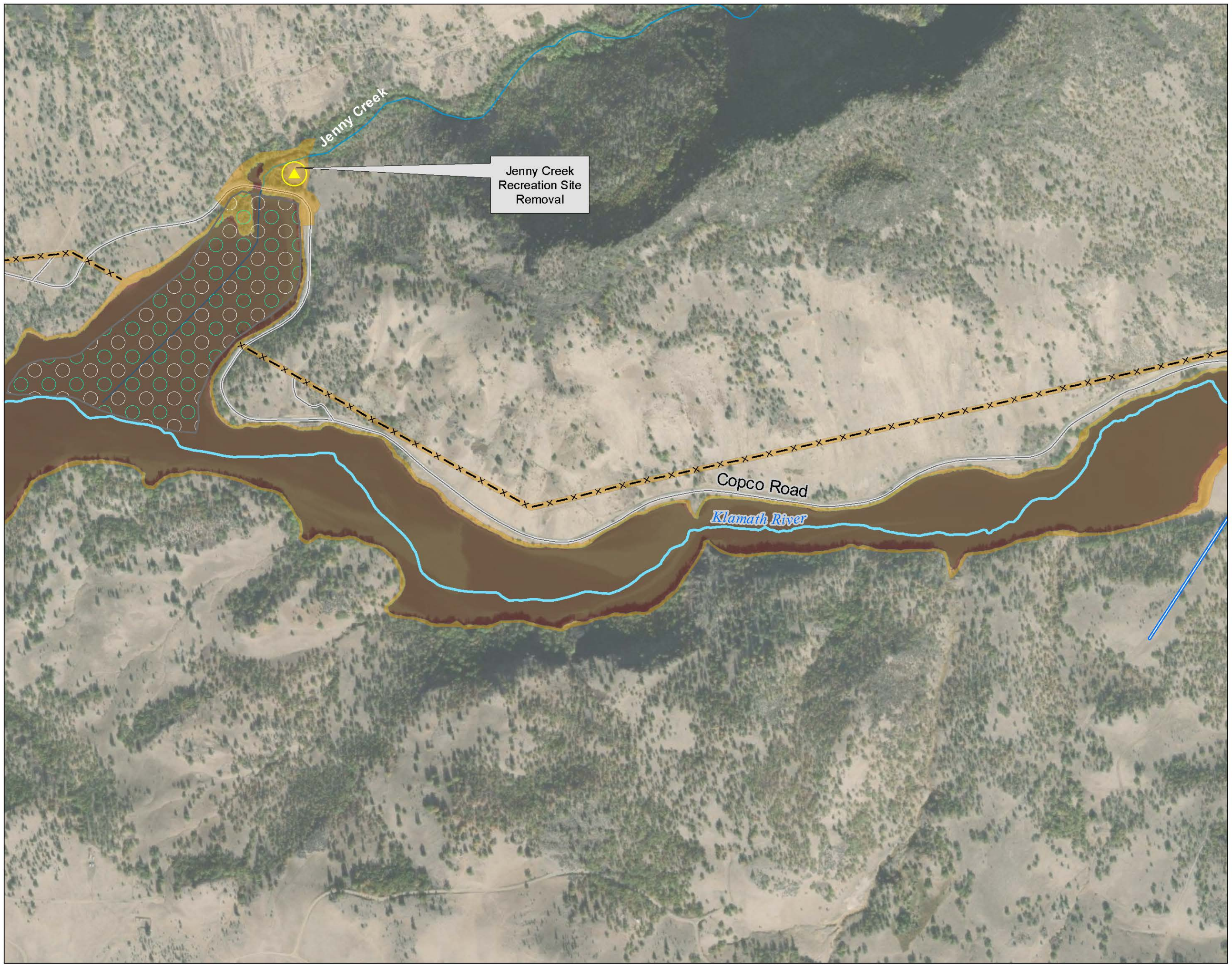
KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

December 2021



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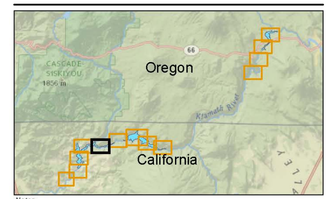

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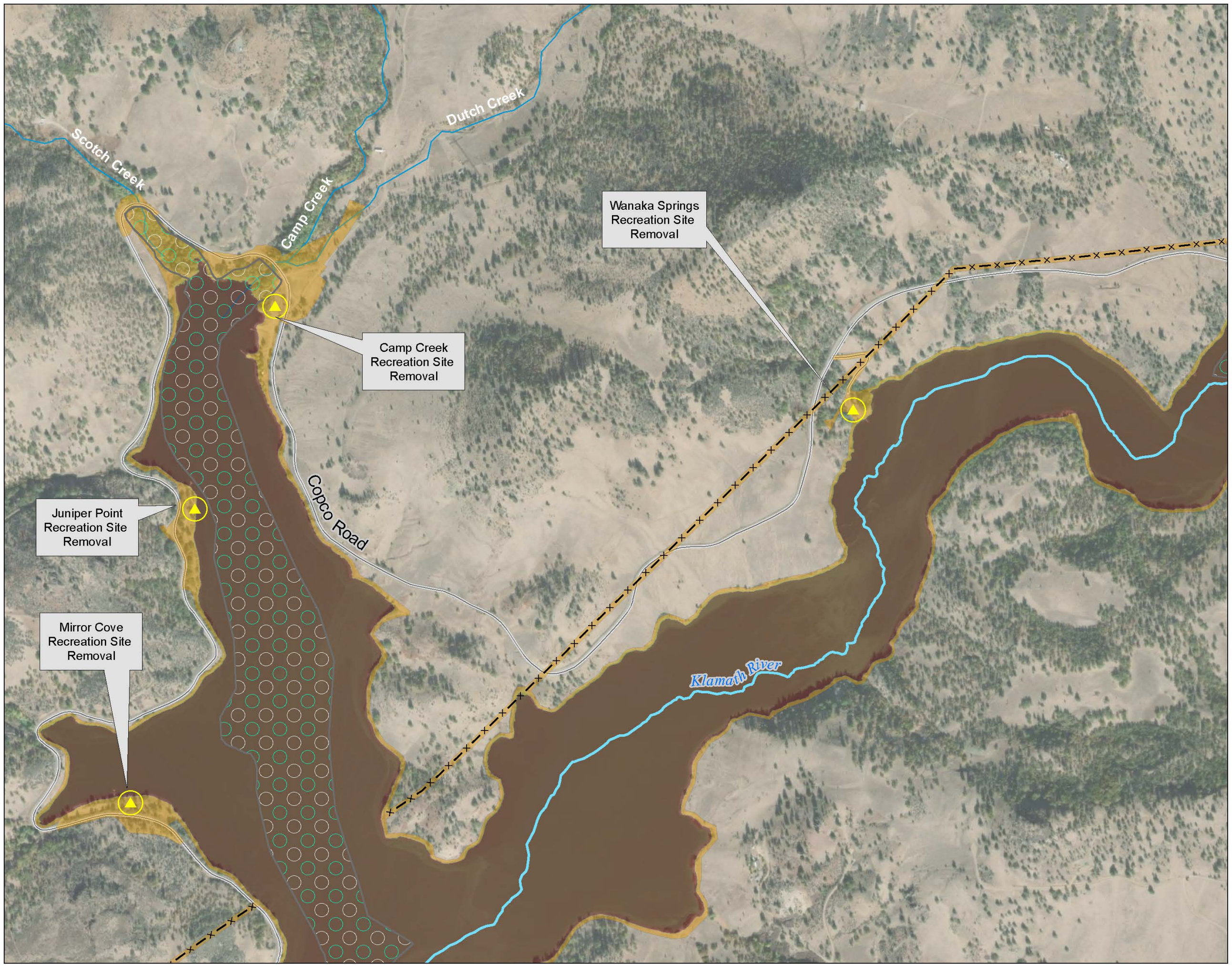


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

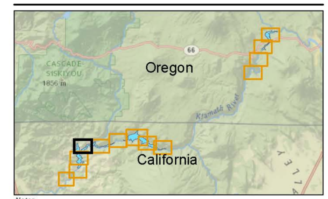
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

	Maximum Limits of Restoration		Access Routes
	Reservoir Area		Recreation Sites to Remove
	High Priority Tributary Restoration Areas		Power Line Removal
			Klamath River
			Streams

PRELIMINARY DESIGN (NOT FOR CONSTRUCTION)



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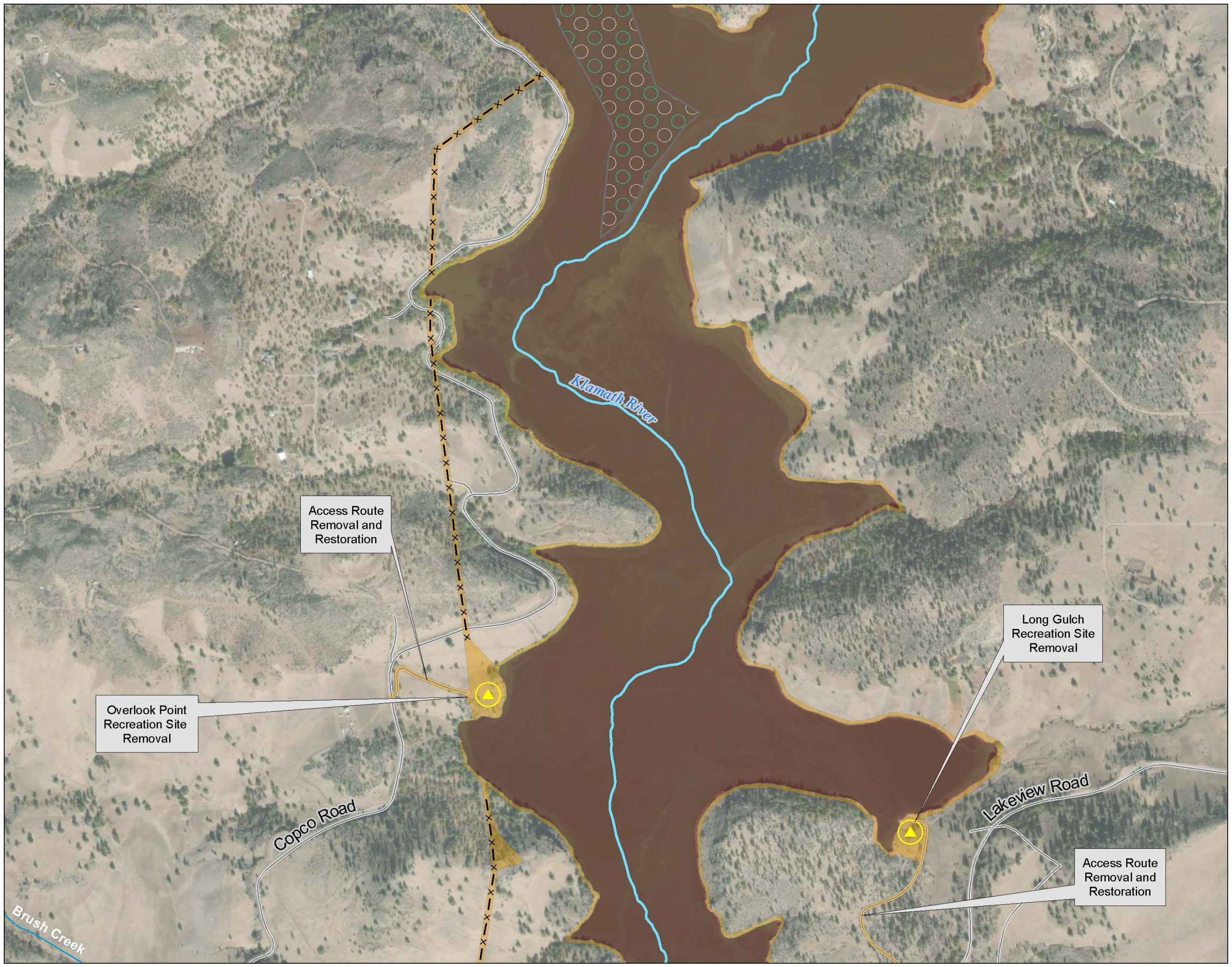


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

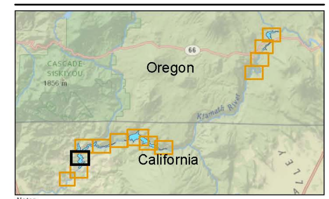
December 2021

N

0 500 1,000 1,500 Feet
(At original document size of 11x17)
1:9,830

- Maximum Limits of Restoration
- Reservoir Area
- High Priority Tributary Restoration Areas
- Access Routes
- Recreation Sites to Remove
- Power Line Removal
- Klamath River
- Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



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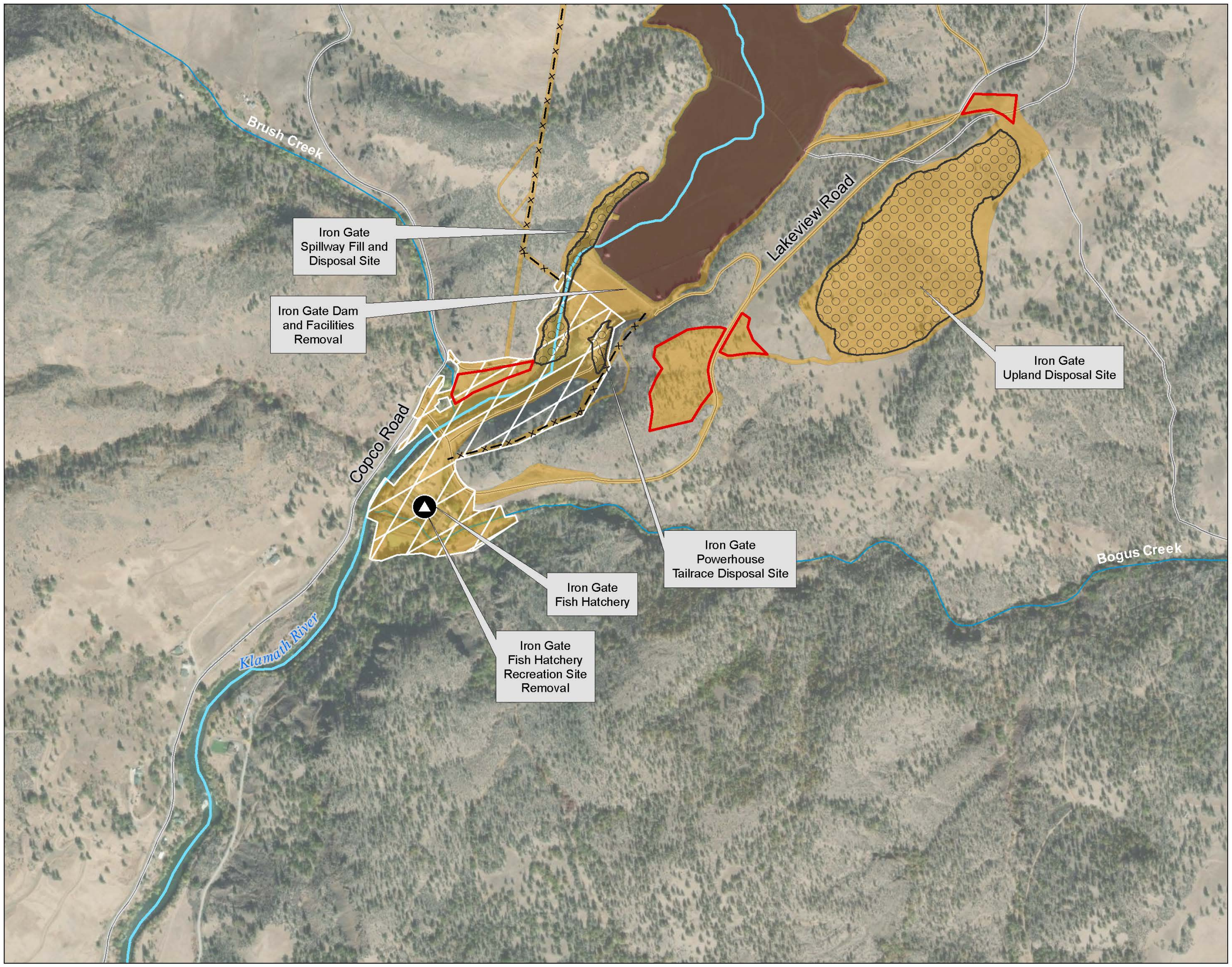


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

December 2021

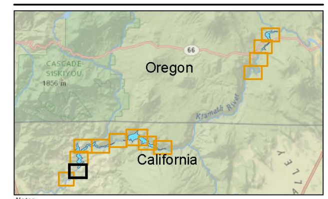
N

0 500 1,000 1,500 Feet

(At original document size of 11x17)
1:9,830

Maximum Limits of Restoration
Reservoir Area
Disposal Sites
Staging Sites
Iron Gate Dam and Associated Facilities Removal and Update
Access Routes
Recreation Sites to Modify
Power Line Removal
Klamath River
Streams

PRELIMINARY DESIGN (NOT FOR CONSTRUCTION)



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KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 1-6
Anticipated Proposed Action Activity Areas

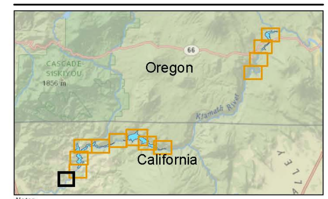
December 2021

N

0 500 1,000 Feet
(At original document size of 11x17)
1:9,480

(tan fill)	Maximum Limits of Restoration	(grey line)	Access Routes
		(light blue line)	Klamath River
		(blue line)	Streams

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



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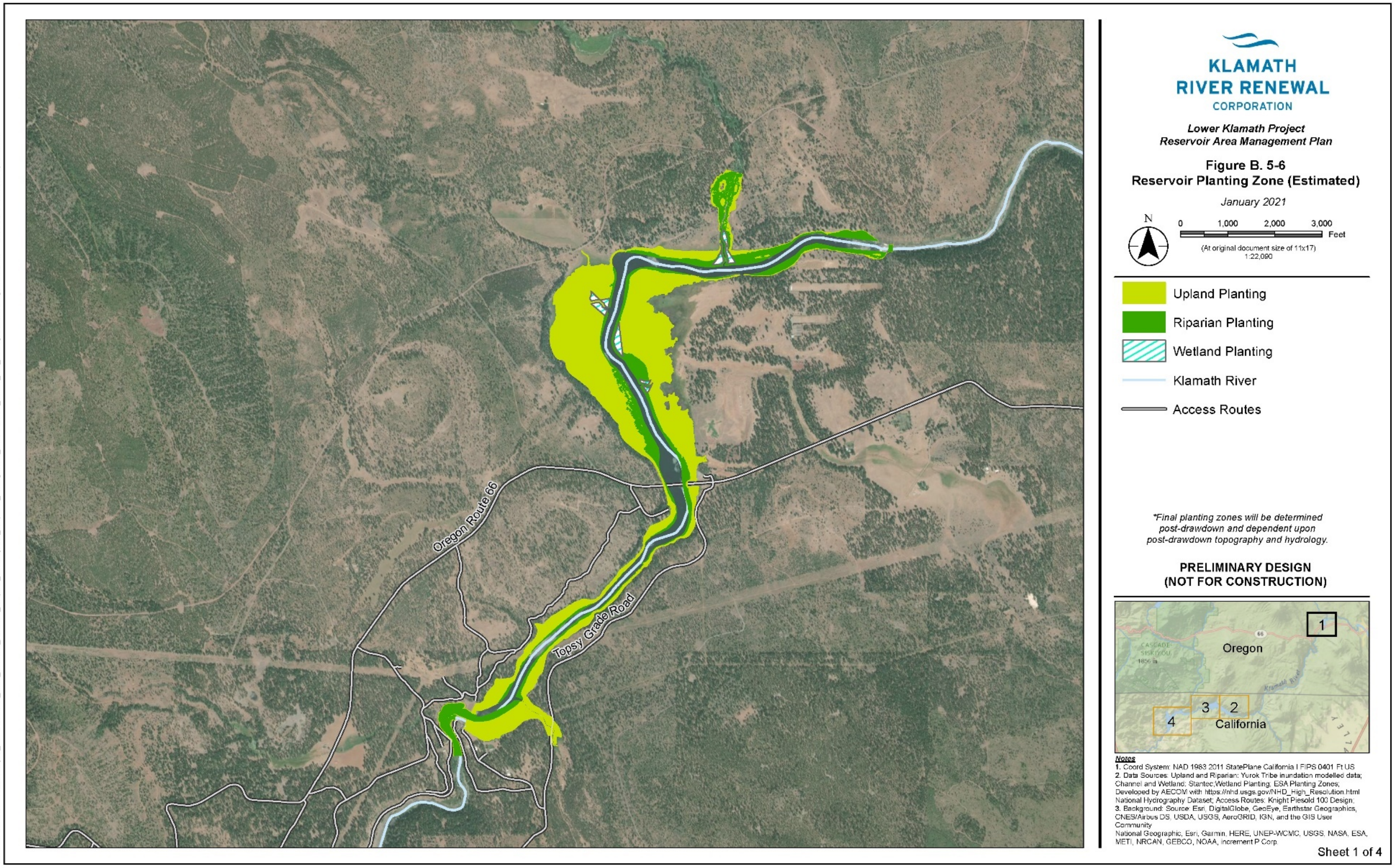

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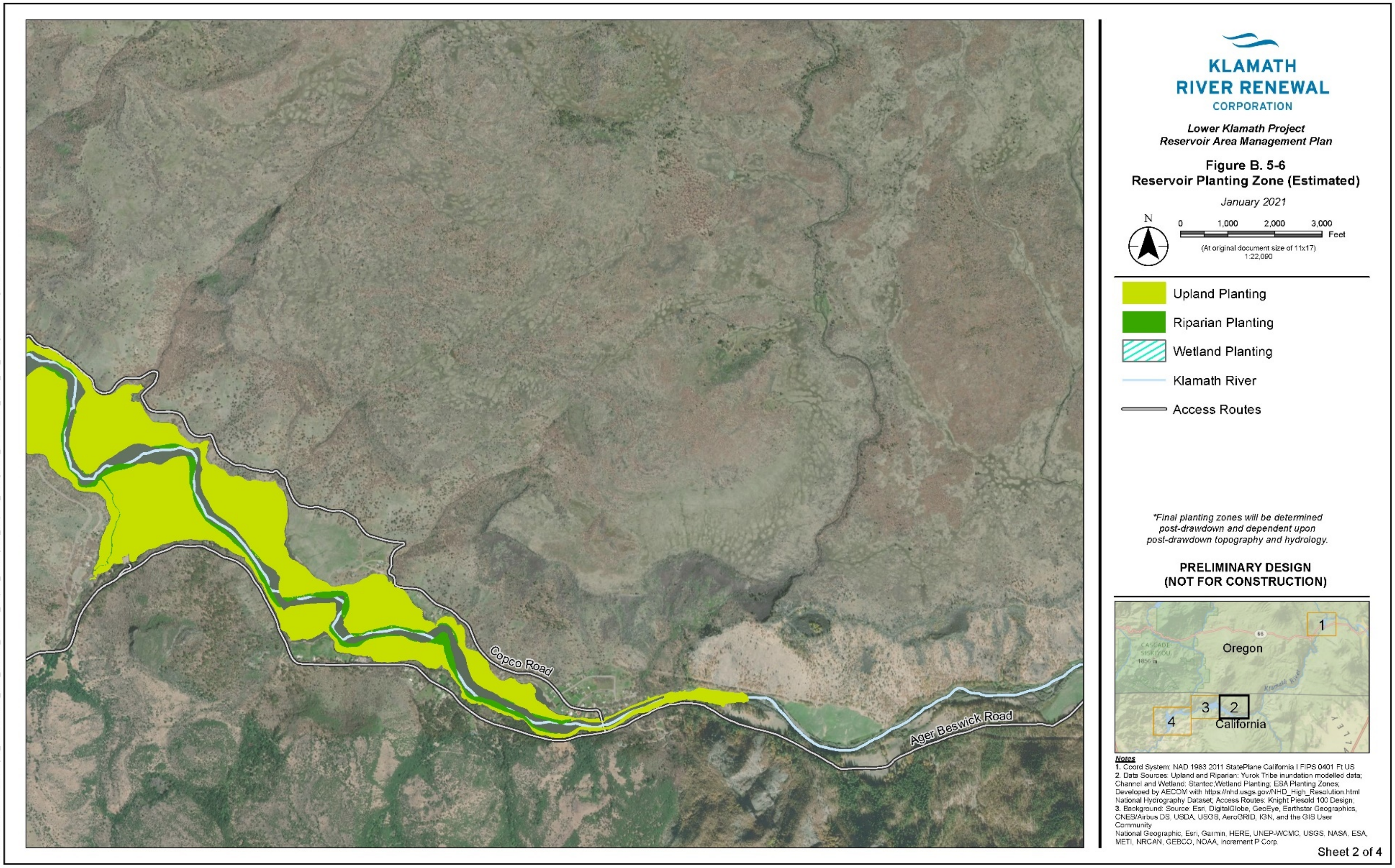

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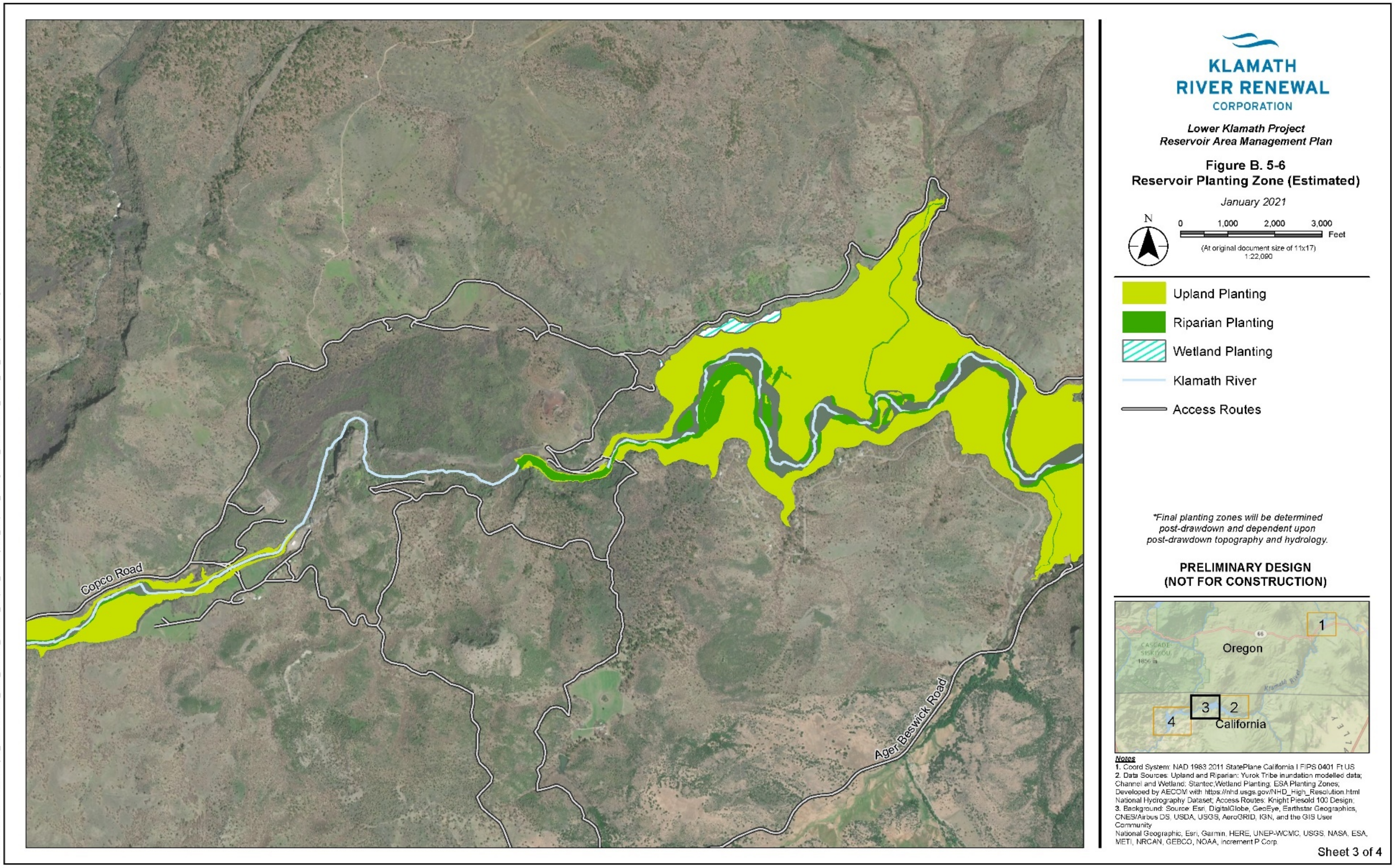

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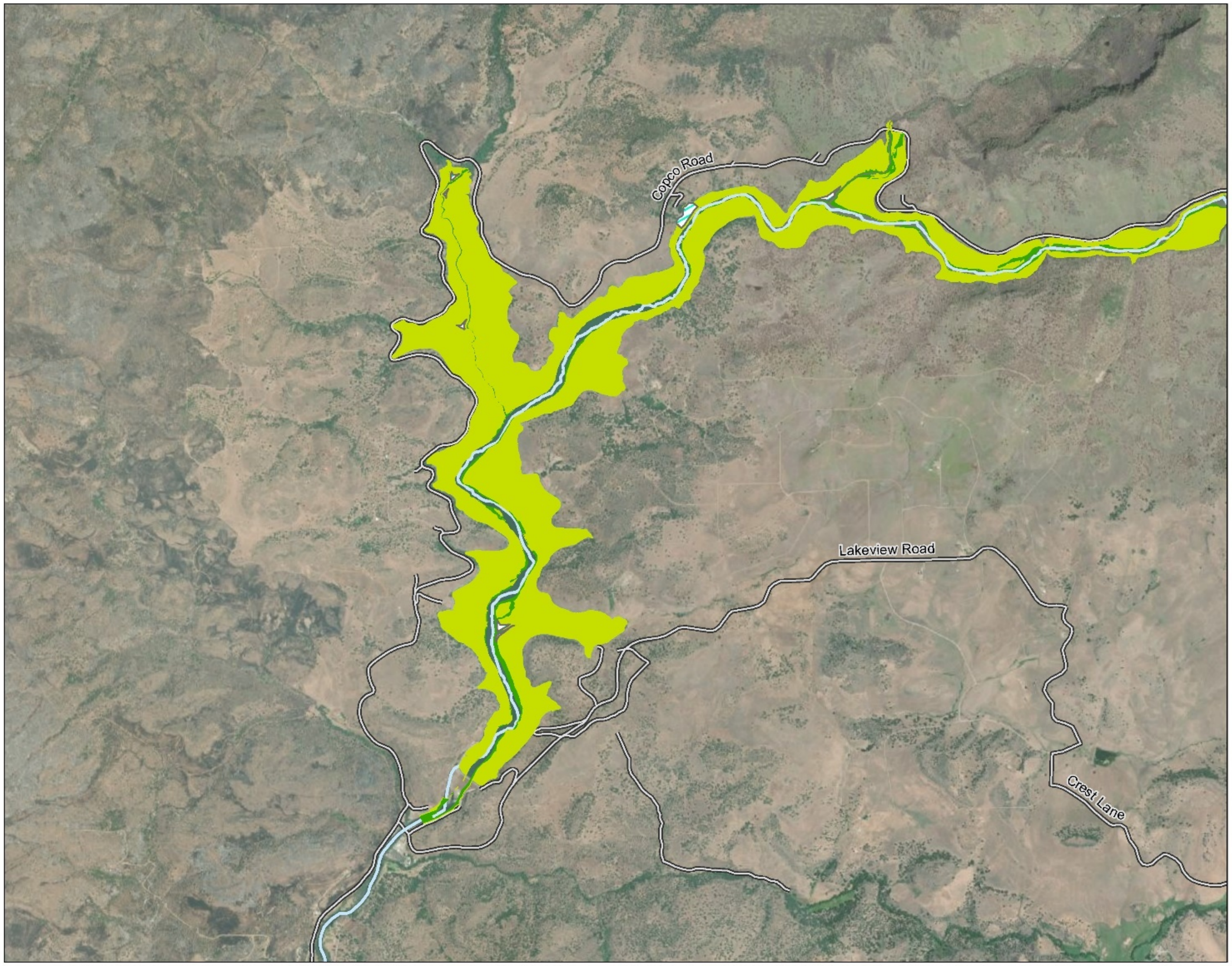


KLAMATH RIVER RENEWAL CORPORATION

Lower Klamath Project
Reservoir Area Management Plan

Figure B. 5-6
Reservoir Planting Zone (Estimated)

January 2021

N

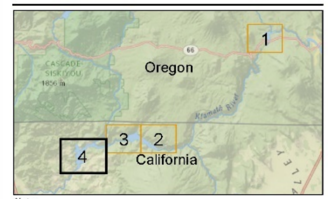
0 1,000 2,000 3,000 4,000 Feet

(At original document size of 11x17)
1:28,120

- Upland Planting
- Riparian Planting
- Wetland Planting
- Klamath River
- Access Routes

**Final planting zones will be determined post-drawdown and dependent upon post-drawdown topography and hydrology.*

PRELIMINARY DESIGN
(NOT FOR CONSTRUCTION)



Notes
1. Coord System: NAD 1983 2011 StatePlane California I FIPS 0401 Ft US
2. Data Sources: Upland and Riparian: Yurok Tribe inundation modelled data; Channel and Wetland: Stantec;Wetland Planting; ESA Planting Zones; Developed by AECOM with https://nhd.usgs.gov/NHD_High_Resolution.html National Hydrography Dataset; Access Routes: Knight Piesold 100 Design;
3. Background: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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Appendix C

Best Management Practices

Table C-1 below provides a categorized list of Best Management Practice (BMP) measures as discussed throughout the Reservoir Area Management Plan. A number of additional BMPs that are relevant to the restoration work described in the Reservoir Area Management Plan are contained in the Construction Management Plan. Such BMPs are explicitly incorporated into the Reservoir Area Management Plan and will be implemented by the Renewal Corporation to extent applicable to the restoration work performed under the Reservoir Area Management Plan. Table C-2 provides a summary of herbicide application buffers for applications near water resources (adapted from the 2021 Biological Assessment).

Table C-1. Best Management Practices (BMPs)

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
Limiting spread of invasive species		1. Maintain 50-foot-wide buffer free of IEV species around access roads and trails. 2. Thoroughly clean clothing and gear following site visits. 3. Check clothing and gear for soil, seeds, and plant materials. 4. Inspect and clean equipment upon entering and exiting the Limits of Work. 5. Inspect and clean vehicles upon entering and exiting the Limits of Work. 6. Train staff, including contractors, on weed identification and methods to avoid the unintentional spread of invasive plants. 7. Manage vegetation using methods that reduce the spread of invasive species and encourage desirable vegetation.
In-Water Work	Significant Interventions	1. ARG will be notified a minimum of 48-hours before start of work. 2. Unless under the guidance of ARG, in-water construction will occur during the in-water work construction windows set forth below. 3. A biologist will evaluate the in-water habitat to determine if salmonids or protected fish occur in the Limits of Work. a. If salmonid or protected fish are or are assumed to be present in the in-water work area, fish rescue, relocation, and exclusion will occur under the direction of a qualified fisheries biologist. i. General conditions for fish capture and relocation activities: Exclusion will include the use of block nets, or similar, to isolate the work area from fish access. The fisheries biologist will evaluate the upstream and downstream extent of the fish exclusion and relocation efforts, which will be based on the minimal amount of wetted channel where salmonids may experience potential injury or

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
		mortality from the in-water activity. Fish relocation will be performed using seine nets, dip nets, and/or electrofishing as determined appropriate and effective by the fisheries biologist. The duration and extent of fish relocation actions will be determined by the fisheries biologist. Once the work area is determined to be cleared of salmonids, in-water work activities will be cleared to begin. • Electrofishing: All electrofishing will be conducted in accordance with the NMFS Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act (NOAA and NMFS, 2000). • Salmonid Handling and Relocation: National Oceanic and Atmospheric Administration (NOAA) Restoration Center's Programmatic Approach to ESA/EFH Consultation Streamlining for Fisheries Habitat Restoration Projects (NOAA and NMFS, 2017), Section 2.4.1.E – Guidelines for Relocation of Salmonids, will guide relocation work. b. If no salmonids or protected fish occur in the work area, a biologist will monitor the in-water work actions to ensure that there is no change in conditions that would require fish exclusion or relocation. The biologist will document and report the completion of the in-water work activity to NMFS and CDFW as described below. 4. Disturbance to existing riparian vegetation and channel banks will be minimized to the extent feasible to complete the required restoration or maintenance action. 5. In the High Priority Tributary Work Areas, flow diversion around the work area will be used if channel bed adjustments are required. 6. The use or storage of petroleum-powered equipment shall be accomplished in a manner to prevent the potential release of petroleum materials into waters of the state. 7. Areas for fuel storage, refueling, and servicing of construction equipment will be located in an area at least 100 ft from a stream or wetland. 8. Oil absorbent and spill containment materials will be on site when mechanical equipment is in operation within 100 ft of the proposed watercourse crossings. If a spill occurs, no additional work shall commence in-channel until the following occurs: (1) the mechanical equipment is inspected by the Renewal Corporation contractor, and the leak has been repaired; (2) the spill has been contained; and (3) ARG is contacted and has evaluated the impacts of the spill.

<table>
<tr><th>CATEGORY</th><th>AREA OR SPECIFIC TASK</th><th>BMP MEASURES</th></tr>
<tr><td></td><td></td><td>9. To minimize potential transport of aquatic invasive species, restoration staff will comply with the relevant BMPs set forth in the Reservoir Area Management Plan.
10. Documentation and Reporting: Photographs of the in-water work location, summary of actions including any fish relocation, and notification of completion of the in-water work will be provided to ARG within one (1) week of the completion of in-water work.
11. Renewal Corporation will notify CDFW at least five (5) business days prior to the start of in-water work that would occur outside the in-water work window.</td></tr>
<tr><td>In-Water Work</td><td></td><td>
<table>
<tr><th colspan="4">In-Water Work Construction Windows</th></tr>
<tr><th>Construction Period</th><th>River</th><th>State</th><th>Work Period</th></tr>
<tr><td>Pre-Drawdown[1]</td><td>Klamath and tributaries</td><td>OR</td><td>07/01-09/30</td></tr>
<tr><td>Pre-Drawdown[2]</td><td>Klamath and tributaries</td><td>CA</td><td>06/15-10/15</td></tr>
<tr><td>Drawdown[3]</td><td>Klamath and tributaries</td><td>OR & CA</td><td>No restrictions</td></tr>
<tr><td>Post-Drawdown</td><td>Klamath and tributaries</td><td>OR</td><td>07/01-09/30</td></tr>
<tr><td>Post-Drawdown</td><td>Klamath and tributaries</td><td>CA</td><td>06/15-10/15</td></tr>
<tr><td colspan="4">1. Jenny Creek: July 1- January 31. Extensions of time must be requested from ODFW.
2. Extensions of time must be requested from CDFW.
3. Tributary work includes reaches from the former reservoir elevation to the confluence of the Klamath River. Prior consultation with ODFW and CDFW will occur if necessary to work above the original reservoir elevation.</td></tr>
</table>
</td></tr>
<tr><td>Herbicide Application</td><td>General</td><td>1. Use herbicides only in an integrated weed or vegetation management context, and only when other non-chemical methods are unsuccessful.
2. Treat only the minimum area necessary for effective control.
3. Implement an herbicide safety/spill response plan to reduce the likelihood of spills, misapplication, reduce potential for unsafe practices, and to take remedial actions in the event of spills.
4. Apply the least amount of herbicide needed to achieve the desired result.
5. All herbicides shall be used and stored according to labeled instructions. Labeled instructions for herbicides used shall be made available to CDFW upon request.
6. Mix herbicides more than 150 feet from any natural waterbody to minimize the risk of an accidental discharge. Place impervious material beneath mixing areas in such a manner as to contain any spills associated with mixing/refilling. Wash spray tanks further than 300 feet away from surface water. Check that all hauling and application equipment is free from leaks and operating as intended.</td></tr>
</table>

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
		7. Have trained applicators apply herbicides under direct supervision of a Qualified Applicator Licensee (Oregon and California applicator license). 8. Use only United States Environmental Protection Agency (EPA)-approved herbicides and follow product label directions and "advisory" statements. 9. Consider surrounding land use before assigning aerial spraying as a treatment method and avoid aerial spraying near agricultural or densely populated areas. 10. Comply with herbicide-free buffer zones to ensure that drift will not affect crops or nearby residents/landowners. 11. Post treated areas and specify reentry or rest times, if appropriate. 12. Notify adjacent landowners prior to treatment. 13. Keep a copy of Material Safety Data Sheets (MSDSs) at work sites. 14. Keep records of each application, including the active ingredient, formulation, application rate, date, time, and location. 15. Consider site characteristics, environmental conditions, and application equipment to minimize damage to non-target vegetation. 16. Turn off applied treatments at the completion of spray runs and during turns to start another spray run. 17. Refer to the herbicide product label when planning revegetation to ensure that subsequent vegetation would not be injured following application of the herbicide. 18. Clean off-road vehicles to remove seeds. 19. Only herbicides amended with a benign dye and registered with the California Department of Pesticide Regulation shall be used.
Herbicide Application	Herbicide Adjuvants and Carriers	1. When recommended by the label, an approved aquatic surfactant would be used to improve uptake. When aquatic herbicides are required, the only surfactants and adjuvants permitted are those allowed for use on aquatic sites, as listed by the Washington State Department of Ecology: http://www.ecy.wa.gov/programs/wq/pesticides/regpesticides.html. (Oregon Department of Agriculture also often recommends this list for aquatic site applications). 2. The surfactants R-11, POEA, and herbicides that contain POEA (e.g., Roundup) will not be used. 3. Herbicide carriers (solvents) are limited to water or specifically labeled vegetable oil. 4. Neonicotinoids will not be used nor will seeds that are coated with neonicotinoids be used.

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
Herbicide Application	Herbicide Application Methods	1. All herbicides shall be applied in accordance with regulations set by the California Department of Pesticide Regulation. 2. Broadcast spraying using booms mounted on ground-based vehicles, with the following restrictions: a. Do not broadcast spray within 100 feet of open water when wind velocity exceeds 5 miles per hour (mph). b. Do not broadcast spray when wind velocity exceeds 10 mph. c. Do not spray if precipitation is occurring or is imminent (within 24 hours). d. Do not spray if air turbulence is sufficient to affect the normal spray pattern. 3. Spot spraying with hand-held nozzles attached to backpack tanks or vehicles and hand-pumped sprayers to apply herbicide directly onto small patches or individual plants 4. Hand and selective application through wicking and wiping, basal bark, frill (“hack and squirt”), stem injection, or cut-stump applications 5. Dyes or colorants, (e.g., Hi-Light, Dynamark) will be used as needed to assist in treatment assurance and minimize over-spraying within 100 feet of live water.
Herbicide Application	Minimization of Herbicide Drift, Leaching, and Runoff	1. Do not spray when wind speeds exceed 10 miles per hour to reduce the likelihood of spray/dust drift. Winds of 2 mph or less are indicative of air inversions. The applicator must confirm the absence of an inversion before proceeding with the application whenever the wind speed is 2 mph or less. 2. Be aware of wind directions and potential for herbicides to affect aquatic habitat area downwind. 3. Keep boom or spray as low as possible to reduce wind effects. 4. Avoid or minimize drift by using appropriate equipment and settings (e.g., nozzle selection, adjusting pressure, drift reduction agents). Select proper application equipment (e.g., spray equipment that produces 200- to 800-micron-diameter droplets spray droplets of 100 microns or less are most prone to drift). 5. Follow herbicide label directions for maximum daytime temperature permitted (some types of herbicides volatilize in hot temperatures). 6. Do not spray during periods of adverse weather conditions (snow or rain imminent, fog, etc.). Wind and other weather data will be monitored and reported for all pesticide applicator reports. 7. Herbicides shall not be applied when the soil is saturated or when a precipitation event likely to produce direct runoff to fish-bearing waters from a treated site is forecasted by National Oceanic and Atmospheric Administration National Weather Service or other

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
		similar forecasting service within 48 hours following application. Soil-activated herbicides can be applied as long as label is followed. Do not conduct any applications during periods of heavy rainfall. 8. Minimize treatments in areas where herbicide runoff is likely, such as steep slopes when heavy rainfall is expected. 9. Minimize use of herbicides that have high soil mobility, particularly in areas where soil properties increase the potential for mobility. 10. Do not apply granular herbicides on slopes of more than 15 percent where there is the possibility of runoff carrying the granules into non-target areas. 11. Plan to treat between weather fronts (calms) and at appropriate time of day to avoid high winds that increase water movements, and to avoid potential stormwater runoff and water turbidity.
Herbicide Application	Protection of Aquatic Resources	1. Obtain National Pollutant Discharge Elimination System (NPDES) permit from North Coast RWQCB and Oregon Department of Environmental Quality (ODEQ). 2. Use local historical weather data to choose the month of treatment. Considering the phenology of the target species, schedule treatments based on the condition of the water body and existing water quality conditions. 3. Review hydrogeologic maps of proposed treatment areas. Note depths to groundwater and areas of shallow groundwater and areas of surface water and groundwater interaction. Minimize treating areas with high risk for groundwater contamination. 4. Minimize the potential effects to surface water quality and quantity by stabilizing terrestrial areas as quickly as possible following treatment. 5. Minimize treatments near fish-bearing water bodies during periods when fish are in life stages most sensitive to the herbicide(s) used, and use spot treatments rather than broadcast or aerial treatments. 6. For treatment of aquatic vegetation: 1) treat only that portion of the aquatic system necessary to achieve acceptable vegetation management, 2) use the appropriate application method to minimize the potential for injury to desirable vegetation and aquatic organisms, and 3) follow water use restrictions presented on the herbicide label.
Herbicide Application	Herbicide Buffer Distances	Table C-2 below provides the no-application buffers to be observed during herbicide applications. Herbicide applications based on a combination of approved herbicides will use the most conservative buffer for any herbicide included. Buffer widths are measured as map distance perpendicular to the bankfull for streams, the upland boundary for wetlands, or the upper bank for roadside ditches.

CATEGORY	AREA OR SPECIFIC TASK	BMP MEASURES
Dust Abatement		1. Apply water or other dust palliatives as necessary to prevent or alleviate dust nuisance and wind erosion while keeping the amount of water used to the minimum amount needed. 2. Alternatively, cover small stockpiles or areas. 3. Dust control measures must be applied in accordance with accepted standard practices and comply with applicable local regulations.
Stormwater Pollution Prevention		See the Stormwater Pollution Prevention Plan for BMPs associated with stormwater sediment runoff.
Spill Prevention and Control		See Construction Management Plan for BMPs associated with spill prevention and control.
Waste Disposal		See Waste Disposal Management Plan for BMPs associated with hazardous materials.

Table C-2. No-Application Buffer Widths in Feet for Herbicide Application by Stream Type and Application Method

HERBICIDE	PERENNIAL STREAMS AND WETLANDS, AND INTERMITTENT STREAMS AND ROADSIDE DITCHES WITH FLOWING OR STANDING WATER PRESENT			DRY INTERMITTENT STREAMS DRY INTERMITTENT WETLANDS DRY ROADSIDE DITCHES		
	BROADCAST SPRAYING	SPOT SPRAYING	HAND SELECTIVE	BROADCAST SPRAYING	SPOT SPRAYING	HAND SELECTIVE
LABELED FOR AQUATIC USE						
Aquatic Glyphosate	100	Waterline	Waterline	50	0	0
Aquatic Imazapyr	100	Waterline	Waterline	50	0	0
LOW RISK TO AQUATIC ORGANISMS						
Dicamba	100	15	15	50	0	0
Metsulfuron-methyl	100	15	Bankfull elevation	50	0	0

Appendix D

Current and Historic Conditions as a Reference for Restoration

Area and General Features of the Lower Klamath Project

The Lower Klamath Project (Lower Klamath Project) is located along the Klamath River in Klamath County, Oregon (J.C. Boyle), and Siskiyou County, California (Copco No.1, Copco No.2 and Iron Gate Dams). The Klamath River originates at the base of the Cascade Mountains in the Oregon desert and flows 254 river miles (RM) through southern Oregon and Northern California to the Pacific Ocean near the town of Requa, California. The figures in Chapters 1.0 and 2.0 of the Reservoir Area Management Plan depict the Limits of Work.

The four (4) dams, powerhouses, and associated facilities slated for removal and site restoration are described below in the Development Context subsections. These descriptions include an overview of the existing facilities in 2020 for orientation during restoration and monitoring activities. In addition, this section includes a description of historic, pre-dam conditions to provide context for restoration activities in the Historical Context/Restoration Potential subsections. An understanding of pre-dam conditions within the Reservoir Areas is necessary to develop appropriate and effective restoration objectives to meet the restoration goals of volitional fish passage, sediment stabilization through revegetation, and habitat enhancement. Restoration objectives described later in this document have been tailored to promote the return of the Reservoir Areas to as close to the pre-dam condition as possible.

Hydropower development descriptions in this section are primarily derived from the *Environmental Report. Final License Application, Klamath Hydroelectric Project (FERC Project No. 2082)* (PacifiCorp, 2004). Information in the historical context/restoration potential sections for each dam and reservoir was derived from the Definite Plan Report (KRRC, 2018) and ALSA (KRRC and PacifiCorp, 2020).

The information set forth in Appendix D is for information purposes only and does not increase or otherwise modify any of the obligations of the Renewal Corporation contained in Chapters 1-8 of the Reservoir Area Management Plan.

J.C. Boyle Development Context

J.C. Boyle Hydroelectric Facility was constructed from 1957 to 1958 and is located at approximately RM 226.0 in Oregon. Major components of the J.C. Boyle Facility include the following:

- A reservoir of approximately 3,200-acre-feet capacity at a reservoir elevation of 3,796.7 feet
- A 68-foot-high combination earth fill and concrete gravity dam that spans approximately 700 feet in length
- A three (3)-bay gated spillway with 36-foot-wide bays
- Two low-level diversion culverts with concrete stoplogs
- A power intake structure and a fish ladder at the intake

- A water conveyance system made up of a 600-ft syphon and pipeline, a 2.2-mile-long concrete power canal, a 1,600-foot-long low-pressure tunnel and two (2) 950-foot-long surface mounted high-pressure steel penstocks
- An eroded scour hole downstream of the forebay structure
- A two (2) turbine, at-surface 98-megawatt (MW) powerhouse and a tailrace channel
- A switchyard, substation, and transmission lines

Recreation facilities at J.C. Boyle include the Topsy Campground and boat launch, Pioneer Park east and west units and boat launches, Spring Island whitewater boating launch, and numerous dispersed shoreline recreations sites.

The J.C. Boyle facilities slated for removal and restoration or partial removal and restoration as of January 2021 are depicted in Figure D-1.

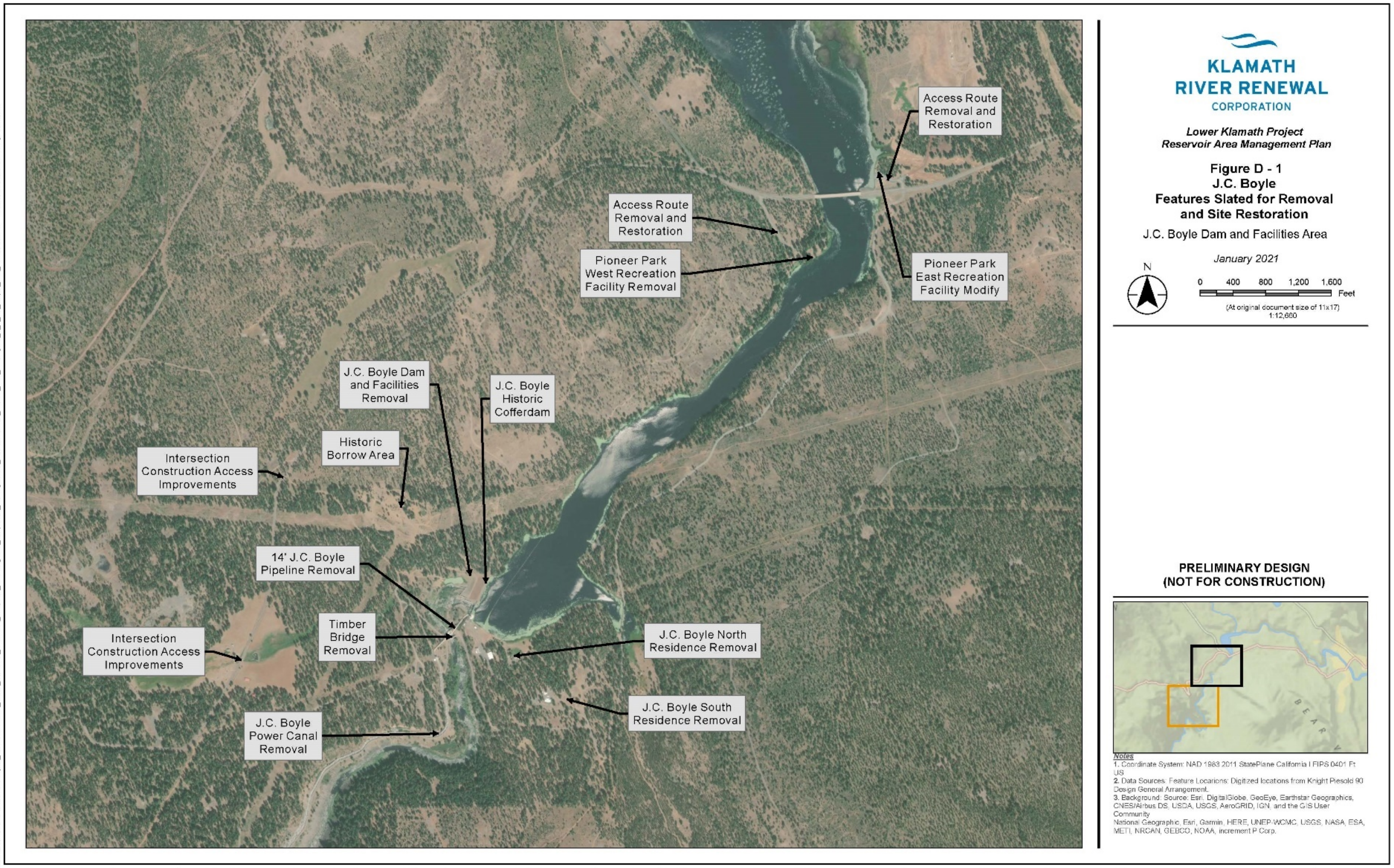

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Figure D-1. Site Reference – J.C. Boyle Dam Features Slated for Removal and Site Restoration (Page 1) Upper Reservoir (Page 2) Lower Reservoir

J.C. Boyle Historical Context/Restoration Potential

Prior to inundation by the J.C. Boyle Dam, the Klamath River had two (2) distinct reaches, a wider Upstream Reach that includes a floodplain/sand bar area, and a narrower more sediment deprived Canyon Reach. Highway 66 Bridge is considered the division between the two (2) reaches (Figure D-2).

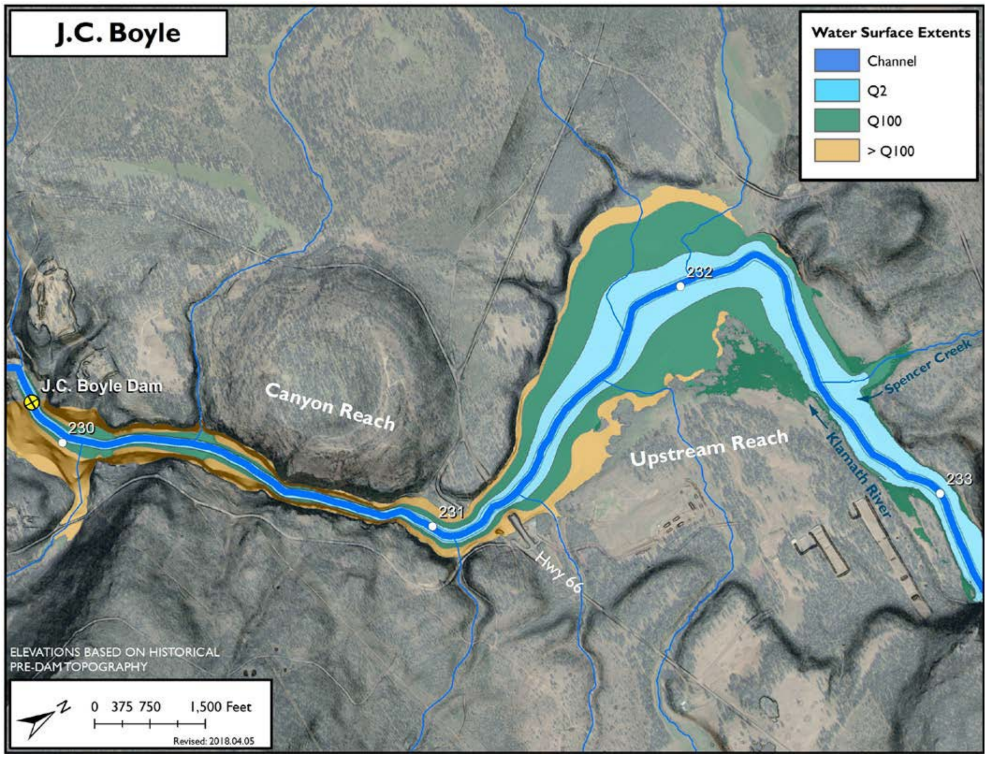

Figure D-2. Estimated Historic River Conditions of J.C. Boyle Reservoir

Source: KRRC, 2018

Note: Slopeshades are of bare earth LiDAR overlaid with aerial imagery and historical topography of J.C. Boyle Reservoir Area with estimated flood inundation boundaries for the 2-year (Q2) and 100-year (Q100) floods. Reach designations and river miles are noted.

In the Upstream Reach, the Klamath River actively modified its channel as suggested by the extensive mapped floodplains and the vegetated and unvegetated bars, including a large semi-vegetated, mid-channel bar upstream of the Highway 66 Bridge (Figure D-3). The majority of the existing reservoir was shallowly inundated during high flows as a result of the low floodplain gradient and the small bank heights of the historical river. Wetland conditions were likely supported in Spencer Creek, which had a multi-threaded distributary character in its lower sections.

In the Canyon Reach, the Klamath River was historically incised several tens to hundreds of feet into the surrounding volcanic bedrock to form a deep, narrow valley (Figure D-4). The narrow valley contained limited space for sediment storage, and, accordingly, there are no mapped historical geomorphic features (USBR, 2011). The Klamath River was single threaded with significant exposures of bedrock on the riverbed and banks that limited channel adjustment.

There is little evidence of bedform development, and most in-channel sediment visible in historical photographs is boulder- or cobble-sized. Two (2)-year and 100-year flood extents were estimated to be narrow, demonstrating the confined nature of the Canyon Reach (KRRC, 2018).

Figure D-3. Historic Aerial Photograph of J.C. Boyle Reservoir Area (1952) Prior to Dam Construction

Source: KRRC, 2018

Note: Highway 66 bridge crosses the Klamath River in this location. Flow is top to bottom. Photograph is oriented north-up. Dam location is out of frame at the bottom left.

Figure D-4. View Looking Upstream at Location Where J.C. Boyle Dam Was Constructed in 1957

Source: KRRC, 2018

Note: View of historical vegetation and rocky, volcanic, slightly incised geomorphology.

Copco No. 1 and No. 2 Development Context

Copco No. 1 Hydroelectric Facility was constructed from 1911 to 1922 and is located at RM 202.2 in Siskiyou County, California. The site is approximately 25 miles east of the Interstate 5 Highway. The Copco No. 1 Facility is accessed by the public Copco Road. Major components of the Copco No. 1 Facility include the following:

- A reservoir of 40,700-acre-feet capacity at a reservoir elevation of 2,611 feet
- A 133-foot-high (maximum height) 410-foot-long concrete arch dam
- A 224-foot-long ogee crest overflow spillway controlled with thirteen spillway gates
- An abandoned and concrete-plugged diversion tunnel and concrete inlet control structure
- A power intake structure and surface mounted steel penstocks
- An at-surface two-unit 22-MW powerhouse
- A switchyard, substation, and transmission lines

Recreation facilities associated with the Copco No. 1 Reservoir included Mallard and Copco Cove with boat launches.

Copco No. 2 Hydroelectric Facility was constructed from 1924 to 1925 and is located between RM 201.8 and RM 200.3 in Siskiyou County, California. Copco No. 2 dam is approximately 25 miles east of the Interstate 5 Highway and is approximately 1,600 feet downstream of the Copco No. 1 dam. The Copco No. 2 Facility is accessed by the public Copco Road. Major components of the Copco No. 2 Facility include the following:

- A reservoir of 58-acre-feet capacity at a reservoir elevation of 2,486.5 feet
- A 32-foot-high concrete gravity diversion dam and a 100-foot-long earth fill embankment section at the right abutment
- A 145-foot-long overflow spillway with five (5) 26-by-11-foot radial gates
- An intake and 5,215-foot-long water conveyance system with a 2,400-foot concrete lined tunnel, 1,345-foot wood-stave penstock, a second 1,095 foot of concrete lined tunnel, and two (2) surface mounted high pressure steel penstocks approximately 375 foot long.
- An at-surface two (2)-unit 27-MW powerhouse with a capacity of 2,676 cubic feet per second at a net head of 140 feet.
- A switchyard, substation, and transmission lines.

The Copco No.1 and Copco No.2 facilities slated for removal and restoration or partial removal and restoration as of January 2021 are depicted in Figure D-5.

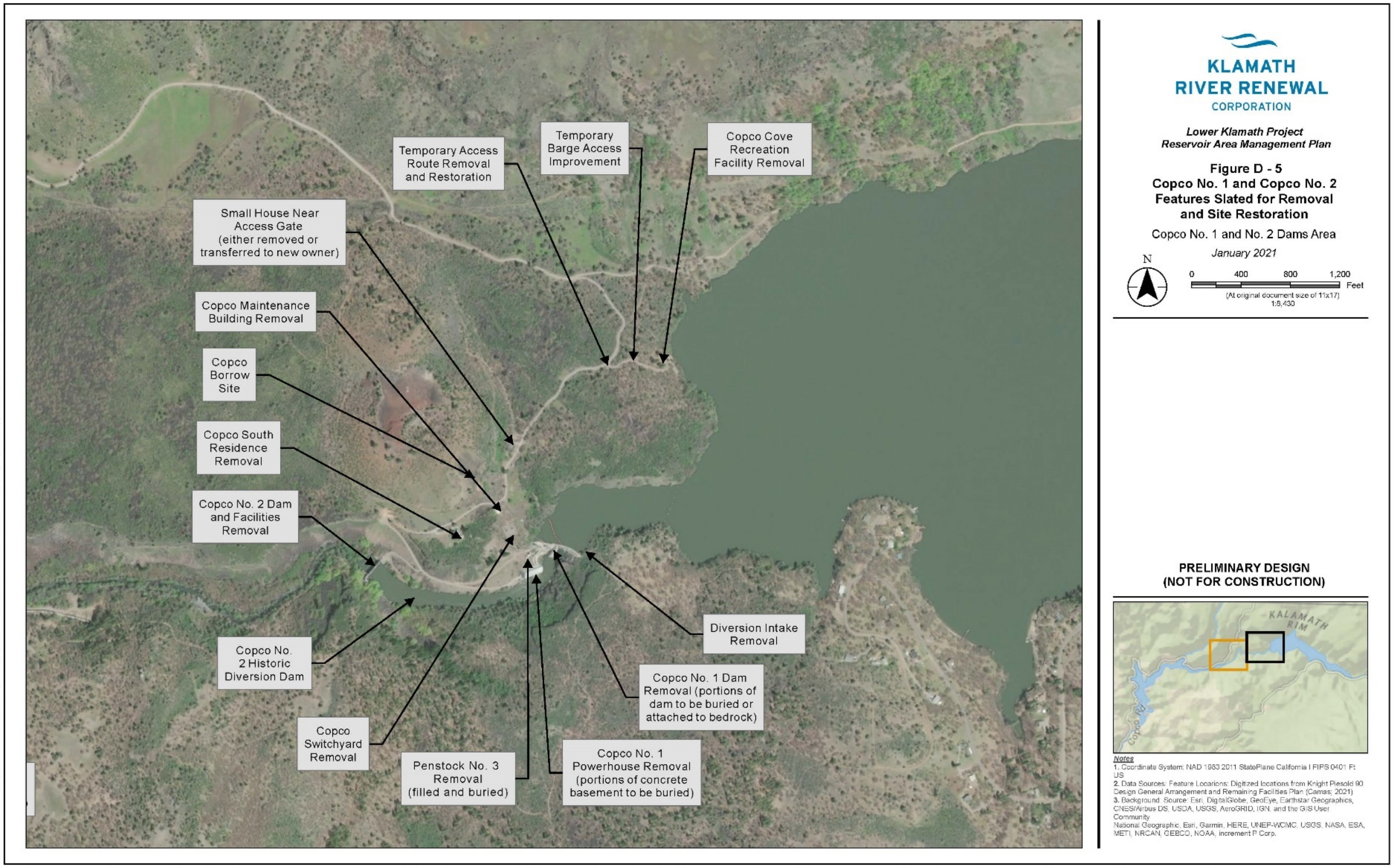

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Figure D-5. Site Reference – Copco No.1 and No. 2 Features Slated for Removal and Site Restoration (Page 1) Lower Reservoir (Page 2) Upper Reservoir

Copco Historical Context/Restoration Potential

Historically, the Klamath River within the Copco No. 1 and No. 2 reach was a meandering, bedrock river inset within lithified fluvio-lacustrine bedrock. The historical valley bottom was relatively wide compared to reaches of the Klamath River downstream of the dam (e.g., historical Iron Gate Reservoir valley) and upstream of the reservoir. The wide and flat valley morphology was the result of aggradation caused by the damming of the ancestral Klamath River by the Copco basalt, a 140,000-year-old lava flow (Hammond, 1983, as referenced in KRRC, 2018). These lava flows created an ancestral lake approximately 130 feet deep at its maximum (35 to 40 feet above modern lake level) that occupied approximately five (5) miles of the Copco valley upstream of RM 202. (KRRC, 2018)

The Klamath River incised into the ancestral lakebed after the lava dam was breached and formed the bedrock meandering valley visible in the historical pre-dam topography. This pre-dam topography was characterized by the flat ancestral lake bed, which is perched up to 50 feet above the historical channel, and asymmetric channel-valley cross-sections, which comprise steep to vertical diatomite banks on the outsides of bend and more gradual alluvium-draped slip-off slopes on the insides of the meanders, morphology indicative of vertical and lateral erosion proceeding in tandem. The grade of the historical Klamath River in the Reservoir Area appeared to be controlled by bedrock outcrops, likely the Copco basalt, at the narrow entrance to the canyon reach where the dams were constructed (locally known as Ward’s Canyon), several hundred feet upstream of the Copco No. 1 Dam location (Figure D-6). (KRRC, 2018)

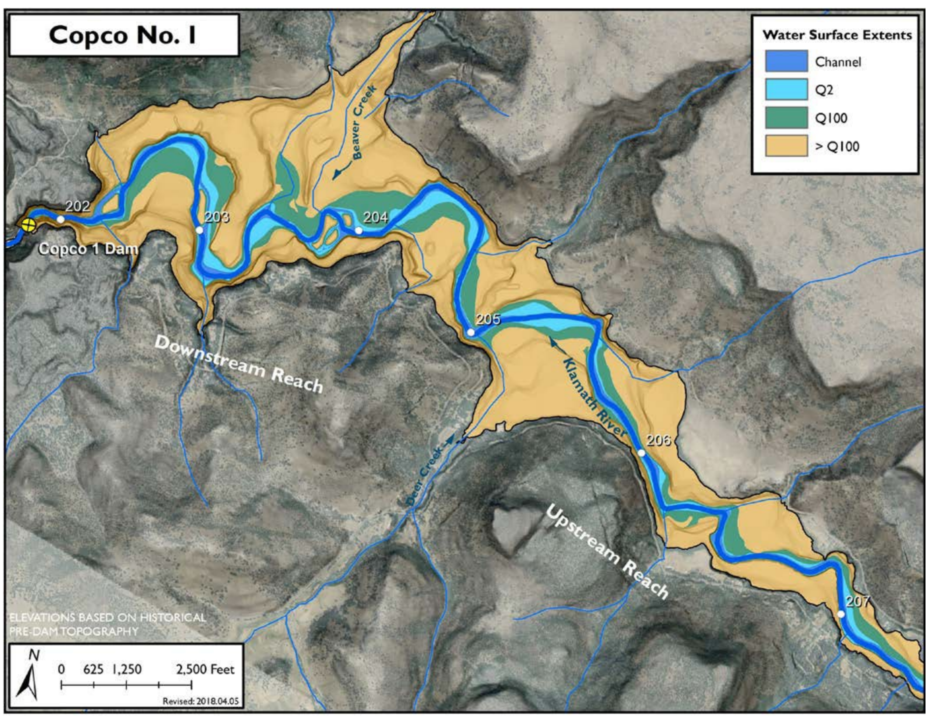

Figure D-6. Estimated Historic River Conditions

Source: KRRC, 2018

Note: Slopeshades are of bare earth LiDAR overlaid with aerial imagery and historical, pre-dam topography of Copco Reservoir Area with estimated flood inundation boundaries for the 2-year (Q2) and 100-year (Q100) floods.

The historical channel was inundating and modifying its narrow floodplain and eroding its diatomite riverbanks as evidenced by the mapped flood inundation boundaries and the presence of a large cut-off meander loop of the mainstem Klamath River occupied by historical Beaver Creek at the time of dam construction. Swales, side channels, remnant meanders, and additional floodplain complexity are noted on the 1906 topographic map (Figure D-7) and visible in the bathymetry. The large aerial extent of the reservoir that is not inundated by the Q100 demonstrates the degree of valley confinement in the reach. (Figure D-6)

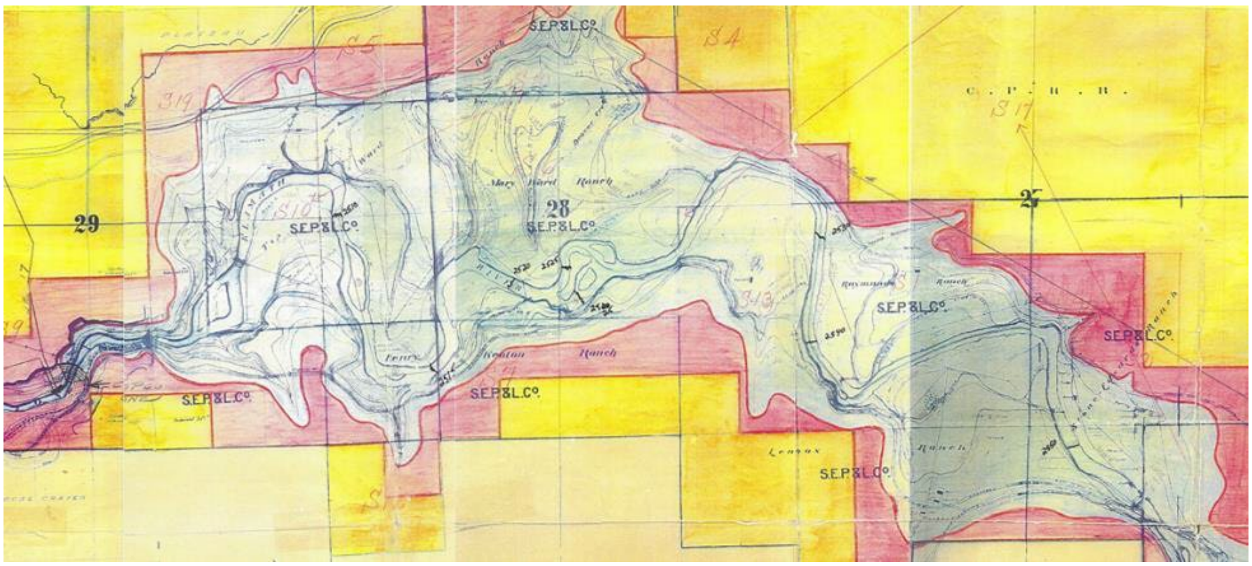

Figure D-7. Topographic Survey from 1906 Survey of Copco Lake Area

Source: KRRC, 2018

The valley bottom was inhabited by humans prior to dam construction, and orchards and ranchlands covered much of the land surface with evidence of widespread land clearing. Oak, juniper, and pine groves are visible in historical pre-dam photographs (Figure D-8) and marked on the topographic survey maps (Figure D-7). Riparian vegetation along the mainstem, tributaries, smaller side channels, and floodplain swales primarily consisted of willows, tule, and brush. Upland vegetation was a mix of oak, pine, juniper, and fir. Prior to dam construction, it appears that the valley bottom was cleared of larger trees (e.g., pine) for agricultural purposes.

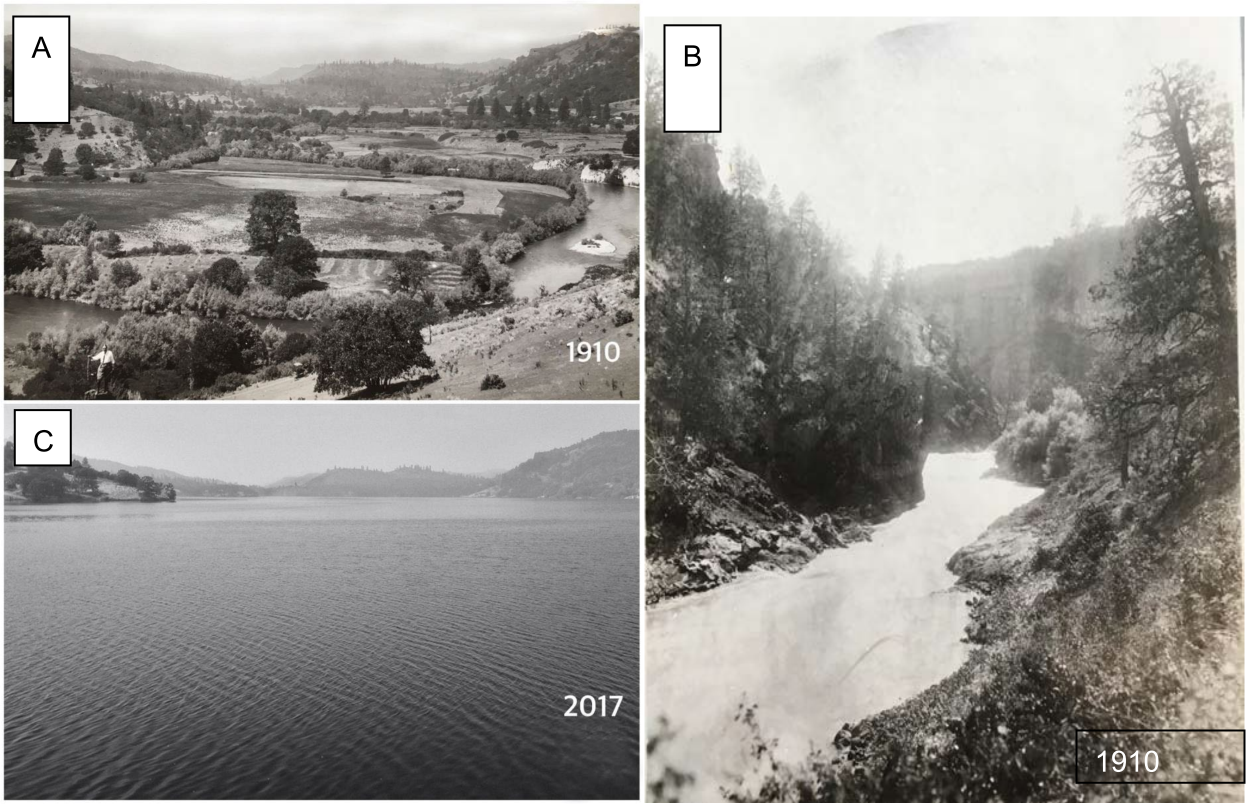

Figure D-8. Historical Photographs of Copco Lake Area, 1910 and 2017

Source: KRRC, 2018

Note: (A) Photo from 1910, prior to Copco No. 1 dam construction showing existing vegetation and land use in the Reservoir Area. Bedrock/valley fill is exposed in the right bank. A sequence of two mapped alluvial terraces are located on river left in the center of the photograph . (B) Ward Canyon looking upstream in the Klamath River prior to dam Construction. (C) Copco No. 2 conditions in 2017.

Iron Gate Development Context

Iron Gate Hydroelectric Facility was constructed from 1960 to 1962 and is located at RM 193.1 in California. The site is located approximately 10 miles east of the Interstate 5 Highway. The Iron Gate Facility is accessed by the public Copco Road. Major components of the Iron Gate Facility include the following:

- A reservoir of 54,714-acre-feet capacity at a reservoir elevation of 2,331.3 feet
- A 189-feet-high, 740-foot-long earth fill embankment dam
- A sheet pile wall at the dam crest to increase reservoir flood attenuation capacity
- A 727-foot-long side channel flip-bucket spillway
- A diversion tunnel that functions as a low-level outlet
- A power intake structure and steel penstock
- An at-surface single unit 18-MW powerhouse
- A switchyard, substation, and transmission lines
- Various fish related pipes, a fish ladder, and six (6) collection ponds that support operations of the Iron Gate Hatchery

Recreation facilities at Iron Gate include the Overlook Point, Wanaka Springs, Camp Creek Day Use Area, Juniper Day Use Area, Mirror Cove, Jenny Creek Day Use Area, Long Gulch Day Use Area, and Fall Creek day-use area and boat launch, campgrounds, and other boat launch areas and dispersed shoreline sites. See the Recreation Facilities Plan for additional details regarding these recreation facilities.

The Iron Gate facilities slated for removal and restoration or partial removal and restoration as of January 2021 are depicted in Figure D-9.

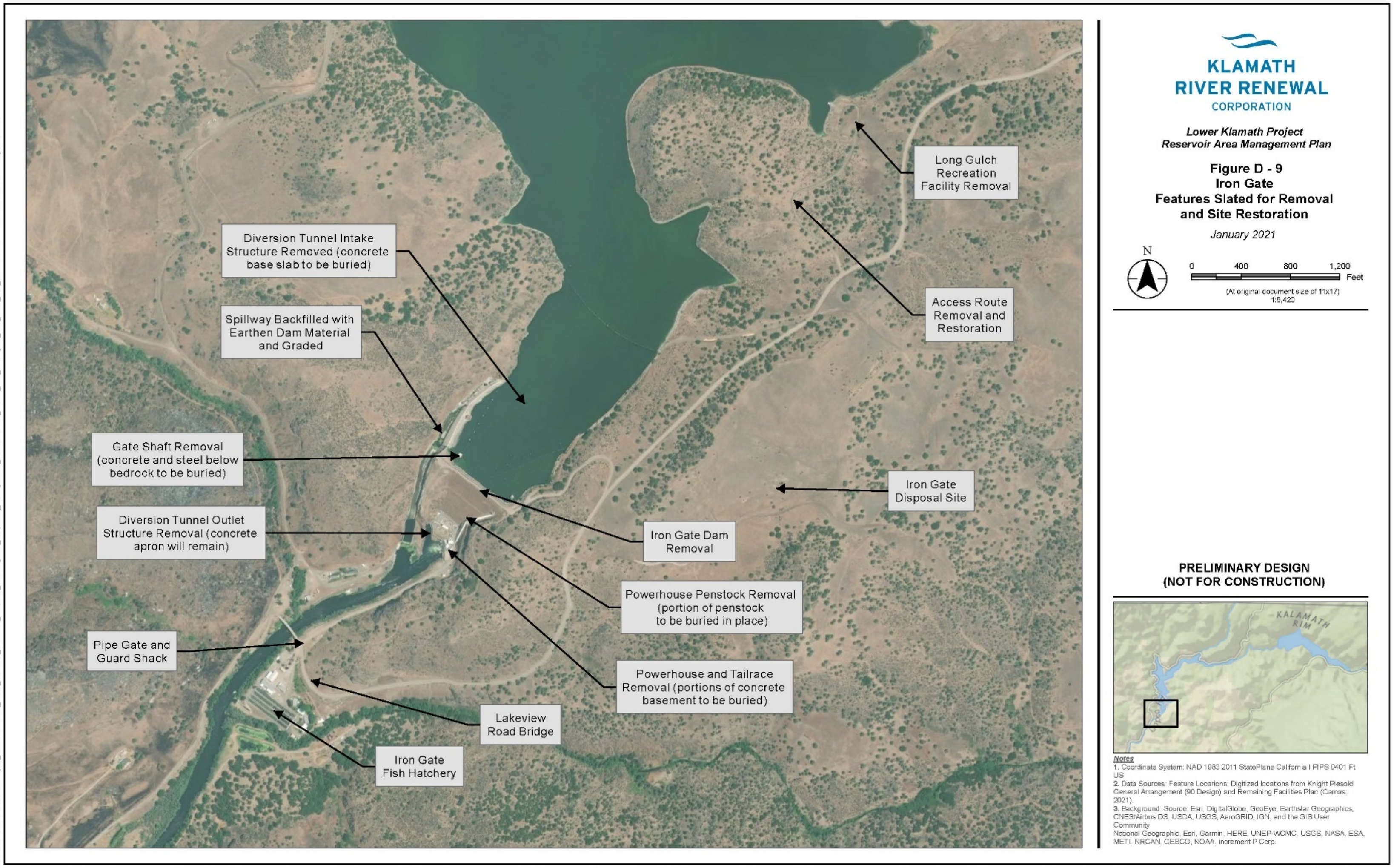

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Figure D-9: Site Reference – Iron Gate Features Slated for Removal and Site Restoration

Iron Gate Historical Conditions/Restoration Potential

In the Iron Gate Reservoir Area, prior to dam construction, the Klamath River was a single-thread channel with low- to moderate-sinuosity that occupied a deep, narrow, and symmetric valley incised into a complex set of intrusive rock, Tertiary age volcaniclastic rocks, and younger basaltic and andesitic lava flows that outcrop in many of the ridges adjacent to the channel (KRRC, 2018). Much of the channel bed was composed of coarse sediment that was sourced from adjacent hillslopes and bedrock exposures and formed rapids in the steep reach. Physical geomorphic conditions (e.g., cross-sectional geometry and channel dimensions) in the Iron Gate reach were relatively uniform longitudinally, except locally at tributary junctions. Several larger tributaries (Fall Creek, Jenny Creek, and Camp Creek) contributed appreciable sediment to the mainstem, and mapped geomorphic features were coincident with the confluences (USBR, 2011). For example, in the downstream reach, Camp Creek, likely contributed a considerable amount of sediment to the mainstem (USBR, 2010), and there was a large alluvial fan at the historical confluence . These geomorphic features were longitudinally extensive but typically limited to one (1) to two (2) channel widths in lateral extent due to the confined nature of the valley. Rapids were visible in photos at several locations coincident with the wider 100-year floodplains depicted in Figure C-10. Anthropogenic disturbance, including mining and road construction, is visible in the bathymetry on the river-left floodplains at RM 194 and RM 195 and Figure C-10 shows estimated pre-dam conditions upstream of the Iron Gate dam.

Prior to dam construction, upland vegetation consisted of grasses with dominant tree species of oak and juniper. Tree concentrations were sparse on southern aspects and considerably thicker on northern aspects and in tributary valleys. A narrow band of willows, tule, and other species lined the riparian zone. Iron Gate dam was constructed using a bypass tunnel to dewater the dam construction zone, an area with relatively steep slopes and sparse vegetation (Figure D-10). The channel and floodplain were narrow and topographically confined as indicated by the relatively narrow flood width extents (Figure D-11).

Figure D-10. View Looking Upstream at Site of Iron Gate Dam during Construction and Showing Reservoir Area

Source: KRRC, 2018

Note: Photo from initial Iron Gate Dam Construction, shows Cofferdam and bypass tunnel.

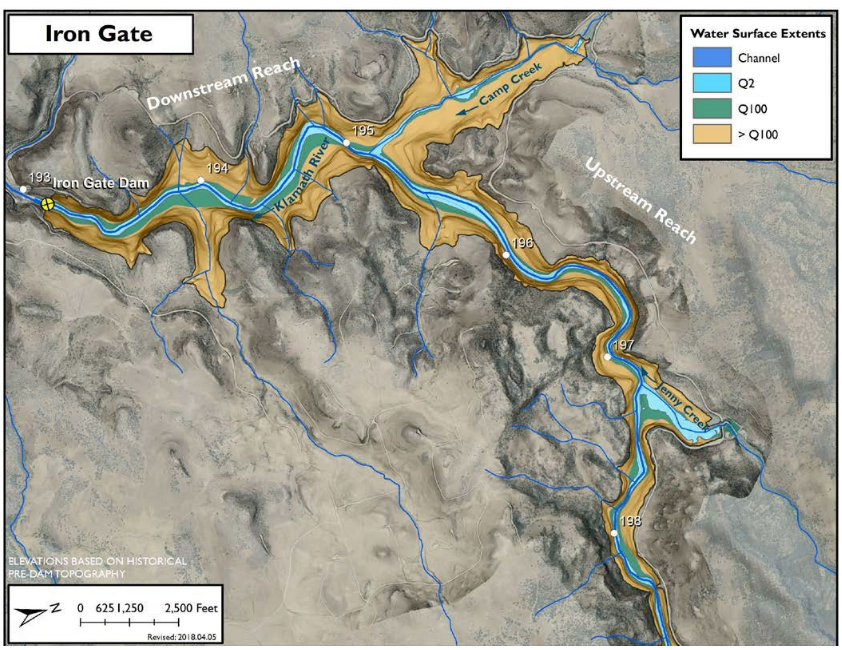

Figure D-11. Estimated Historic River Conditions Based on Historical Topography with Flood Inundation Estimations

Source: KRRC, 2018

Note: Slopeshades are of bare earth LiDAR overlaid with aerial imagery and historical topography of Iron Gate Reservoir Area with estimated flood inundation boundaries for the 2-year (Q2) and 100-year (Q100) floods (Definite Plan Report, 2018).

References

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USBR. 2011. *Reservoir Area Management Plan for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration.* Technical Report No. SRH-2011-19.

Appendix E

Methodologies for Calculating Anticipated Reservoir Conditions Post-Drawdown

Methodologies for Calculating Anticipated Reservoir Conditions Post-Drawdown

While acknowledging high uncertainty, there is still a need to approximate post-drawdown topography to quantify probable earthwork volumes and to aid in selecting active sediment evacuation locations. The process for estimating the post-drawdown topography is summarized below and described in the following sections:

1. Identify and analyze historic topographic data and existing bathymetric data to approximate probable channel alignments and channel sizes
2. Estimate sediment thicknesses using past sediment coring studies
3. Make reasonable assumptions to how the sediment will respond to dewatering based on past sediment analyses of each reservoir

E.1 Available Topographic Data

Historical topographic maps were used to provide the pre-dam elevation baseline for the Reservoir Areas. The Iron Gate drawings were dated January 29, 1957; Copco Reservoir drawings were dated August 12, 1940; and J.C. Boyle Reservoir drawings were dated March 30, 1963. These maps were digitized by AECOM and provided digitally as a Tagged Image Format (TIF) to the project team.

In 2018, topographic and bathymetric data was collected for the reservoirs by GMA Hydrology, Inc. for AECOM. This data combined Light Detection and Ranging (LiDAR), bathymetric LiDAR, multibeam, sweep and Global Navigational Satellite System (GNSS) real-time kinematic (RTK) collected data to develop topographic information for the inundated and exposed portions of the reservoir. The project team received this data and converted the 2.6-foot grid digital elevation model (DEM) into a 1 foot grid DEM.

Initially, it was thought that these two surfaces could be used to determine sediment thicknesses within each reservoir; however, it was determined that the analyses would not be accurate. This is because, when the surfaces were compared, there were significant portions of the historic topographic data above the 2018 data for all three (3) reservoirs. With the 2018 data being the most current and most accurate, it was determined that the historic topography of the inundated areas was faulty. Therefore, the historic topography was not used in developing the post-drawdown surface.

E.2 Sediment Thickness Estimation

Without pre-dam topography to compare the 2018 bathymetric data to, past sediment studies were used to estimate sediment thicknesses. In 2011, USBR published *Hydrology, Hydraulics, and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration*. The study developed a multivariate regression equation to estimate sediment thickness based on historic and current sediment coring data. The results were published in the report that contained isoline sediment depth figures (Figures 5-35, 5-36, and 5-37) for each reservoir. Those figures were georeferenced, and the isolines were digitized.

A comparison of the total sediment volumes published in the report, and the sediment volumes generated from the digitized isolines are provided in Table E.1.

Table E.1 Comparison of Sediment Volumes

	Volume of Sediment (cubic yards)		
Source	J.C. Boyle	Iron Gate	Copco
Reclamation (2011)	1,000,000	4,710,000	7,440,000
Digitized Isolines	932,000	4,517,189	6,760,000

E.3 Post-Drawdown Surface

Assumptions were made about how the sediment would respond to dewatering to develop the anticipated post-drawdown surfaces. These assumptions were based past sediment analyses and typical responses of natural sediment evacuation from previous dam removal projects. The first major assumption made was that all sediment within the vertical extents of all active channels would naturally evacuate. The second assumption made is that the Klamath River and its tributaries would occupy approximately the same alignment as they historically occupied. These alignments and channel widths were based on historic photos, apparent depressions in the 2018 bathymetric data, and regional geomorphic curves for bankfull width. The third assumption made was that all sediment confined within steep and narrow valleys would naturally evacuate. For example, the sediment contained within the steep and confined fluvial valley of the downstream extents of the J.C. Boyle Reservoir was assumed to all naturally evacuate. The final two assumptions were based on sediment studies that focused on angle of repose and the drying and shrinking of sediments. It was assumed that the sediment would initially dry and shrink by 40 percent, and sheer cliffs would fall to an angle of repose of 10V:1H. The angle of repose was applied from the estimated top of banks and extended outward until it daylighted to the shrunk sediment surface.

The combination of these assumptions with both the sediment depth surface and the 2018 bathymetric data was used to generate the anticipated post-drawdown surface.

Appendix F

Establishment of Restoration Priorities within the Reservoirs

Restoration Priorities

Restoration priorities are driven by the overall project goals of restoring volitional fish passage, stabilizing exposed sediment with native vegetation, establishing native plants and the secondary goal of enhancing native aquatic habitat. Priorities also considered the challenging natural environment for plant establishment, including variable soil quality, low rainfall, high summer temperatures, and competition from invasive species. From this, the following four (4) restoration tiers were identified:

- **1st Tier – Klamath River.** The highest Lower Klamath Project priority is providing volitional fish passage on the Klamath River. This will be achieved through the primary habitat restoration actions (drawdown, sediment evacuation, and dam removal). Mainstem habitat connectivity is important for re-establishing natural distributions of anadromous salmonids and Pacific lamprey in the Klamath River Basin. Fish passage will be promoted by reconstructing a fish-passable and geomorphically appropriate channel through the footprints of the former dams. In addition, any anthropogenic structures in the river channel, either known or uncovered post-drawdown, will be removed. Additional measures may be taken to opportunistically encourage floodplain benches and channel complexity where post-drawdown conditions, access, time, and budget allow. Generally, the restoration approach for the Klamath River is to restore natural processes so that the river and associated habitats can recover without significant intervention (natural process based restoration).
- **2nd Tier – Perennial Tributaries.** The secondary priority is perennial tributaries, particularly at the tributary confluences with the Klamath River and where tributaries have formed deltas around the reservoir rim. Tributaries and tributary mouths tend to be highly used habitats by anadromous salmonids and Pacific lamprey. Tributaries can support several life stages necessary for anadromous salmonids to complete their life history, including spawning, egg incubation, juvenile rearing, and overwintering. Tributary mouths provide habitat for anadromous salmonids originating in the tributary, as well as adults and juveniles during migration and rearing. Because tributaries are expected to have lower suspended sediment loads than the mainstem as it adjusts to its restored condition, tributary mouths may also be particularly important refugia habitat for salmonids and Pacific lamprey in the first few years following drawdown. Restoration prioritization of tributaries is discussed in detail in Selection of Restoration Activities at Tributaries and Confluences.
- **3rd Tier – Natural Springs.** Natural springs and seeps are water sources that can be used to create wetlands, add channel complexity by supporting spring-fed alcoves or side channels, and widen riparian areas. Appropriate planting and focused, minor grading can add complexity and connectivity to ecosystems associated with the river and springs. Expanded and revegetated areas serve as seed sources for passive restoration in adjacent areas, provide critical functions in terms of refugia and foraging for terrestrial species, and improve potential biological productivity for a range of species, including aquatic organisms.

- **4th Tier – Intermittent and Ephemeral Tributaries.** Although perennial tributaries are the highest priority, there are selected intermittent tributaries that may provide non-natal juvenile rearing refuge habitat. If access and budget allow, restoration actions may address connectivity at the mainstem confluence of the larger intermittent tributaries to provide expanded habitat and/or increased biological productivity.

These tiers were applied to each reservoir to identify High Priority Tributaries and low priority tributaries. The resulting areas are those with the greatest opportunity to enhance habitat value through direct actions, such as grading and installing enhancement features.

Restoration Opportunities: J.C. Boyle

While the lower reach of J.C. Boyle is confined, the less confined upper reach presents more restoration opportunity. Given the relatively low sediment deposition in J.C. Boyle, little intervention is anticipated to be needed to reconnect with Klamath River with adjacent habitats. Active restoration in the J.C. Boyle Reservoir is limited to Spencer Creek, a fish-bearing, perennial stream. Spencer Creek was identified for restoration actions in the 2018 Definite Plan Report (Appendix H, Figure 5.1; KRRC 2018) and remains a priority tributary for restoration. The three (3) unnamed tributaries, which were identified for active grading in the 2018 Definite Plan Report (Sites 1 to 3), are anticipated to recover through natural processes augmented by active revegetation and IEV controls. Specific restoration activities in the J.C. Boyle Reservoir are described in Restoration Opportunities: J.C. Boyle.

Spencer Creek extends for approximately 13 miles above its confluence with the mainstem Klamath River and has perennial flow. No stretches within the longitudinal profile exceed the gradient and length for natural fish passage barriers. With the exception of a short stretch of step-pools in the first mile of the creek, the lower six (6) miles are primarily characterized by riffle-pool bedforms. After that, the streambed slope steepens, and the estimated channel type becomes primarily step-pool.

Fall-run Chinook salmon and steelhead trout were present on Spencer Creek prior to dam construction (Hamilton et al., 2005). The Klamath River upstream limit for Coho salmon and Pacific lamprey is believed to have extended at least to Spencer Creek, which has suitable habitat for Coho salmon (Hamilton et al., 2005; NOAA and NMFS, 2014; DOI, USDC, and NMFS, 2007). Additionally, Huntington (2006) suggests that approximately 13 miles of Spencer Creek are “potential anadromous fish habitat.” Based on this analysis, Spencer Creek is considered a High Priority Tributary.

The revegetation approach at J.C. Boyle Reservoir will be similar to other reservoirs; however, the seed mix and planting palettes will be adjusted to reflect its higher elevation, shallower reservoir depth, and different plant communities around the reservoir. IEV control will be implemented before the restoration implementation begins. Spencer Creek, which drains into the reservoir, will serve as a reference site for the revegetation portion of the restoration.

Because of the striking topographical contrast between the two (2) reaches of the reservoir, there will be a large difference in the revegetation approach. The Upstream Reach above the Highway 66 bridge has mostly gentle slopes and includes large and broad riparian floodplains that will have favorable hydrology for riparian and wetland habitat restoration, while the Canyon Reach downstream of the bridge passes through a narrow rocky gorge with minimal restoration opportunities.

Canyon Reach will not be able to support much vegetation because the bedrock riverbed and the constricting rock wall bank conditions will result in high water velocities, expedited removal of any fine sediment, and very little suitable growing substrate along the narrow banks. Revegetation will be implemented by seeding only areas with suitable growing substrate.

Restoration Opportunities: Copco No.1 and Copco No.2

Copco No. 1 Reservoir is the reservoir with the highest restoration potential based on its wider, less confined valley and meandering mainstem. Copco No. 1 has restoration opportunity areas along the mainstem as well as key tributaries. The two (2) main restoration areas targeted for restoration at Copco No. 1 Development (Appendix H, Figure 5.4; KRRC 2018) are the Beaver Creek Complex, an intermittent stream with historic fish presence, and a spring-fed floodplain and wetland complex made up of natural springs to receive wetland planting. One of the six (6) sites identified for active grading in the 2018 Definite Plan Report for Copco No. 1, Site 2, is included in the above priorities. Site 1, the historic side channel complex on the mainstem, is a focus area for assisted sediment evacuation during drawdown. Sites 3 through 6 are considered lower priority and therefore will not be targeted for restoration actions. In addition, the following intermittent tributaries identified in the 2018 Definite Plan Report are considered lower priority: Deer/Indian Creek, Raymond Gulch, Unnamed Copco No. 1 Tributary, Spannaus Gulch, Snackenbury Creek, Unnamed Copco No. 1 Tributary. Long Prairie Creek at the upstream end of Copco No. 1 is also a low priority tributary, though it was not included in the 2018 Definite Plan Report. Specific restoration activities in the Copco No. 1 Reservoir are described in Restoration Opportunities: Copco No. 1 and Copco No. 2.

Revegetation at Copco No. 1 and Copco No. 2 will have seed mixes and planting pallets that reflect lower elevation and potentially deeper reservoir sediment than JC Boyle. IEV control will be initiated before the restoration implementation begins.

Restoration Opportunities: Iron Gate

Iron Gate Reservoir is located in a relatively confined valley with little to no pre-dam floodplain connectivity, so restoration opportunities are primarily focused on the larger tributaries. The three (3) main restoration areas on Iron Gate are Jenny Creek, the Camp/Scotch Creek Complex, and Wanaka Springs. Jenny Creek and the Camp Creek Complex are identified for active grading in the 2018 Definite Plan Report (Appendix H, Figure 5-7). The 2018 Definite Plan Report also included Unnamed Tributary 1 and Long Gulch (Site 1; KRRC 2018), which are considered low priority for restoration. Wanaka Springs is not included in the 2018 Definite Plan Report but has been included above to be consistent with approach of prioritizing natural wetlands and seeps. Fall Creek, at the upstream end of the Iron Gate Reservoir; and Bogus

Creek, located downstream of Iron Gate Dam were not included in the 2018 Definite Plan Report and therefore are not considered High Priority Tributaries; however, regulatory agencies have noted that mainstem connectivity at these tributary confluences is important. The mouths of these creeks will be monitored following drawdown, and residual sediment will be removed as needed for fish passage. Specific restoration activities in the Iron Gate reservoir are described in Restoration Opportunities: Iron Gate.

The longest of the studied tributaries, Jenny Creek is perennial and extends for 22.3 miles upstream of its confluence with Iron Gate Reservoir. The lower 3.5 miles are primarily made up of step-pool bedforms, and the next 16 miles upstream are at a gentler slope before the gradient steepens again towards the headwaters. Though Jenny Creek does not have reaches that meet the length and gradient criteria for a natural passage barrier as described above, field notes indicate that falls located two (2) miles from the present reservoir limit are a natural passage barrier (RDG, 2018b). There is also a low-head dam located approximately 1.1 miles upstream of Copco Road Jenny Creek Bridge that is a man-made fish passage barrier. In addition, a series of cascades in the first mile upstream from the existing reservoir limit may be an obstacle at low-flow conditions (RDG, 2018b). Spawning habitat may be limited, as the visible substrate mostly consisted of boulders (RDG, 2018b). According to PWA (2009), of the studied creeks, Jenny Creek has the greatest potential to provide quality anadromous fish habitat. More specifically, Jenny Creek has resident rainbow trout and contains suitable rearing habitat for Coho (DOI, USDC, and NMFS, 2007), and about one (1) mile of the creek is considered “accessible habitat” to Pacific lamprey (Hamilton et al., 2010, as cited in Close et al., 2010). Based on this analysis, Jenny Creek was considered a High Priority Tributary.

Dutch and Camp Creeks are intermittent according to the Department of the Interior (DOI), the U.S. Department of Commerce (USDC), and NMFS (2007) (and consistent with recent field observations). Camp Creek is characterized by multiple channels and developed riparian vegetation at its mouth, transitioning to riffle-pool and plane-bed bedform for the lower 1.5 miles. Moving upstream, the bedform then becomes considerably more varied, spanning all classes from regime to cascade until its upstream extent at RM 8.6. The Dutch-Camp Creek confluence occurs at Camp Creek RM 1.3. Dutch Creek extends for about 3.7 miles upstream of the confluence and varies in classification largely between riffle-pool and step-pool.

Camp Creek is documented to have been habitat for *Oncorhynchus mykiss* (Hamilton et al., 2005, 2016). Coho salmon have also been observed in Camp Creek, which is believed to provide natal rearing habitat (NOAA and NMFS, 2014). Additionally, steelhead are known to occur in the Oregon portion of Camp Creek. In fact, along with Fall Creek and Jenny Creek, Camp Creek is named in the PWA study (2009) as one (1) of the three (3) tributaries to Iron Gate that may have provided “high quality” salmonid habitat, in this case particularly for spawning and non-natal rearing. It is currently unknown whether the culvert under Copco Road near Iron Gate Reservoir is passable (RDG, 2019). This culvert is being replaced with a larger, fish passable crossing as described in Restoration Priorities. Based on this analysis, Camp Creek was considered a High Priority Tributary.

Scotch Creek is an intermittent stream that empties into the Iron Gate Reservoir at a cove on the northern side near the mouth of the Camp/Dutch Creek Complex. Scotch Creek is 8.4 miles long and flows into the post-dam course of Camp Creek approximately 1.2 miles upstream of where Camp Creek confluences with the Klamath River mainstem. The slope analysis for Scotch Creek suggests no one (1) bedform type is dominant in the lower three (3) miles of the creek. The upper six (6) miles predominantly consist of step-pools with cascades toward the headwaters; a natural passage barrier occurs at RM 5.0. Historically, steelhead trout were observed in Scotch Creek (Hamilton et al., 2005) and *Oncorhynchus mykiss* currently reside in this reach. It may also be suitable rearing habitat for Coho salmon (DOI, USBR, and NMFS, 2007). It is currently unknown whether the culvert under Copco Road near Iron Gate Reservoir is passable (RDG, 2019). This culvert is being replaced with a larger, fish passable crossing as described in Restoration Priorities. Based on this analysis and due to its connectivity with Camp Creek, Scotch Creek was considered a High Priority Tributary.

Long Gulch is 2.8 miles long and flows into the eastern side of Iron Gate Reservoir. It is primarily made up of estimated step-pool bedform through the first 2.8 miles, after which the gradient rises steeply toward its headwaters. An existing culvert presents an unnatural fish passage barrier at approximately at RM 0.7 (450 ft upstream of the reservoir rim). In addition, a natural passage barrier based on length and gradient criteria is located at RM 2.6. Currently, Long Gulch suffers from high turbidity and poor water quality due to cattle grazing (PWA, 2009). There is an existing wetland seep along the north bank of Long Gulch that currently daylights into the Iron Gate reservoir; this wetland should be re-connected to Long Gulch following drawdown. Long Gulch also contains two (2) submerged culvert crossings that will be removed within the Reservoir Area. Based on this analysis, Long Gulch was considered a low priority tributary that will receive select structure removal actions.

Fall Creek is located approximately 10.5 miles upstream of Iron Gate Dam and flows into the Klamath River from the north. Fall Creek's watershed is 15 square miles (USGS, 2019) and discharges into the upstream, north side of Iron Gate Reservoir. Fall Creek's flow is perennial (DOI, USBR, and NMFS, 2007). Fall Creek has a moderately steep to steep gradient for approximately its first mile and a steep gradient for the next approximately 1.5 miles. A culvert 100 feet upstream of the mouth at Daggett Road is considered a passage barrier (particularly for juvenile fish) (RDG, 2018a). This culvert is being replaced with a larger, fish passable crossing as described in Restoration Priorities. Approximately one (1) mile upstream of the mouth, the steep, natural falls represent the upper limit of passage for all fish life stages. The Draft EIR for the Lower Klamath Project License Surrender further identified Fall Creek as one (1) of four (4) "primary tributary habitat[s] available for salmonids," along with Jenny, Shovel, and Spencer Creeks (SWRCB, 2018). Coho spawning was observed in Fall Creek in the past (DOI, USDC, and NMFS, 2007), and about 1.2 miles of the creek were identified as "accessible habitat" for Pacific lamprey (Hamilton et al., 2010, as cited in Close et al., 2010).

Fall Creek Hatchery is located on Fall Creek approximately 2,000 feet upstream of its confluence with the Klamath River. Fish rearing and production at Fall Creek Hatchery ceased in 2003 (KRRC, 2018); however, the Fall Creek Hatchery will be rehabilitated as part of the Lower Klamath Project. Although Fall Creek was not included in the 2018 Definite Plan Report, it is included in this analysis because the Fall Creek Hatchery will become operational prior to dam removal. While Fall Creek is considered a high priority tributary because of the hatchery and presence of suitable habitat, it is a low priority for active restoration under the Lower Klamath Project, and direct restoration actions will be limited to providing connectivity at its confluence with the Klamath River and revegetating lands that are currently submerged under Iron Gate Reservoir.

Revegetation at Iron Gate have seed mixes and planting pallets that reflect lower elevation and potentially deeper reservoir sediment than JC Boyle. IEV control will be initiated before the restoration implementation begins.

Selection of Restoration Activities at Tributaries and Confluences

This section describes how various tributaries to the three (3) reservoirs have been prioritized for restoration actions and then discusses the specific restoration actions for the tributaries, including grading and large wood and riparian planting.

Table F-1 provides a summary of restoration actions.

Table F-1. Summary of Restoration Actions by Area

RESTORATION AREA	ASSISTED SEDIMENT EVACUATION DURING DRAWDOWN	SELECTIVE GRADING	HABITAT ENHANCEMENT FEATURES	RIPARIAN PLANTING (AVERAGE WIDTH)	OTHER
J.C. BOYLE RESERVOIR					
Klamath River		Stabilize unnatural sediment deposits, as needed		50-foot wide along mainstem	Fish passable channel at dam; remove former crossing
Spencer Creek	Focus Area		Large wood, willow baffles, boulder clusters	30-foot wide	
COPCO NO. 1 AND NO.2 RESERVOIRS					
Klamath River (entire length)		Stabilize unnatural sediment deposits, as needed		50-foot wide along mainstem	Fish passable channel at dam

RESTORATION AREA	ASSISTED SEDIMENT EVACUATION DURING DRAWDOWN	SELECTIVE GRADING	HABITAT ENHANCEMENT FEATURES	RIPARIAN PLANTING (AVERAGE WIDTH)	OTHER
Klamath River – Historic Side Channel Complex	Focus Area	Spot grading to reconnect side channel		50-foot wide along mainstem	
Spring-fed Wetlands					Wetland planting
Beaver Creek	Focus Area	Spot grading along entire reach for connectivity	Large wood, willow baffles, boulder clusters	30-foot wide	
IRON GATE RESERVOIR					
Klamath River		Stabilize unnatural sediment deposits, as needed		50-foot wide along mainstem	Fish passable channel at dam;
Jenny Creek	Focus Area	Excavate delta at reservoir rim	Large wood, willow baffles, boulder clusters	30-foot wide	
Camp/Scotch Creek Complex	Focus Area	Excavate delta at reservoir rim; selectively along channel length	Large wood, willow baffles, boulder clusters	30-foot wide	
Wanaka Springs					Wetland planting
Long Gulch				30-foot wide	Remove remnant crossing(s); Wetland planting at seep

Note: This table lists restoration actions primarily focused on enhancing aquatic habitats. Quantity and locations of habitat enhancement features will vary. Other actions to enhance upland habitats within the Reservoir Areas include seeding, planting, irrigation and IEV management activities.

In addition to the sites listed above, low priority tributaries will receive riparian seeding/planting and be graded if needed for mainstem connectivity. Low priority tributaries include the following:

- Iron Gate Reservoir – Long Gulch, Unnamed Iron Gate Tributary 1, Fall Creek
- Copco No. 1 Reservoir – Raymond Gulch, Unnamed Copco1 Tributary, Spannaus Gulch, Snackenbury Creek, Unnamed Copco No. 2 Tributary and Long Prairie Creek
- J.C. Boyle Reservoir – Unnamed J.C. Boyle tributaries 1, 2, and 3

In addition, Fall and Bogus Creeks located in the vicinity of Iron Gate Reservoir may I also have blockage removed if needed (for connectivity at the confluence only).

Prioritization of Tributaries

The five (5) High Priority Tributaries (Figure F-1) identified as restoration areas in Restoration Priorities (i.e., Spencer Creek, Beaver Creek, Jenny Creek, Scotch Creek, and Camp Creek) were selected based on the following factors:

- Watershed size and flow regime (perennial or intermittent)
- Historic presence of salmon and/or steelhead
- Potential future incisions risk
- Channel type, including presence of suitable spawning and rearing habitat and/or natural fish passage barriers

These five (5) High Priority Tributaries are considered to have the highest potential to support target fish species based on the factors above. These High Priority Tributaries were identified by evaluating and prioritizing the 10 largest tributaries identified in the Definite Plan Report. Below we present the analysis for future incision risk and channel slope analysis, followed by a brief discussion of each tributary.

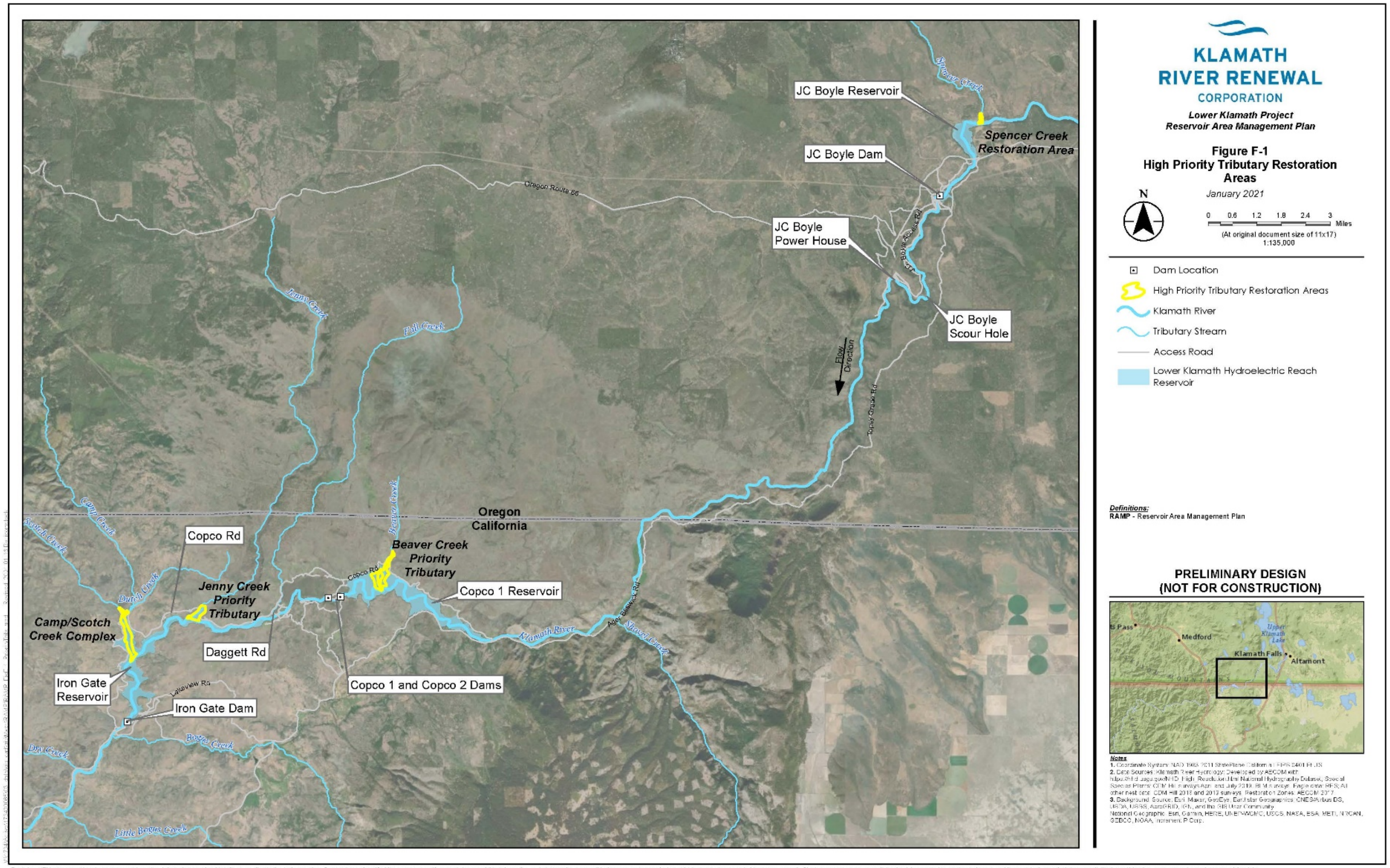

Figure F-1: High Priority Tributaries for Restoration Actions

Tributary Incision Risk Assessment

Differential incision is a potential fish passage risk for tributary channels that have developed sedimentary deltas at the reservoir rim. Preferential erosion of the finer, unvegetated sediment below the reservoir level but not the coarser, well vegetated sediment deposited above the water line could result in headcuts that form barriers to fish migration, as well as degraded, deeply incised channels that offer limited fish habitat benefit. This incision risk was previously studied (GMA, 2003) for the four (4) tributaries considered especially important either for potential fisheries or for sediment delivery to the mainstem of the Klamath River: Camp/Scotch Creek Complex and Jenny Creeks on Iron Gate, Beaver Creek on Copco No. 1, and Spencer Creek on J.C. Boyle. The study included surveying the portions of the deltas above and below the reservoirs that formed when each tributary was inundated and comparing them with the pre-dam topography (estimated using historic maps). Based on these comparisons it appears that the existing channels in the Camp/Scotch Creek Complex are up to 16 ft higher than the historic channels due to sediment that has been deposited in the alluvial fans. The difference in channel elevation for the deltas at Jenny and Spencer Creeks, while smaller at two (2) to four (4) ft deep, could still present an incision risk.

Above the reservoir level, the delta sediment is quite coarse and well vegetated, creating a relatively erosion-resistant surface. Below the reservoir level, the alluvial fan sediment is unvegetated and while coarser than the sediment in the main body of the reservoirs, is likely finer and more erodible than the material immediately upstream. Hence, a possible condition soon after the reservoirs are drawn down is for tributary channels with thick alluvial deposits such as the Camp/Scotch Creek Complex to incise in the finer sediment immediately below reservoir level and then for the incision to be arrested by the coarser sediment or road crossings upstream. This may create the potential for "hanging" tributaries with knickpoints (which could be potential fish passage barriers) at the transitions between incision and bed stability.

It appears that the GMA Hydrology (GMA) 2003 study was focused on the tributaries where incision was most likely to be a risk. The remaining tributaries do not appear to have deposited deltas as thick as the Camp/Scotch Creek Complex, and hence are assumed to have a lower risk of headcuts developing.

The recommended design approach for Scotch, Camp, and Jenny Creeks is to actively remove sediment from the deltas during and after drawdown, including some coarse delta sediment that is now above the reservoir water level. Spencer Creek is not included in this approach because of its thinner sediment and because of culturally sensitive sites that constrain excavation. The goal of sediment removal in this area is to prevent partial incision from creating headcuts that impede fish migration, as well as to restore a wider floodplain along the tributaries than would otherwise emerge, with side slopes that are gentle enough to support planting of riparian trees. The channel invert will be excavated down to the historic invert, assuming that this is identifiable as the boundary between overlying gravel and sand and underlying boulders and cobble. Sediment removal may be achieved by hydraulic methods during drawdown (e.g., jetting, boat waking) or by earth-moving equipment following drawdown.

Channel Type and Fish Passage Analysis

During preliminary design, documentation of the 16 tributaries identified in the Definite Plan Report was reviewed. Of these, 11 tributaries with either fish habitat potential or larger watersheds were further analyzed to assess channel slope, from which potential natural fish passage barriers and habitat type were inferred. (Note that the following six (6) tributaries from the Definite Plan Report (KRRC 2018) were not included in the slope analysis due to their smaller watershed size (i.e., less than three (3) square miles): Unnamed Iron Gate 1, Spannaus Gulch, Raymond Gulch, Unnamed Copco No. 1, Snackenbury Creek, and Unnamed J.C. Boyle 1).

Channel slope was used to infer channel bedform using the Montgomery-Buffington classification scheme (1998). We recognize that parameters in addition to slope are used to classify channels in the Montgomery-Buffington scheme, and that in a sediment-limited watershed channel type may shift towards steeper classes than those indicated using slope alone, but this provided an efficient desktop method to quickly evaluate a large length of tributaries. Calculated slopes were also used to evaluate whether the tributary slopes likely constituted natural barriers for fish passage, and this was cross-referenced against field notes and a literature review of historic fish presence.

Stantec Consulting Services Inc. (Stantec) provided station-elevation data for key tributaries from the estimated post-drawdown surface to just above the current water line of each reservoir. These were tied into profiles cut from 2013 U.S. Geological Survey Digital Elevation Models for the upstream portion of key tributaries. These datasets were resampled at uniform 25-foot intervals to calculate gradients for the Montgomery-Buffington classification.

Table F-2 shows the different slopes used to assign Montgomery-Buffington channel type, overlain with a compilation of published gradient limits on fish passage for various salmonid species (recognizing that fish passage limitations are naturally variable and affected by other factors such as hydrology and the length and hydraulic properties of the reach in question).

Table F-2: Montgomery-Buffington Stream Classification and Fish Passage Criteria

<table>
<tr><th>BED SLOPE</th><th>CHANNEL TYPE (MONTGOMERY-BUFFINGTON)</th><th>LIMITS OF COHO AND CHINOOK SALMON USAGE</th><th>LIMITS OF ADULT STEELHEAD USAGE</th></tr>
<tr><td><0.1%</td><td>Regime</td><td rowspan="4">0-7% usable for migration, spawning and rearing[1]</td><td rowspan="4">0-12% usable for migration, spawning and rearing[1]</td></tr>
<tr><td>0.1- 2%</td><td>Riffle-pool</td></tr>
<tr><td>1- 2%</td><td>Riffle-pool to plane-bed overlap</td></tr>
<tr><td>1- 3%</td><td>Plane-bed</td></tr>
</table>

BED SLOPE	CHANNEL TYPE (MONTGOMERY-BUFFINGTON)	LIMITS OF COHO AND CHINOOK SALMON USAGE	LIMITS OF ADULT STEELHEAD USAGE
3-10%	Step- pool	>8% to 10% gradients for more than 1,000 feet are natural barriers to migration[2] Gradients from 7-16% are potentially passable[1]	
10-30%	Cascade	>16% for more than 525 feet are natural barriers to migration[1] >20% for >30 feet are also impassable[3]	12-20% used for migration but not rearing/spawning. >20% for more than 525 feet are natural barriers to migration[1]
>30%	Colluvial	Impassable	Impassable

Sources:

1. Washington Department of Fish and Wildlife (WDFW): Fish Passage Inventory, Assessment, and Prioritization Manual (WDFW, 2019).
2. California Department of Fish and Game (CDFG): California Salmonid Stream Habitat Restoration Manual, Section IX (CDFG 2004).
3. Oregon Department of Forestry (ODF) rules: cited in "Inventory of Barriers to Fish Passage in California's Coastal Watersheds" (Coastal Conservancy, 2004; page 1 Appendix A).

Most published limits of salmonid migration fall within the cascade class. While short, 30-foot segments of greater than 20 percent slope are considered impassable, the topographic data were not of fine enough resolution to allow for analysis on that scale. Instead, the following discussion considers a reach impassable if the stream slope is greater than 16 percent on average for a length of 525 feet. The data were smoothed by taking a moving average of slope values over a sliding window of 525 feet. This analytical approach was supplemented with field notes and literature review. The results are summarized in Table F-3.

Prioritization Summary

A summary of tributary characteristics, results of analyses discussed above, and the final prioritization of the eleven largest tributaries is presented in Table F-3 followed by a brief discussion of each. Based on this analysis, each tributary was classified as a High Priority Tributary or a low priority tributary for restoration actions, defined as follows:

- **High Priority:** Restoration activities planned along the tributary to remove reservoir sediment, facilitate fish passage, and/or enhance habitat.
- **Low Priority:** The only intervention planned is minor grading at the mainstem confluence if needed for connectivity.

Note that there are six (6) additional tributaries identified in the Definite Plan Report (KRRC, 2018) that are not listed in Table F-3 due to their smaller watershed size (less than three (3) square miles). These six (6) tributaries are also considered low priority: Unnamed Iron Gate 1, Spannaus Gulch, Raymond Gulch, unnamed Copco No. 1, Snackenbury Creek and unnamed J.C. Boyle 1.

Table F-3: Characteristics of Key Tributaries

TRIBUTARY	RESERVOIR	APPROX. WATERSHED AREA (ACRES)[1]	Q2 (CFS)[1]	FLOW REGIME	HISTORICAL FISH PRESENCE[2]	LIMIT OF ANADROMY	POTENTIAL BARRIER	INCISION POTENTIAL AT RESERVOIR RIM	PRIORITY
Spencer Creek	J.C. Boyle	54,500	N/A	Perennial[3]	Chinook salmon, Coho salmon, Pacific lamprey, steelhead trout	None	N/A	No	High
Long Prairie Creek	Copco No. 1	26,600	187	Perennial, TBD[4]	N/A	RM 0.2	Steep gradient	N/A	Low
Beaver Creek	Copco No. 1	3,600	42.2	Intermittent[3]	Coho salmon[9]	RM 1.5	Steep gradient	N/A	High
Jenny Creek	Iron Gate	134,700	927 (1,400)	Perennial[3]	Chinook salmon, Coho salmon	RM 0-1 at low flows	Falls[5]	Yes	High
Camp Creek	Iron Gate	12,700	126	Intermittent[8]	Chinook salmon, Coho salmon, steelhead trout	RM 6.6 on Camp Creek	Steep gradient	Yes	High
Scotch Creek	Iron Gate	11,500	115	Intermittent	Steelhead trout	RM 5.0	Steep gradient	Yes	High
Fall Creek	Iron Gate	9,600	82.2	Perennial[3]	Chinook salmon, Coho salmon, Pacific lamprey, steelhead trout	RM 0.1 RM 1.0	Culvert[6] Steep gradient	N/A	Low
Long Gulch	Iron Gate	900	11.1	Intermittent[7]	N/A	RM 2.6	Steep gradient	N/A	Low

Notes:

1. USGS, 2019
2. Hamilton et al., 2005, unless otherwise noted
3. DOI, USDC, and NMFS, 2007.
4. RDG 2018b.
5. RDG, 2019, Fish Passage Structure INVENTORY.
6. PWA, 2009.
7. Intermittent according to DOI, USDC, and NMFS, 2007 and recent field observation (October 2019); perennial according to PWA, 2009.
8. Brownell et al., 1999
9. Flow $(Q)_2$ for Jenny creek estimated as 1400 cfs based on preliminary analysis by Knight Piesold
10. RM = River mile as measured upstream from estimated mainstem confluence

Appendix G

Geomorphology Monitoring / Adaptive Management Field References

Appendix G-1: Castro and Thorne 2019

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RESEARCH ARTICLE

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The stream evolution triangle: Integrating geology, hydrology, and biology

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Abstract
The foundations of river restoration science rest comfortably in the fields of geology, hydrology, and engineering, and yet, the impetus for many, if not most, stream restoration projects is biological recovery. Although Lane's stream balance equation from the mid-1950s captured the dynamic equilibrium between the amount of stream flow, the slope of the channel, and the amount and calibre of sediment, it completely ignored biology. Similarly, most of the stream classification systems used in river restoration design today do not explicitly include biology as a primary driver of stream form and process. To address this omission, we cast biology as an equal partner with geology and hydrology, forming a triumvirate that governs stream morphology and evolution. To represent this, we have created the stream evolution triangle, a conceptual model that explicitly accounts for the influences of geology, hydrology, and biology. Recognition of biology as a driver leads to improved understanding of reach-scale morphology and the dynamic response mechanisms responsible for stream evolution and adjustment following natural or anthropogenic disturbance, including stream restoration. Our aim in creating the stream evolution triangle is not to exclude or supersede existing stream classifications and evolutionary models but to provide a broader "thinking space" within which they can be framed and reconsidered, thus facilitating thought outside of the alluvial box.

KEYWORDS
channel evolution model (CEM), conceptual model, fluvial geomorphology, river restoration, stream evolution model (SEM), stream classification

1 | INTRODUCTION

The stream evolution triangle (SET) is a conceptual model that blends long-established principles of fluvial geomorphology with results emerging from recent research revealing the high degree to which biological agents affect stream processes and systems (Atkinson, Allen, Davis, & Nickerson, 2018; McCluney et al., 2014). Conceptual models are useful when attempting to integrate information from natural science disciplines in order to understand complex systems (Fortuin, van Koppen, & Leemans, 2011) and are consequently well-suited to fluvial systems. With the SET, we attempt to create a conceptual space inclusive enough to represent wide ranges of process drivers, stream forms, and evolutionary pathways but simple enough to allow for creative thinking and rapid evaluation of both established and new ideas (Jackson, Trebitz, & Cottingham, 2000).

In common with existing stream classifications (e.g., Leopold & Wolman, 1957; Montgomery & Buffington, 1993; Rosgen, 1996; Schumm, 1985 [Figure 1]) and evolution models (e.g., Cluer & Thorne,

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meaningful patterns, based on measures of similarity and difference (Naiman, Lonzarich, Beechie, & Ralph, 1992). With respect to process response, the balance between hydrology and geology is implicit to the basal axis of the SET, along which the influence of biology is minimal. This accords with Lane's balance (Lane, 1955), which represents alluvial channel stability solely as a function of stream power (hydrology) and sediment supply/calibre (geology).

Physics-based stream classification has advanced our understanding of river form and process, and its application has proven useful in the contexts of river engineering, management, and restoration. However, a limitation of conventional stream classifications is the perception that there is a finite number of enduring stable stream types that change only in response to an extreme event or a step change in one of the controlling variables. This can lead to an erroneous conclusion that a stream of a designated type will not, and perhaps should not, change through time.

Channel and stream evolution models (CEMs or SEMs) provide an alternative to morphological classifications in that they characterise streams in terms of patterns and trends of adjustment, rather than stasis (Cluer & Thorne, 2014; Schumm et al., 1984; Simon & Hupp, 1986). Although useful for describing and understanding temporal and spatial sequences of change, existing evolutionary models also rely on physics-based arguments and explanations, eschewing consideration of the influence of biological agents in conditioning, let alone driving morphological change. In this context, the SEM represented an advance over earlier CEMs in that it associates the range and value of ecosystem benefits provided by an incised stream with its stage of evolution. However, the SEM still frames ecosystem functions as being dependent on the morphological outcomes of fluvial processes, rather than representing biology as an evolutionary driver in its own right.

In summary, existing stream classifications and evolutionary models start with the premise that river form results from physical interactions between the flow regime, sediment regime, and channel boundary materials. In the SET, we cast biology as an equal partner with geology and hydrology, forming a triumvirate that governs stream morphology, drives morphological adjustment, and steers the sequential path along which disturbed streams evolve. Further, the SET recognises that the form, function, and evolutionary trajectory of a stream may be dominated by a single driver, a pair of drivers, or (more usually) some combination of all three, depending on its catchment, landscape, and management contexts.

2 | FOUNDATIONS

The SET depicts the relative influences of geology, hydrology, and biology on stream form and process (Figure 1). Triangular representations of three characteristics or traits are well established in natural science and are known as ternary or triangle plots or diagrams (Flemming, 2000; Frohlich, 1992). Hence, the SET can appropriately be described as a ternary diagram.

Stream types may be differentiated in the SET depending on where they plot in terms of the relative influences of geology, hydrology, and biology. Streams with one predominant driver will plot close to that corner of the triangle. Streams with codominant drivers, such as island-braided streams controlled by biology and hydrology, will plot midway along the axis connecting those drivers. Conversely, if all three drivers have equal influence, a stream plots near the centre of the triangle. It follows that in terms of stream classification, the space within this ternary diagram represents a wide range of driver-defined process domains and associated stream types and evolutionary trends. It further follows that when there is a change in the relative influences of the high-level drivers, this alters the plotting position, reflecting a shift in process domain that initiates a responsive adjustment in stream form along a new evolutionary path.

Stream responses may be relatively simple and short lived or complex and long-lasting, depending on the magnitude and duration of the causal change in one or more of the drivers. For example, a flood event temporarily increases the influence of hydrology, shifting the plotting position towards the "hydrology" corner. The relative influences of geology and/or biology must decrease, because the three relative influences must sum to 100%. After a flood, the influence of hydrology returns to its pre-event value, and the plotting position shifts away from the hydrology corner.

The potential for more complex responses to disturbance can be illustrated by the impacts of a drought. If the drought is short lived, the plotting position shifts away from the hydrology corner, increasing the relative influences of geology and/or biology. When the drought ends, the influence of hydrology returns to its pre-event value, and the plotting position shifts back towards the hydrology corner. However, if the drought is severe, it not only may reduce river flows but also may stress riverine ecosystems—thus diminishing the influence of biology as well as hydrology. When an event directly affects multiple drivers, adjustments to changes in their relative influences become more difficult to evaluate and predict. Also, stream adjustments to an event impacting more than one driver will likely be protracted, nonlinear, and morphologically complex.

3 | UNDERSTANDING THE DRIVERS AND THEIR INFLUENCES

Geology is a process driver because highly erosion-resistant boundary materials, such as intact bedrock, coarse colluvium, strongly cohesive clays, or cemented sediments, limit the capacity of a stream to adjust its geometry, at least over multidecadal timescales. But erosion resistance is just one of numerous ways that geological influences on stream form and process can be represented (Figure 2a).

The decreasing influence of geology can also be characterised using bands that grade from "source," through "transport," to "response" (Montgomery & Buffington, 1993; Figure 2b). In source reaches, primary erosion supplies weathered rock and colluvium to the fluvial system. These reaches are nonalluvial and insensitive to disturbance. In transport reaches, sediment loads are limited by the supply of sediment from local and upstream sources. This makes them more sensitive to disturbance than source reaches but less sensitive

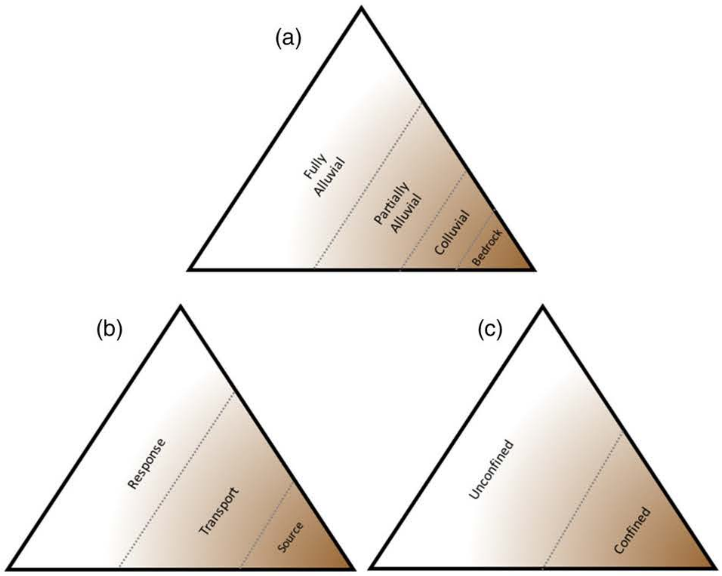

FIGURE 2 Examples of decreasing influence of geology with distance from the "geology" corner of the stream evolution triangle [Colour figure can be viewed at wileyonlinelibrary.com]

than fully alluvial response reaches, where sediment loads are limited only by the capacity of the stream to transport alluvium.

The importance of valley confinement is highlighted by Fryirs, Wheaton, and Brierley (2016). Streams vary from those that are geologically "confined" within narrow valleys to those that are "unconfined" because they flow through wide valleys with space for development of streams with meandering, braiding, or anastomosing planforms (Figure 2c). When an alluvial stream is channelised, incised, and/or stabilised by river engineering, process–response mechanisms are distorted, and morphological outcomes artificially mimic those of geological confinement. Consequently, in the SET, the impact of constructing nonerodible structures is to shift the plotting positions of naturally alluvial or partially alluvial streams towards the "geology" corner of the triangle.

Geologically controlled and artificially stabilised channels are relatively simple, typically featuring rectangular, trapezoidal, or triangular cross sections, with longitudinal slopes dictated by landscape gradients, and single-thread planforms that follow faults, lineaments, narrow valleys, or anthropogenically fixed courses. These streams are resilient to fluvially driven, morphological change even when subjected to extreme hydrological events. They are also insensitive to changes in the associated biological communities. Consequently, streams that plot close to the geology corner of the SET are relatively unresponsive to disturbance, and their morphologies are persistent—at least over steady (Schumm & Lichty, 1965) and human timescales. Even in such geologically controlled streams, heavy wood loading can result in more complex morphologies and habitats, which could move these streams towards the biology corner.

Hydrology is a process driver because it is energy imparted to the landscape by flowing water that powers fluvial processes. Channel dimensions scale on stream discharge, and thus, the relative influence of hydrology is often dominant in very large rivers, generally tending to diminish as stream size decreases. However, all aspects of the flow regime affect the influence of hydrology on stream form and function (including flow frequency, magnitude, seasonality, and duration), and particular attributes and combinations of attributes act to intensify or weaken the influence of hydrology. Hence, there are multiple ways other than the discharge magnitude to characterise how the influence of hydrology increases with proximity to the hydrology corner.

The influence of hydrology is amplified in arid areas where mean annual discharge is low but morphological effectiveness is high due to storm-dominated, flashy flows (Skidmore et al., 2011). For example, the Gila River in the Sonora Desert was observed to widen by a factor of 20 during a single flood event, with the impacts of that single storm persisting for half a century (Burkham, 1972). Hence, the Gila River would plot close to the hydrology corner in the SET despite its relatively low mean annual flow. At the other end of the flow variability, spectra are spring-fed streams with nearly flat annual hydrographs, such as the Deschutes River, Oregon, whose channel has changed little over centuries (O'Connor, Grant, Curran, & Fassnacht, 1999). Between these extremes, flow regimes range from those in basins subject to rain-on-snow flood events, through rivers characterised by low-intensity, long-duration rainfall and runoff from frontal depressions to high-alpine, snow-fed streams that rarely experience rainfall at all (Figure 3a).

The natural flow regimes of many streams and rivers have been purposefully or inadvertently altered by catchment and water

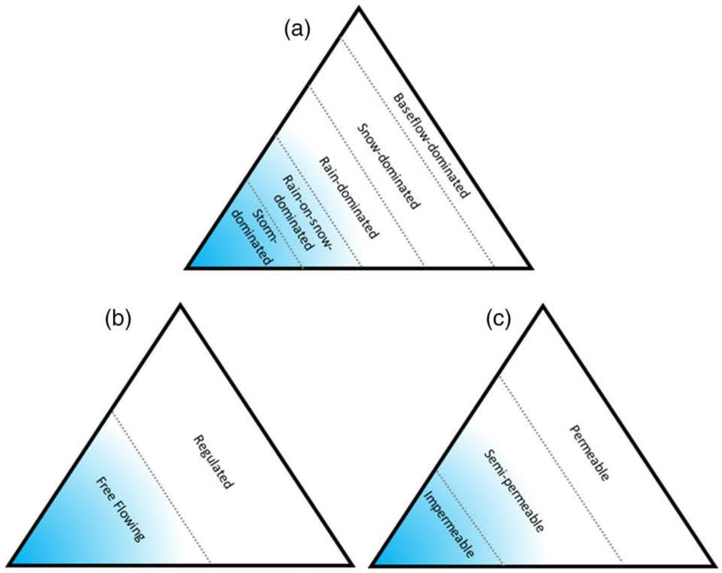

FIGURE 3 Examples of decreasing influence of hydrology with distance from the "hydrology" corner of the stream evolution triangle [Colour figure can be viewed at wileyonlinelibrary.com]

resource development, with impacts that may either truncate or magnify the influence of hydrology. For example, using dams and diversion channels to reduce natural flow, variability shifts the plotting positions of regulated rivers away from the hydrology corner (Figure 3b). Conversely, urbanisation that significantly increases the proportion of the catchment that is impermeable has been shown to increase flows and flashiness, shifting affected streams closer to the hydrology corner (Figure 3c).

Hydrologically dominated and unregulated streams are more responsive to fluvially driven, morphological change because hydrology drives channel adjustments, whereas geology and biology generally resist them. Due to their alluvial nature and lack of biological control, hydrologically dominated streams are temporally variable and complex, typically featuring braided channels with mobile beds and high width-to-depth ratios. Hydrologically dominated streams are also sensitive to changes in the associated biological communities through, for example, colonisation of bars by woody vegetation (Bertoldi et al., 2015). Consequently, streams that plot close to the hydrology corner are more responsive to disturbance than those near the geology corner, and their morphologies are transient and changeable over steady (Schumm & Lichty, 1965) and human timescales.

Biology is a process driver because energy imparted to the landscape by organisms drives biogeomorphic processes as well as modifying fluvial processes. The effectiveness of biology as a process driver has long been recognised through, for example, the statistically significant impact of dense, woody bank vegetation on the stable widths of gravel-bed rivers (Hey & Thorne, 1986). Evidence of the influence of vegetation on river form also comes from the sedimentary record, where concordance has been shown between the appearance and spread of trees in fluvial landscapes during the Devonian and Carboniferous periods (between about 300 and 420 million years ago), and planform transitions from sheet braided to meandering and then anastomosed (Davies & Gibling, 2010). Conversely, a close association between the disappearance of vegetation and planform metamorphosis was demonstrated by a switch from meandering to braiding in South African rivers when vegetation was eliminated during the Permian–Triassic extinction, about 250 million years ago (Ward, Montgomery, & Smith, 2000).

The morphological impacts of vegetation have received considerable attention and clearly demonstrate one way in which biology affects river forms and processes. In the SET, the influence of vegetation can be represented by plotting streams with riparian zones colonised by wetland obligate species near the apex because there is frequent and close interaction between vegetation and the stream. However, streams surrounded by upland vegetation species plot closer to the base because such vegetation rarely, if ever, interacts directly with stream flows (Figure 4a).

Upland species may still, indirectly, affect stream processes having been recruited by the stream through lateral erosion and/or gravity-induced, mass failure. This is the case because although live vegetation (including standing trees) significantly influences stream forms and functions, a considerable body of research establishes that trees continue to impact fluvial processes even after their demise, in the form of large wood pieces and log jams (Abbe & Montgomery, 1996). Indeed, reintroduction of large wood and construction of engineered log jams have become staple actions in modern river

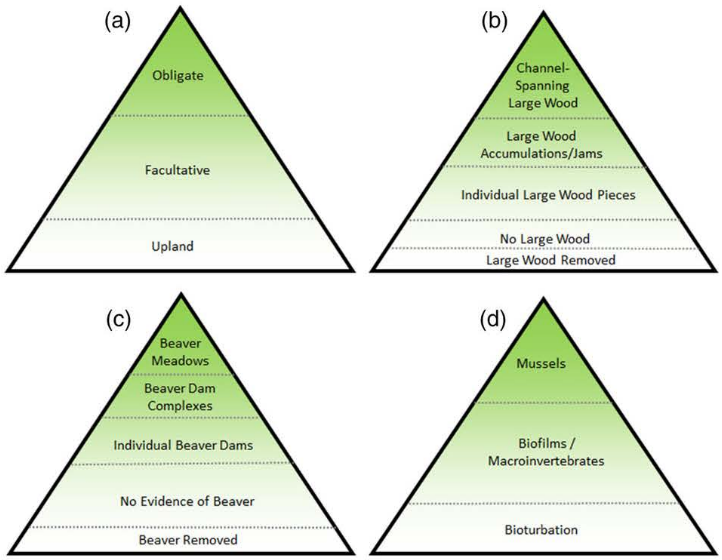

FIGURE 4 Example of decreasing influence of biology with distance from the "biology" corner of the stream evolution triangle expressed through (a) riparian vegetation by wetland indicator status rating (Lichvar, Melvin, Butterwick, & Kirchner, 2012; obligate = almost always occurs in wetlands; facultative = occurs in wetlands and nonwetlands; upland = almost never occurs in wetlands), (b) presence and abundance of large wood, (c) presence and relative dam building activity of beaver; and (d) biologically induced bed stability or instability [Colour figure can be viewed at wileyonlinelibrary.com]

restoration. This is a testimony to the influence of large wood on channel morphology, channel-forming processes, and channel–floodplain connectivity (Abbe & Montgomery, 1996; Gurnell, 2012). It follows that the influence of biology can also be characterised in terms of the relative size and spatial organisation of large wood or, indeed, its absence or removal (Figure 4b).

Biological influence is, obviously, exerted by animals as well as plants. Historically, beavers were endemic to most of North America (*Castor canadensis*) and Europe (*Castor fibre*), and their effects on hydrology, hydraulics, sediment dynamics, morphology, and floodplain connectivity are known to have been pervasive (Pollock, Lewallen, Woodruff, Jordan, & Castro, 2017). In areas characterised by beaver occupation and dam building, valley morphology is often described as a "beaver meadow," indicating the intensity of geomorphic change resulting from beaver activity (Polvi & Wohl, 2012). When beavers were driven towards extinction during the late 19th century, their removal often resulted in channel degradation, disconnection from the floodplain, lowering of groundwater tables, and impoverished stream ecologies that are only now starting to recover in response to restoration projects that increasingly include beaver reintroduction or recolonisation (Pollock et al., 2017; Figure 4c).

Although the morpho-dynamic influences of large animals like beaver and wolves (Polvi & Wohl, 2012) are well known, it is easy to underappreciate the impacts of very small animals, especially when their habitats are masked. Yet recent research has established that benthic life also affects riverine processes, particularly through its impact on bed mobility. For example, colonisation of a stream by freshwater mussels (*Unionoida*) and/or macroinvertebrates such as caddisfly (*Trichoptera*) can significantly reduce bed mobility compared with that of uncolonised stream beds formed in otherwise equivalent sediments (Zimmerman & de Szalay, 2007). Conversely, bioturbation by crustaceans such as crayfish (*Astacoidea* and *Parastacoidea*) or by spawning salmon (*Onchorynchus* spp.) can increase bed mobility by disrupting the surface armour in gravel-bed rivers (DeVries, 2012; Harvey et al., 2011). It follows that the influence of biology can be characterised in the SET on the basis of the presence, abundance, and health of benthic life (Figure 4d) as well as that of riparian vegetation and mammals.

4 | MORPHO-DYNAMIC DOMAINS, STREAM CLASSIFICATION, AND STREAM EVOLUTION

4.1 | Morpho-dynamic domains

The influence axes of the process drivers describe morpho-dynamic domains within the SET, which are zones characterised by particular combinations of relative geological, hydrological, and biological influence. Because the axes are not scaled or rigidly defined and because the influences are relative, the SET can accommodate a wide range of stream classifications and evolutionary models, thus providing a flexible, conceptual "thinking space" within which to evaluate not only current channel forms but also sensitivity to disturbance, past trends of change, and possible future trajectories of adjustment. However, attempting to map the morpho-dynamic domains within the SET and populate them with typical examples, a priori would risk closing down, or at least constraining, the thinking space we seek to create. Accepting this, there is still a case for making that space a little less abstract by including here three examples of rivers that illustrate morpho-dynamic domains associated with the corners of the triangle.

An archetypal example of a stream naturally controlled by geology is the Colorado River within the Grand Canyon. In addition to being laterally constrained, the river is also hydrologically emaciated as it is regulated by multiple upstream dams. Also, the influence of biology is muted because vegetation on the floor of the canyon is sparse. Accordingly, this reach of the Colorado River plots in the geology corner of the SET (Figure 5a).

The Rakaia River, New Zealand, rises in the Southern Alps before draining across the broad expanse of the Canterbury Plains. In its middle reach, the Rakaia is geologically unconstrained, and its flow regime features highly variable discharges, including great floods driven by rainstorm, snowmelt, and rain-on-snow events. Sediment loads are high, deriving from rapid erosion in the headwater basins. Consequently, the middle reach of the Rakaia plots in the hydrology corner of the SET (Figure 5b).

The Rio Negro is a tributary to the River Amazon. Globally, it is the seventh largest river by discharge, and its lower course has created a

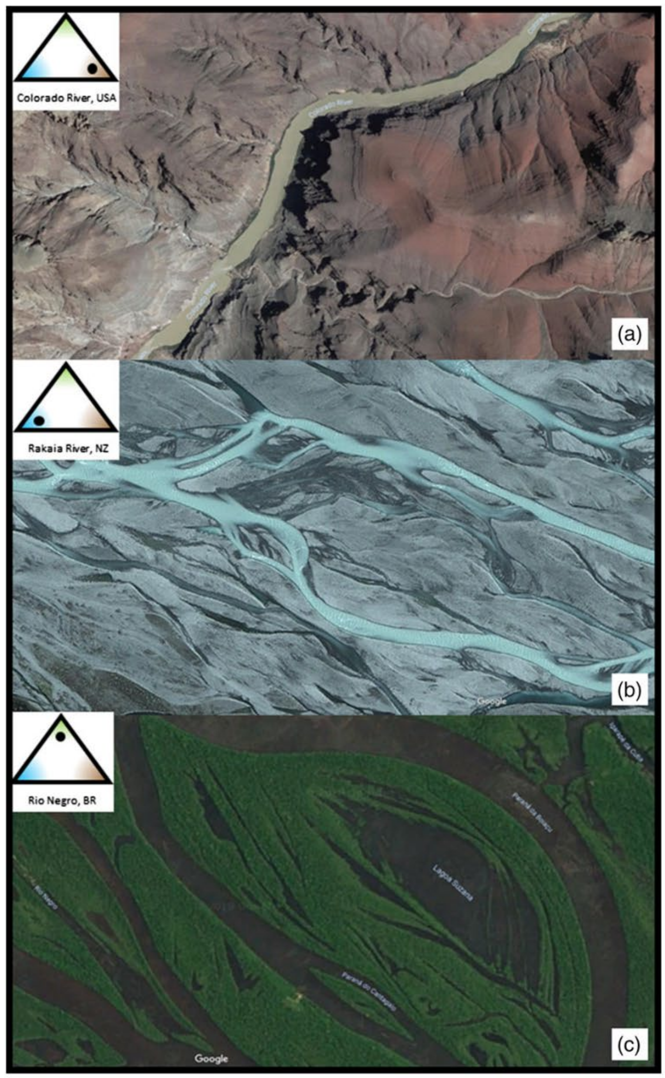

FIGURE 5 Archetypal examples of world rivers representing the three corners of the stream evolution triangle. Images from Google Maps [Colour figure can be viewed at wileyonlinelibrary.com]

continuous riparian corridor that is up to 30-km wide. On the basis of its discharge, it might be expected that the Rio Negro would plot in the hydrology corner of the SET. However, the sediment load of the Rio Negro is disproportionately small, and its planform is anastomosed, featuring an intricate network of anabranches bordered by islands and floodplains that are densely vegetated by obligate and facultative wetland species (Figure 5c). On the basis of these attributes and despite its huge discharge, form and process in the lower Rio Negro are dominated by biology, and hence, it plots at the apex of the SET.

4.2 | Stream classification

Morpho-dynamic domains within the SET have associated characteristic stream morphologies that are conventionally classified as particular channel types. In this context, the SET is able to accommodate a wide range of existing stream classifications, including those of Schumm (1985; Figure 1) and Rosgen (1996; Figure 6), which rely on physical attributes such as slope, bed material, number of channels, sinuosity, width-to-depth ratio, and confinement. Plotting these classifications in the SET provides new insights because plotting position associates stream types with the relative influences of all three process drivers. Generally, ease of adjustment decreases with proximity to any corner of the triangle, as the influence of one driver becomes controlling and, hence, the stream type becomes more persistent.

For example, in the geology corner, the morphologies of bedrock channels are highly resilient to change because their boundaries are fixed, at least over timescales of decades to centuries. In the hydrology corner, the wide, braided subchannels of alluvial rivers with abundant runoff, mobile sediments, and little or no vegetation adjust constantly, but the braided planform persists through time. Near the apex, where the influences of hydrology and geology are muted and the life of the river predominates, flows are slower, boundaries are erosion resistant, and the multiple channels are relatively small, making anastomosed planforms resilient to disturbance. In contrast, closer to the centre of the triangle, the relative influences of geology, hydrology, and biology are finely balanced. In this region of the SET, frequent adjustments to stream processes are intrinsic to the single-thread–meandering morphologies that predominate.

What the SET adds to existing classifications is explicit recognition that, when affected by multiple drivers, a stream's morphology adjusts constantly in response to fluctuations in their relative influences. In the SET, morphology and ease of adjustment are both indivisibly tied to the relative influences of the process drivers, conditioning the stream system's susceptibility or resilience to change, and its capacity for recovery or relaxation following major disturbance.

4.3 | Evolutionary pathways

Morpho-dynamic domains within the SET also have associated characteristic stream evolution stages and trajectories that occur in response to various types of disturbance. Consequently, the SET provides a

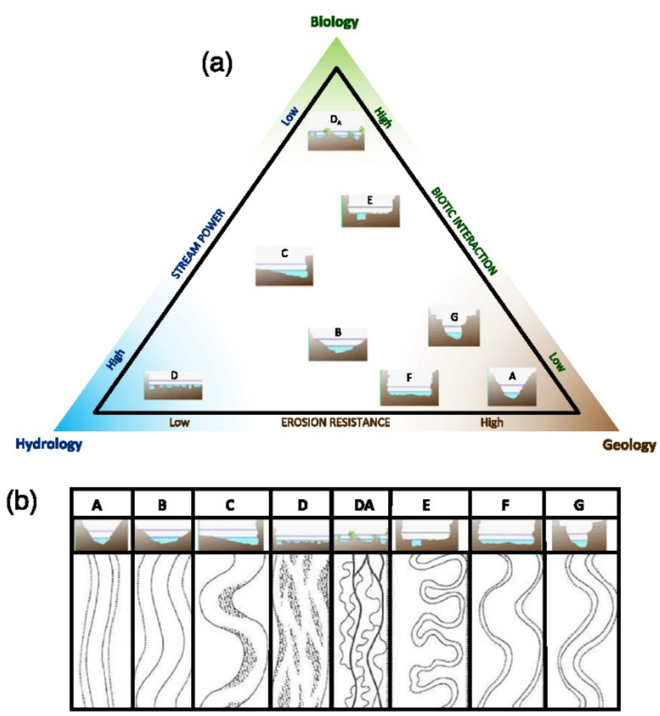

FIGURE 6 (a) Stream evolution triangle with example classification system (Rosgen, 1996); (b) Rosgen Stream Classification System (modified from Rosgen, 1996) [Colour figure can be viewed at wileyonlinelibrary.com]

suitable template for plotting the stages in channel and stream evolution models, such as that of Cluer and Thorne (2014; Figure 7).

In the original CEMs, morphological adjustments are represented as a linear sequence, whereas in the later SEM, the sequence is represented as being cyclical. Although both linear and cyclical behaviours are observed in nature, it is rare for a single site to follow the precise sequence of evolutionary stages envisaged in either the CEMs or the SEM. The advantage of plotting evolutionary stages within the SET is that this highlights the possibility of a stream following other evolutionary pathways, depending on how the relative influences of the process drivers vary through time and space during postdisturbance evolution.

In the SEM, an evolving stream passes rapidly through some evolutionary stages although it may linger in others (Cluer & Thorne, 2014). The SET captures this temporal variability because the plotting positions for different stages indicate not only their morphological form and function but also, through their proximity to a corner or the centre of the triangle, their ease of change, which governs how long an evolving stream spends in a particular evolutionary stage.

Finally, even in rapidly evolving systems, it is unusual for a given site to complete the eight-stage SEM cycle, because this requires at least a decade of undisturbed, incremental evolution and, more often than not, the cycle is interrupted, advanced, or reversed by subsequent disturbances or complex responses in the fluvial system (see Zheng, Thorne, Wu, & Han, 2017). Although the SEM's evolutionary pathway does plot coherently in the SET (Figure 7), it is no longer prescribed deterministically. In the SET, channel morphologies and evolutionary pathways are emergent properties, charted on the basis of changes in the relative influences of the high-level drivers and morphological susceptibility or resilience to change. Consequently, although some evolutionary trends are more probable than others, as in nature, a disturbed stream's evolutionary path is not predetermined. In this regard, uncertainty stemming from natural variability is inherent to the SET.

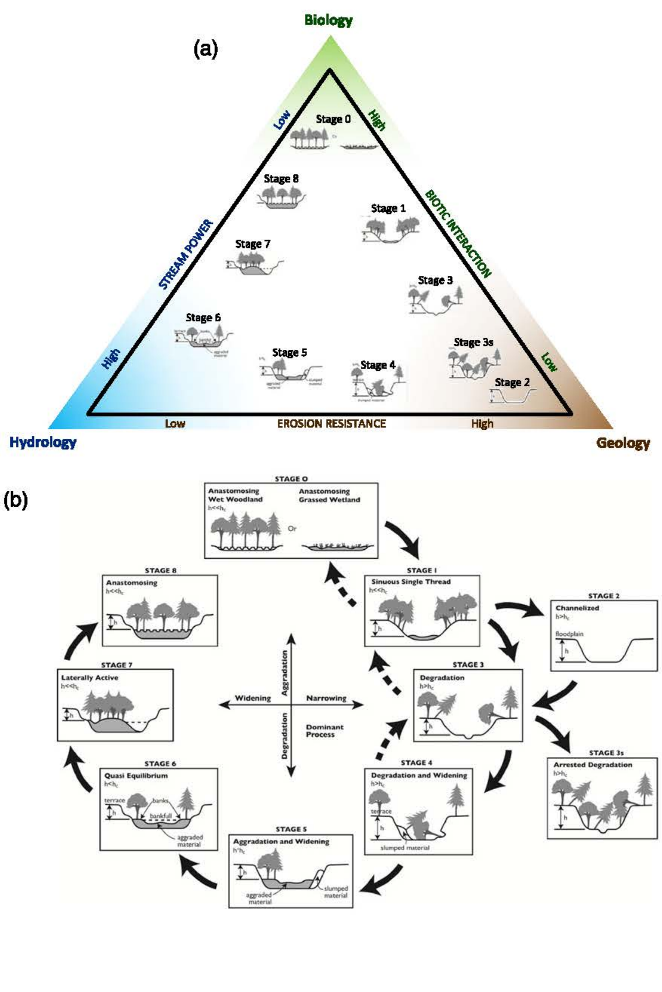

FIGURE 7 (a) Stream evolution triangle with stages of stream evolution (Cluer & Thorne, 2014); (b) stream evolution model (Cluer & Thorne, 2014) [Colour figure can be viewed at wileyonlinelibrary.com]

5 | STREAM DISTURBANCE, RESPONSE, AND RECOVERY

Fluvial geomorphology has long recognised that disturbance may result from a variety of natural events or human actions that affect catchment runoff, sediment yield, or the channel's dimensions, geometry, and resistance to flow and erosion (Knighton, 1998). In river science and management, the significance of disturbance resulting from changes to catchment, floodplain, riparian, and in-channel vegetation has been widely appreciated for decades (Thorne, Soar, Skinner, Sear, & Newson, 2010). More recently, disturbances that affect longitudinal and/or lateral connectivity in the fluvial system are receiving increasing attention (Wohl et al., 2018), whereas the importance to river forms and processes of changes to catchment, stream, and aquatic ecology is now accepted (Atkinson et al., 2018).

The SET reveals that for postdisturbance recovery to be robust and enduring, some degree of biological uplift is essential and re-establishment of a healthy and functional ecosystem (represented by migration upwards of plotting position in the SET) depends on the rate of recolonisation compared with the frequency of physical or biological disturbance (Shafroth, Stromberg, & Patten, 2002). The SET can aid understanding in both the impact of a disturbance and recovery at the reach and system scales, because it represents causal relationships between changes in the process drivers (and hence SET-defined, morpho-dynamic domains) and the types of disturbance, morphological response, and evolutionary trajectory that result. In this context,

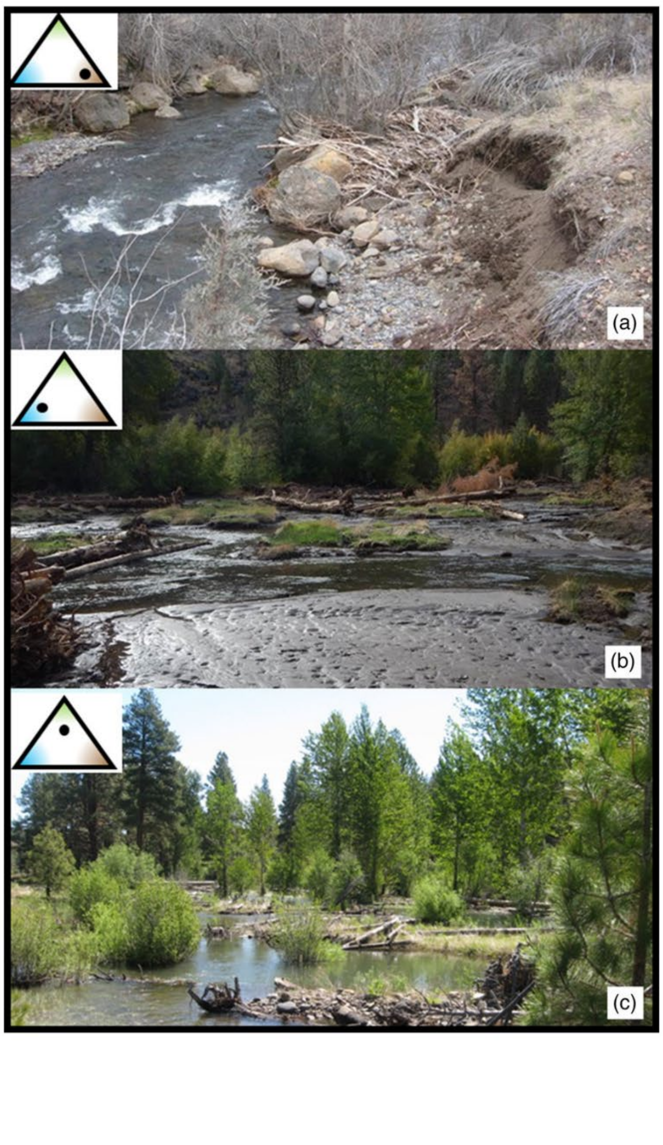

FIGURE 8 Whychus Creek, Oregon, restoration project phases over 1 year. Photos courtesy of Paul Powers [Colour figure can be viewed at wileyonlinelibrary.com]

restoration of disturbed streams should facilitate either recovery to the predisturbed condition or evolution towards a new, dynamically metastable morphology. Either pathway involves biological uplift. What restoration should avoid is locking an actively evolving stream into an artificially stable configuration using engineered structures.

If disturbance is simple and limited to one driver, such as hydrology, recovery may be relatively straightforward and even predictable using physics-based theories of complex response in alluvial systems (Hey, 1979). However, the SET illustrates that when a "game changing" natural or human disturbance triggers changes in process domains dominated by biology (through, for example, species extinctions or ecosystem collapse), profound changes in relative influence and major shifts of plotting position in the SET result. This indicates that natural recovery will be slow, convoluted, and functionally indeterminate, unless assisted by appropriate and well-designed river restoration.

That recovery to the predisturbance condition can be achieved through resetting the floodplain, and channel network is illustrated by a restoration project on Whychus Creek, Oregon. Prior to restoration, the postdisturbance-incised channel was vertically and laterally stable, plotting near the geology corner (Figure 8a). Filling the incised channel reconnected the stream to its floodplain, initially moving the system close to the hydrology corner (Figure 8b). Subsequent bar and floodplain recolonisation by wetland and riparian vegetation then shifted Whychus Creek towards the biology corner (Figure 8c), following a path close to the hydrology–biology side of the triangle.

6 | CONCLUSIONS

A conceptual model provides a space within which complex systems with unpredictable relationships and indeterminate outcomes can be assessed and evaluated to help elucidate potential trajectories of change and scenarios for possible future conditions. Conceptual models are "thinking tools," and the best outcome of a conceptual model is not a precise answer but deeper thinking. According to Fortuin et al. (2011), conceptual models help to "structure, retrieve, and construct knowledge, which thereby substantially improves the learning process."

In this spirit, the SET reframes physics-based fluvial geomorphology to acknowledge and explicitly account for the power of biology as a process driver. The SET's flexibility and inclusiveness are its greatest assets because the aim is not to constrain or supersede conventional wisdom but to expand and support thinking outside of the alluvial box when studying, managing, engineering, and restoring stream systems.

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Appendix G-2: Rapid Geomorphic Assessment (RGA) Field Forms

RAPID GEOMORPHOLOGICAL ASSESSMENT (RGA) FIELD FORM

Stream Name	Observers	Date
Reach Name	Weather over past 2-5 days (No of days precip/average daytime temp.)	Weather (Temp, Precipitation)
Upstream Reach Boundary	Downstream Reach Boundary	Flow Conditions

MORPHOLOGY

☐ Typical Photo Captured

Increasing particle size & gradient ↑

☐	Bedrock	Lack alluvial bed. Some material in scour holes temporarily
☐	Cascade	No pools. Turbulent flow over large protruding grains
☐	Step-Pool	vertical steps and pools present
☐	Plane-Bed	Featureless bed. Homogeneous habitat
☐	Riffle-Pool	Alternating riffles and pools
☐	Dune-Ripple	bed mobile at most stages, dune-forms
☐	Multi-Thread	Multiple channel in lowlands

Average Bankfull Width (ft): ________

SUBSTRATE

☐ Typical Photo Captured

	Estimated Relative Abundance			
	>50% Mostly	30-50% Some	15-30% Little	1-15% Few
Bedrock	☐	☐	☐	☐
Boulder (>256 mm)	☐	☐	☐	☐
Cobble (64-256 mm)	☐	☐	☐	☐
Gravel (2-64 mm)	☐	☐	☐	☐
Sand (0.6-2 mm)	☐	☐	☐	☐
Fines (<0.6 mm)	☐	☐	☐	☐

RIPARIAN VEGETATION

☐ Typical Photo Captured

	Left Riparian Corridor	Right Riparian Corridor
	Average Riparian Width (ft)	
	_______	_______
	Estimated Relative Abundance	
Cover Type: Tree	_____ %	_____ %
Shrub	_____ %	_____ %
Herbaceous	_____ %	_____ %
Bare	_____ %	_____ %

Estimated relative abundance should add up to 100%

NOTES

BANK STABILITY

Based on USDA Stream Visual Assessment Protocol, 2009*

☐ Typical Photo Captured

	Banks are stable; protected by roots of natural vegetation, wood, and rock No excessive erosion or bank failures	Banks are moderately stable, protected by roots of natural vegetation, wood, or rock or a combination of materials Evidence of erosion or bank failures, some with reestablishment of vegetation	Banks are moderately un-stable; very little protection of banks by roots of natural wood, vegetation, or rock Excessive bank erosion or active bank failures	Banks are unstable; no bank protection with roots, wood, rock, or vegetation Numerous active bank failures
Left Bank	10 9	8 7 6	5 4 3	2 1 0
Right Bank	10 9	8 7 6	5 4 3	2 1 0

* USDA, 2009. Stream Visual Assessment Protocol Version 2. National Biology Handbook, Subpart B - Conservation Planning, United States Department of Agriculture Natural Resources Conservation Service

RAPID GEOMORPHOLOGICAL ASSESSMENT (RGA) FIELD FORM

CHANNEL FRINGE COMPLEXITY

Developed from: USDA 2009* and Ode et al. 2016**

Within the reach, observe the approximate abundance of different habitat features that provide diverse and complex habitat for fish along the channel margins. Only features that are within the stream's bankfull channel should be considered. Typical habitat features along the channel margins include the items outlined in the table below

Habitat features along channel margins	Abundance			
	Absent 0%	Sparse 1-10%	Moderate 10-40%	Heavy > 40%
Logs, large wood	0	1	2	3
Small wood accumulations	0	1	2	3
Overhanging vegetation	0	1	2	3
Live tree and/or shrub roots	0	1	2	3
Undercut banks	0	1	2	3
Aquatic vegetation	0	1	2	3
Small boulder clusters	0	1	2	3
Large boulders	0	1	2	3
Connected off-channel habitats	0	1	2	3
Other	0	1	2	3

Note: the sum of the percentages of the different features does not necessarily need to equal 100%

Channel Fringe Complexity = Sum of all abundance scores = ______

(Sums greater than 10 shall be assigned a channel fringe complexity of 10)

Habitat Features - Descriptions

- **Logs, large wood**—fallen trees or parts of trees that are submerged in the water and large enough to remain during normal flows
- **Small wood accumulations**—submerged accumulations of small wood pieces, twigs, branches, leaves, and roots. Though likely to be temporary components of stream habitats, their pieces will continue to provide structural complexity as the debris moves within the reach
- **Overhanging vegetation**—tree branches, shrub branches, or perennial herbaceous vegetation growing along the streambank and extending outward over the stream's surface, providing shade and cover
- **Live tree and/or shrub roots**—roots and rootlets, generally from trees but sometimes from mature dense shrubs at or beneath the water surface
- **Undercut banks**—water-scoured areas extending horizontally beneath the surface of the bank by at least 6 inches, forming underwater pockets used by fish for hiding and thermal cover
- **Aquatic vegetation** - emergent, submerged, or floating leaf aquatic plants thick enough to serve as cover
- **Small boulder clusters**—groups of 2 or more smaller rocks (>10 and <20 inches in diameter) interspersed relatively close together in the channel
- **Large boulders**—submerged or partially submerged large rocks (>20 inches in diameter)
- **Connected off-channel habitats**—side channels, flood plain wetlands, backwaters, alcoves etc. Features must be hydraulically connected to the mainstem under low or moderate flows
- **Other** — locally important habitat features

NOTES:

* USDA, 2009. Stream Visual Assessment Protocol Version 2. National Biology Handbook, Subpart B - Conservation Planning, United States Department of Agriculture Natural Resources Conservation Service

** Ode, P.R., A.E., Fetscher, and L.B. Busse. 2016. Standard Operating Procedures for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 004

RAPID GEOMORPHOLOGICAL ASSESSMENT (RGA)
FIELD FORM

FLOODPLAIN ROUGHNESS

Typical photo captured ☐

Based on USDA Stream Visual Assessment Protocol, 2009*

Part 1 - Impact of Large Woody Debris (LWD) on Floodplain (F.P.) Hydraulic Roughness

	LWD within the F.P. significantly increases hydraulic roughness and Majority of the LWD within the F.P. is expected to remain in-situ until veg. establishment	LWD within the F.P. significantly increases hydraulic roughness and Majority of the LWD within the F.P. has the potential to mobilize prior to veg. establishment	LWD within the F.P. moderately increases hydraulic roughness and Majority of the LWD within the F.P. is expected to remain in-situ until veg. establishment	LWD within the F.P. moderately increases hydraulic roughness and Majority of the LWD within the F.P. has the potential to mobilize prior to veg. establishment	No LWD within the F.P. or LWD within the F.P. has minimal or no impact on hydraulic roughness
LWD Roughness	4	3	2	1	0

Part 2 - Impact of Vegetation (Veg.) on Floodplain Hydraulic Roughness

Natural plant community covers the entire riparian planting zone and is generally contiguous throughout the reach		Natural plant community covers more than 1/2 to 2/3 of riparian planting zone and is generally contiguous throughout the reach and Vegetation gaps do not exceed 10% of the estimated length of the stream	Natural plant community covers more than at least 1/2 of riparian planting zone and Vegetation gaps do not exceed 30% of the length of the stream	Natural plant community covers more than 1/4 of riparian planting zone and Vegetation gaps exceed 30% of the length of the stream	Natural plant community covers less than 1/4 of riparian planting zone and Vegetation gaps exceed 30% of the length of the stream
Veg. Roughness	10 9	8 7	6 5	4 3 2	1 0

Floodplain Roughness = LWD Roughness + Veg. Roughness = ______ (Sums greater than 10 shall be assigned a F.P. roughness of 10)

FLOODPLAIN CONNECTIVITY

Typical photo captured ☐

Based on USDA Stream Visual Assessment Protocol, 2009*
Buffington
Thorne

Valley Configuration Frequency of F.P Inundation	Fully Un-Confined / Largely Un-Confined and Active channel and floodplain are connected throughout reach and flooded multiple times per year	Largely Unconfined and Floods up to bankfull discharge retained in-channel. Larger floods spill into floodplain	Partially Confined and Active channel appears to be connected to the floodplain, with infrequent inundation	Largely Confined and Active channel appears to be disconnected from the floodplain, with infrequent inundation	Largely Confined / Fully Confined and Wide range of flood flows contained within active channel with very infrequent or no inundation
F.P. Connectivity	10 9	8 7	6 5	4 3 2	1 0

* USDA, 2009. Stream Visual Assessment Protocol Version 2. National Biology Handbook, Subpart B - Conservation Planning, United States Department of Agriculture Natural Resources Conservation Service

RAPID GEOMORPHOLOGICAL ASSESSMENT (RGA) FIELD FORM

INDICATORS OF DEGREDATION, AGGRADATION, AND STABILITY

Based on USDA Stream Visual Assessment Protocol, 2009*

Degradation

- ☐ Terraces (abandoned floodplains)
- ☐ perched channels or tributaries
- ☐ headcuts and knickpoints
- ☐ exposed pipe crossings
- ☐ suspended culvert outfalls and ditches
- ☐ undercut bridge pier
- ☐ exposed tree roots
- ☐ leaning trees
- ☐ narrow/deep channel
- ☐ banks undercut on both sides of riffles
- ☐ armored channel bed
- ☐ hydrophytic vegetation located high on bank
- ☐ failed revetments due to undercutting
- ☐ compacted channel bed
- ☐ Cut face on bar forms
- ☐ Channel worn into undisturbed overburden/bedrock

Aggradation

- ☐ Buried structures (e.g. culverts and outfalls)
- ☐ reduced bridge clearance
- ☐ Presence of midchannel bars
- ☐ outlet of tributaries buried in sediment
- ☐ sediment deposition in floodplain
- ☐ buried vegetation
- ☐ channel bed above the floodplain elevation (perched)
- ☐ Significant backwater in tributaries
- ☐ Uniform sediment deposition across the channel
- ☐ hydrophobic vegetation located low on bank or dead in floodplain
- ☐ unvegetated point bars
- ☐ Large uncompacted point bars
- ☐ rills or remnant channels in riparian areas
- ☐ coarse material in riffles embedded
- ☐ poor longitudinal sorting of bed materials

Stable

- ☐ Vegetated bars and banks
- ☐ Limited bank erosion
- ☐ evidence of frequent overbank flows
- ☐ algae growth on substrate
- ☐ No exposed pipeline crossings, bridge footings, or abutments
- ☐ roots or large trees anchored in soil
- ☐ Older bridges, culverts, and outfalls with invert at or near grade
- ☐ Mouth of tributaries at or near existing main stem stream grade

STREAM EVOLUTION TRIANGLE

From Castro and Thorne, 2019

SET Stages - Indicate location on SET triangle

0 - **Anastomosing:** dynamically meta-stable network of ana branching channels with vegetated islands

1 - **Sinuous:** Stable and laterally active. Sediment sorting and transfer

2 - **Channelized:** Re-sectioned land drainage, flood control, or navigation channels

3 - **Degrading:** incising and abandoning its floodplain. Banks stable geotechnically

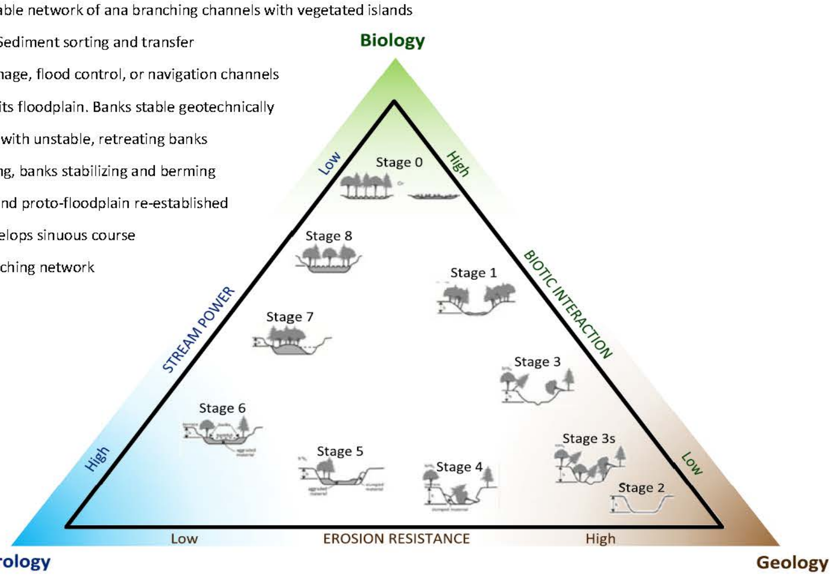
4 - **Degradation and Widening:** incising with unstable, retreating banks

5 - **Aggradation and Widening:** Bed rising, banks stabilizing and berming

6 - **Quasi-Equilibrium:** regime channel and proto-floodplain re-established

7 - **Laterally active:** regime channel develops sinuous course

8 - **Anastomosing:** meta-stable anabranching network



* USDA, 2009. Stream Visual Assessment Protocol Version 2. National Biology Handbook, Subpart B - Conservation Planning, United States Department of Agriculture Natural Resources Conservation Service

** Castro, J.M. and Thorne, C.R. 2019. The Stream Evolution Triangle: Integrating Geology, Hydrology, and Biology

RAPID GEOMORPHOLOGICAL ASSESSMENT (RGA)
FIELD FORM

FIELD MAP AND NOTES

Appendix H

Native Revegetation and Invasive Exotic Vegetation Treatment

Appendix H-1: Performance Criteria Monitoring Protocols

Klamath Revegetation Project Monitoring

Permanent vegetation treatment plot surveys will be conducted annually beginning in the spring of Year 4 and continue until the revegetation performance criteria has been achieved. The surveys will provide quantitative data for assessing the progress of vegetation development in the newly exposed reservoirs and will be used to determine progress toward achieving the revegetation performance criteria after dam removal. Data will be compared to those data collected from reference plots from surrounding vegetation communities to determine performance criteria progress and will be compared to control plots located in areas within the reservoirs left unseeded and unplanted to determine the effectiveness of seeding and planting on vegetation development.

Quantitative Survey Layout

Quantitative surveys will be conducted in treatment plots randomly located within the Reservoir Areas after dam removal. Data from treatment plots will be analyzed to detect changes over time and will consist of four surveys. These data will be used to address the following revegetation performance criteria and determination of success trajectory:

- Species richness is increasing over time and meeting performance criteria targets
- Cover of vegetation is increasing over time and meeting performance criteria targets
- Native woody species densities are increasing over time and meeting performance criteria targets
- Native plants are more abundant than non-native plant species and are meeting performance criteria targets

Treatment Plots

Permanent treatment plots will be a combination of four surveys (detailed below in Table H-1). The first survey consists of a line-intercept transect to measure changes over time in vegetation cover. Each of the 20 meter transects will be surrounded by an 8 by 20 meter plot extending 4 meters perpendicular to the line-intercept. Within this plot, all species present will be recorded to determine species richness, a tally of all woody plant species greater than 30 centimeters tall, noting whether the stems are alive or dead, to determine woody plant density and mortality rates. The woody species tally will provide data on mortality statistics and density measurements. Along the line-intercept transect, 80 square centimeter plots will be established to determine the frequency of native and nonnative species.

Table H-1. Surveys Conducted in the Permanent Nested Line-Intercept Plots

SURVEY	SURVEY DIMENSIONS	PURPOSE
Line-intercept transect	20 meter line	Measure cover of vegetation cover over time
Species list	160 square meters	Provides overview of species richness over time
Woody plant tally	160 square meters (or smaller if necessary)	Measures the abundance of woody plants greater than 30 centimeters over time and measures mortality.
Rooted sub-frequency quadrats	Ten 80 square centimeter plots located along the line-intercept	Measures native and non-native species frequency

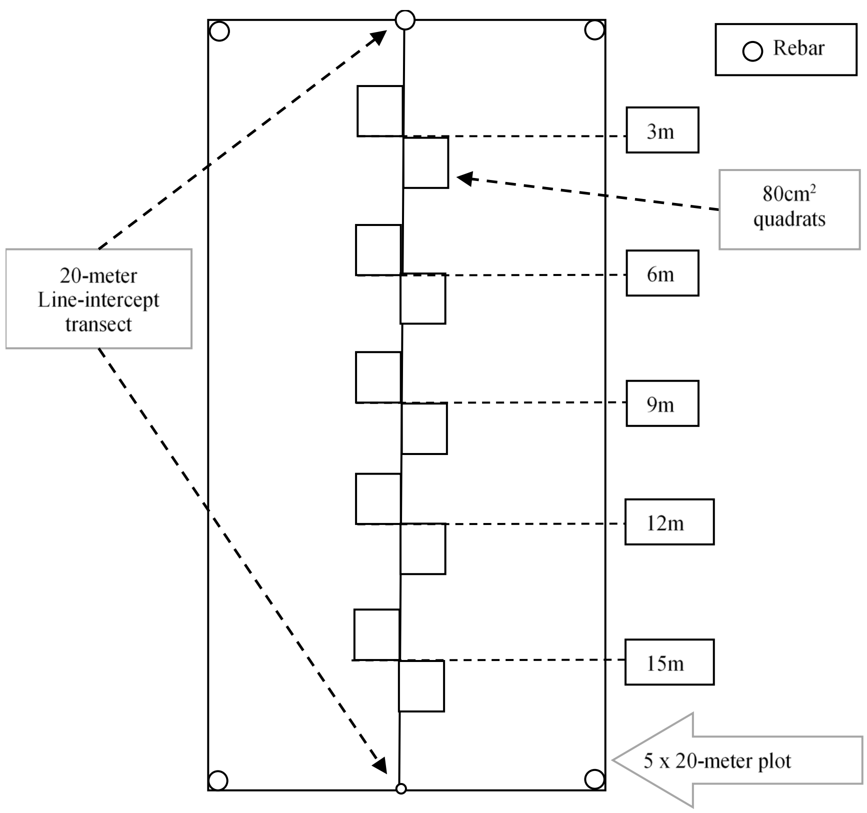


Figure H-1. Layout of Permanent Nested Line-Intercept Plots

Vegetation Cover Survey: Line-Intercept Transect

A primary objective of revegetation is to ensure that the amount of vegetation cover in the dewatered reservoirs increases over time and approximates reference plots in the surrounding plant communities. Permanent line-intercept transects, 20 meters long, will be established and surveyed annually. When measuring vegetation cover, the smallest unit of measurement used will be 1 centimeter. The line-intercept transects will measure the cover of bare-ground, large woody debris, woody plants (by species), and herbaceous plants (not to species). The total cover of vegetation will be determined by the subtracting the total cover of bare ground by 20 meters. This method ensures that the total cover of vegetation does not exceed 20 meters, which could result from the multiple layers of cover provided by woody species and the cover beneath the trees and shrubs provided by the understory.

Locating the Line-Intercept Transects

The beginning of each line-intercept transect will be located at pre-determined random points. The 20 meter line will fall entirely within a single habitat type and treatment. The final locations of the intercept transect may need to be adjusted by the monitoring crew based on field conditions. Reasons for rejecting or moving a line-intercept location are as follows:

- Line-intercept follows along a watercourse for more than 10 percent of the length.
- Unsafe conditions due to unusually steep terrain, large unstable woody debris, etc.
- The line-intercept crosses through more than one habitat type or treatment.

After locating the beginning of the line-intercept, record a Global Positioning System (GPS) point using the data dictionary provided in the GPS unit.

Field Methods for Line-Intercept Transects

- Install 4 foot rebar at start of the line and record GPS point
    - Cap the rebar with plastic protective cap
- Measure the slope to determine if any slope corrections are needed
- Anchor the measuring meter tape to the rebar at the transect start and end point
    - The line should be taut, do not allow vegetation to deflect the alignment of the tape. The line should be as close to the ground as possible
- Stretch tape out 20 meters perpendicular the Klamath river along the reservoir transect azimuth
- Install 4 foot rebar and plastic protective cap at end of line-intercept transect
- Take photos looking down the transect, both directions
- Begin survey at the start of the measuring tape (0 cm) and work down the transect line
    - Stay on the north side of the line
    - Position yourself directly above the line.
    - Use a plumb-bob or meter stick when measuring along tape that is elevated off the ground.
- Measure the start and end point of the following categories along the tape:
    1. Large woody debris (LWD)
        - Defined as wood ≥ 10 cm diameter
        - Only note if no vegetation cover overhangs the LWD

    2. Herbaceous plants (HERB)
        - Any herbaceous vascular plants including grasses, forbs, ferns, etc.
        - The measurement is of foliar cover of the vertical projection of exposed leaf area. The cover would equal the shadow cast if the sun was directly overhead

- Only measure this category if there is no woody cover above the herbaceous layer
  - Small openings in the canopy or overlap within the plant are excluded
  - Species identification is not necessary for this category

If a plant is dead, DO NOT record the cover as herbaceous. Instead, consider dead herbaceous plants as bare ground, since a new plant can grow in that space.

However, if the plant is senesced but alive (i.e., it is late in the summer or early fall) OR the dead plant was an annual (i.e., *Deschampsia*), count the plant in the herbaceous category.

Woody plants by species

- Trees and shrubs should be identified to species
- Only the upper-most canopy is included . DO NOT include canopies under the upper-most woody canopy)
- Exclude gaps in the canopy less than 5 centimeters (2 inches/5 centimeters)
- Include leaves and stems as canopy
- Canopies of the same species that overlap one another are not measured separately (ignore the overlap)
- Ignore cover that extends beyond the end of the tape
- Ignore intersections along the transect that are **less than 1 centimeter**

Species Richness Plots

Within each species richness plots, a 160 square meter plot will be established, extending 4 meters in both directions perpendicular to the line-intercept. A species list will be created, a woody plant survey will be recorded, and a fixed photo point will be established within each plot. The following list describes specific field procedures for establishing and surveying the 8 by 20 meter (160 square meter) plots:

- Position the corners of the plot 4 meters perpendicular to both ends of the line-intercept plot
- Mark each corner with rebar and cap with protective plastic caps
- Square the corners to ensure that the plot will be a true rectangle and that all sides are equal
- Stretch meter tape around the four outer corners to mark the plot boundaries

In addition, all species within the 8 by 20 meter plots will be recorded. The species list will be organized by lifeform; woody plant (trees, shrubs, and vines), or herbaceous (forb, graminoid, and ferns and allies). Nativity will be determined using CalFlora (www.calflora.org), the *Jepson Manual: Vascular Plants of California Second Edition*, or *Flora of the Pacific Northwest: An Illustrated Manual*, second edition.

Field Methods for Species Richness Plots

Within each 160 square meter plot, identify all species present. Includes woody plants, forbs, graminoids and ferns and their allies. Minimize walking inside the plot for this survey. If walking within the plot is necessary, try and walk on bare-ground, rocks or woody debris. Remember, treatment plots are meant to be re-surveyed annually for up to five years, so stepping on a woody plant or killing a seedling will have a significant impact on the data.

Woody Plant Tally

Within each 160 square meter plot, count all woody plants by species and size class.

Field Methods for Woody Tally Plots

- Tally all living woody plants by species and size class
- Tally all dead woody plants on a separate line on the data sheet. Note species if possible.

IEV Frequency Plots

Along each line intercept transect, ten 80 square centimeter plots will be established and surveyed to determine the frequency of nonnative, invasive exotic species (IEV). Every second plot (of the 10) will be constructed of polyvinyl chloride (PVC) quadrats and established perpendicular to the line-intercept transect at five locations, 3 meters apart on either side of the line, beginning at the 3 meters mark on the line-intercept transect (Figure H-1). A species list (capturing all species within the plot - IEV, nonnative, and native) will be recorded within each plot. The quadrat will be split into 4 sub-quadrats. Frequency for all species present will be noted for all four sub-quadrat. A species is considered ‘present’ if it is rooted within the sub-quadrat. Data collected from the ten plots will be combined and each species will be given a score of 1-40 based on presence or absence recorded within each sub-quadrat. For example, if *Elymus caput-medusae* (ELYCAP) is present in three out of the 40 sub-quadrats, then it would have a score of 3 for that entire treatment plot. **Photos will be taken of each quadrat from above**. Each photo will be taken from an oblique angle where feasible.

Field Procedure for IEV frequency plots

- Place quadrat perpendicular to the measuring tape along the line-intercept at 3 meter intervals (Figure H-1).
- Take a photo of the plot while the quadrat is in place.
- Identify all plants rooted in the entire quadrat to species only.
- Note the number of sub-quadrats each species is rooted within (1-4).
- Exclude plants that are not rooted within the quadrats.

Appendix H-2: IEV Monitoring Protocols

IEV Qualitative Monitoring

Monitoring the Reservoir Areas for IEV presence is critical to successful treatment and prevention. This monitoring protocol is not meant to be quantitative; it is primarily designed to ensure early detection and rapid response to IEV species establishing in the former reservoirs after dam removal. Quantitative data collection is described above in Appendix H-1. Data will be assessed during the growing season and used to develop a strategy for immediate treatment. Data provided in this survey is more detailed than traditional qualitative data that attempt to assess IEV abundance on the landscape and has been used for qualitative assessments (Woodward et al., 2011).

These surveys will be complemented by incidental observations of IEV populations in the former reservoirs by other staff or by the general public.

Reservoir IEV Surveys

IEV spatial surveys will be conducted twice annually, once in spring and once in the summer. A team of up to four biologists will survey all Reservoir Areas with hand-held GPS units recording any populations encountered. Data dictionaries in each unit will be filled out at each IEV location. The data dictionary will provide critical information on species abundance, phenology, distance to water, and any treatment of the population that may have occurred at the location. No hard copy data sheets will be used for this survey.

Survey Protocols

A biologist/surveyor will scout the area before recording point to ensure the point location best represents the center of the population(s) encountered. The following methods will be employed for surveys:

- While traversing within the Reservoir Areas where no IEV are present surveyor will record the path traveled using the GPS units (line feature)
- When IEV are encountered, a GPS point (not polygon) will be recorded
- Separate points will be taken for each species encountered at each location
- Each point represents what is visible within 30 meters of the point location for each species encountered

References

Woodward A.C., C. Torgersen, J. Chenoweth, K. Beirne and S.A. Acker. 2011. Predicting spread of invasive exotic plants into de-watered reservoirs following dam removal on the Elwha River, Olympic National Park, Washington. U.S. Geological Survey Open-File Report 2011-1048, 64p.

Appendix H-3: Data Analysis Protocols

Revegetation Data Analysis

Data from the permanent vegetation plot surveys will analyzed annually to determine the trajectory of vegetation development as outlined in the performance criteria and to direct adaptive management during the maintenance and monitoring period (Chenoweth et al., 2021). Data will be entered into a database specifically designed for the Lower Klamath Project. Data will be analyzed using R software for statistical computing. All analyses will be performed using the latest version of R Studio. Key packages used will be vegan (Oksanen et al., 2018), labdsv (Roberts, 2016) and indicspecies (De Cáceres and Legendre, 2009).

Quantitative data analysis will focus on five response variables: vegetation cover, species composition, species richness, relative frequency of IEV, and density of woody plants. Although species composition is not included in any performance criteria, it will help to guide adaptive management during the maintenance and monitoring phase. Vegetation cover is calculated as the total cover of herbaceous plus woody species cover along each line-intercept. IEV relative frequency is calculated as the frequency of IEV plants as a proportion of the total frequency of all plants rooted in the 80 square centimeter plots (total IEV count/total count all species).

For quantitative analyses, univariate responses (vegetation cover, IEV frequency, species richness, and density of woody plants) will be expressed as Euclidean distance matrices. Multivariate responses (i.e., species composition) will be expressed as a Bray-Curtis dissimilarity matrix.

Statistical analyses will primarily be conducted using permutational multivariate analysis of variance (PERMANOVA; Anderson, 2001) with $\alpha = 0.05$ and 9,999 permutations to determine statistical significance of the resulting pseudo-F -statistics (Legendre and Legendre, 2012). The potential explanatory variables in all models will be geographic location of plot (Universal Transverse Mercator (UTM) coordinates), distance to reservoir edge, restoration condition (reference plot, treatment plot, or control plot), whether the plot was planted (yes, no), or seeded (yes, no). UTM coordinates will be included as the first terms in all models to account for possible spatial autocorrelation. We will test for the main effects of treatments, (seeding, planting) and compare mean values to the mean values collected at reference plots for each performance criteria. We expect statistically significant differences between reference and restoration plots since the performance criteria targets are a percentage of reference and not expected to be the same. Means will be calculated for all response variables within all habitat types and compared to the means collected at reference plots to track progress towards performance criteria. We will use the control plots within the Reservoir Areas (unseeded and unplanted areas) to determine if planting and seeding provides statistically significant differences in response variables.

Indicator Species Analysis (ISA) will be applied to the compositional matrix (all plants) to identify species strongly associated treatments (seeded and/or planted compared to unplanted and/or unseeded and to reference plots). ISA will be performed using multi-level pattern analysis (De

Cáceres et al., 2010), allowing species to be indicators of individual combinations of treatment and restoration condition or habitat type (i.e. riparian or upland). The Indicator Value (IV) of each species will be calculated as the product of the species' relative abundance and relative frequency within each group. IVs will be tested for statistical significance using 10,000 permutations. We will focus our attention on species with IV ≥ 0.5 and $p \leq 0.05$. Determining indicator species can assist with future planting efforts. For example, seeded or planted species that are revealed to be indicators at certain sites are likely to be excellent performers in the restoration conditions and can be used to plant sites not performing well or in control areas that are failing to revegetate naturally.

IEV Monitoring Data Analysis Protocol

Data points collected using hand-held GPS units of all IEV populations within the Reservoir Areas collected outside of the permanent plots will be combined and summarized during the growing season to direct treatments. Each treatment will receive a GPS data point recording treatment information (i.e., date, treatment method, etc.). At the end of each field season, all data of treatments and IEV locations will be totaled and summarized by species and reservoir. Data each year will be compared to previous years within each Reservoir Area. We expect a slow increase of some IEV populations within the first few years before native vegetation is well established and treatment efficacy is refined to manage the specific conditions encountered in the unique environment created by dam removal (Chenoweth et al., 2021).

References

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. *Austral Ecology*. 26: 32-46

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United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), and The Xerces Society. 2014. Agronomy Technical Note No. 9: Preventing or

Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Other Conservation Practices.

Appendix H-4: Data Sheets

Klamath Revegetation Monitoring
Line-Intercept Data From

version 12/2/20

Reservoir: ________________ Zone: _____________ Treatment: ___________ Plot No. ___ ___ ___ ___-___ ___ Date: M__ __ D __ __ Y __ __ __ __

Crew: ____ page ___

notes:	Category				Woody Species									
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End

Entered by _______________date __/__/____

Klamath Revegetation Monitoring
Line-Intercept Data From

version 12/2/20

Reservoir: ________________ Zone: _____________ Treatment: ___________ Plot No. ___ ___ ___ ___-___ ___ Date: M__ __ D __ __ Y __ __ __ __

Crew: ____ page ___

notes:	Category				Woody Species									
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End

Entered by _______________date __/__/____

Klamath Revegetation Monitoring
Rooted Quadrat Frequency

version 12/03/20

Reservoir: ________________ Habitat: _____________ Treatment: ___________ Plot No. ___ ___ ___-___ ___

Crew: ____ Date: M__ __ D __ __ Y __ __ __ __

Page ___ of ____

Quadrat	Species

Quadrat	Species

Entered by _______________date __/__/____

Klamath Revegetation Monitoring
Rooted Quadrat Frequency

version 12/03/20

Reservoir: ________________ Habitat: _____________ Treatment: ___________ Plot No. ___ ___ ___-___ ___

Crew: ____ Date: M__ __ D __ __ Y __ __ __ __

Page ___ of ____

Quadrat	Species	Quadrat	Species

Entered by _______________date __/__/____

Klamath Revegetation Monitoring
Woody Plant Tally

version 12/2/20

Reservoir: ________________ Zone: ______________ Treatment: ___________ Plot No. ___ ___ ___-___ ___

Crew: ____ Date: M__ __ D __ __ Y __ __ __ __

Species	TALLY			Species	TALLY		
	Size class	Live	Dead		Size class	Live	Dead

Notes (i.e. healthy, drought stress, discoloration, etc):

Entered by ________________date __/__/____

Klamath Revegetation Monitoring
Woody Plant Tally

version 12/2/20

Reservoir: ________________ Zone: _____________ Treatment: ___________ Plot No. ___ ___ ___-___ ___

Crew: ____ Date: M__ __ D __ __ Y __ __ __ __

Species	TALLY		
	Size class	Live	Dead

Species	TALLY		
	Size class	Live	Dead

Notes (i.e. healthy, drought stress, discoloration, etc): ____________________________________

Entered by ________________date __/__/____

Appendix H-5: Seed Contracts and Seed Production Summary

Table H-5.1 Native Vegetation Seed Contracts and Seed Production Summary (Current as of Fall 2021)

Species	Contract Status	Contract Type	Vendor	Seed source	2020 harvest (actua)	2021 harvest (actual)	2022 harvest (est)	seeds/lb	Total lbs (est)	Total seeds estimated	Storage Location
Achillea millifolium	Current	Custom field	BFI	2018 Wild collect, PCS	565	*200*	0	2,790,000	**765**	**2,134,350,000**	BFI
Amsinckia menziesii	Current	Custom field	HRF	2020 Wild collect, Yurok	0	150	200	156,766	**350**	**54,821,070**	HRF
Amsinckia menziesii	Closed	Custom field	JHS	BLM Medford	0	140	0	156,766	**140**	**21,947,240**	JHS
Artemisia douglasiana	Current	Custom field	BFI	2018 Wild collect, PCS	0	*100*	0	340,000	**100**	**34,000,000**	BFI
Bromus carinatus	Current	Commercial	BFI	Burnt Creek	7,230	*5,354*	0	80,000	**12,584**	**1,006,720,000**	BFI
Croton setigerus	Current	Custom field	HRF	2019 Wild collect, Yurok	96.9	40	40	52,060	**176.9**	**9,209,414**	HRF
Deschampsia cespitosa	Current	Custom field	BFI	2019 Wild collect, Yurok	0	883	95	2,500,000	**978**	**2,445,000,000**	BFI
Drymocallis glandulosa	Current	Custom field	BFI	2018 Wild collect, PCS	0	22	0	1,135,000	**22**	**24,970,000**	BFI
Elymus cinereus	Current	Custom field	BFI	2018 Wild collect, PCS	675	2,400	0	130,000	**3,075**	**399,750,000**	BFI
Elymus elymoides	Current	Commercial	BFI	Norcross Klamath	3,500	1,300	3,000	165,836	**7,800**	**1,293,520,800**	BFI
Elymus glaucus	Current	Custom field	BFI	2018 Wild collect, PCS	3,000	5,150	600	110,000	**8,750**	**962,500,000**	BFI
Elymus spicatus	Current	Custom field	BFI	2020 wild collect, Yurok & BFI (Agate Desert)	0	*700*	700	130,488	**1,400**	**182,683,200**	BFI
Elymus triticoides	Current	Custom field	BFI	2018 Wild collect, PCS	680	400	0	51,000	**1,080**	**55,080,000**	BFI
Eriophyllum lanatum	Current	Custom field	BFI	2019 Wild collect, Yurok	0	24	130	1,306,077	**154**	**201,135,858**	BFI
Eriophyllum lanatum	Current	Custom field	BFI	2020 Wild collect, Yurok	0	4	260	1,306,077	**264**	**344,804,328**	BFI
Eriophyllum lanatum	Current	Custom field	CPMC	2019 Wild collect, Yurok	0	*25*	65	1,306,077	**90**	**117,546,930**	CPMC
Eschscholzia californica	Current	Commercial	HRF	Lodoga Hills, Colusa Co	0	400	400	234,000	**800**	**187,200,000**	HRF
Euthamia occidentalis	Current	Custom field	BFI	2018 Wild collect, PCS	15	*200*	0	2,500,000	**215**	**537,500,000**	BFI
Festuca idahoensis spp *roemeri*	Current	Commercial	BFI	Ashland Cascades, BFI	209	*833*	1,000	450,000	**2,042**	**918,900,000**	BFI
Grindelia camporum	Closed	Custom field	S&S	2018 Wild collect, PCS	1,715	0	0	132,000	**1,715**	**226,380,000**	CPMC
Horderum brachyantherum	Current	Commercial	HRF	Santa Rosa, Sonoma Co, HRF	0	0	500	85,000	**500**	**42,500,000**	HRF
Hordeum jubatum	Closed	Custom field	HRF	2019 Wild collect, Yurok	35	1	0	129,500	**36**	**4,662,000**	HRF
Koeleria macrantha	Proposed	Commercial	BFI	Medford Roundtop, BFI	0	500	500	1,592,721	**1,000**	**1,592,721,000**	BFI
Lupinus microcarpus var *densiflorus*	Current	Custom field	HRF	2020 Wild collect, Yurok	0	0	50	13,529	**50**	**676,450**	HRF
Lupinus microcarpus var *densiflorus*	Current	Custom field	HRF	2020 Wild collect, Yurok	0	0	30	13,529	**30**	**405,870**	HRF
Lupinus microcarpus var *microcarpus*	Current	Custom field	HRF	BLM Medford (two sources)	0	13	0	13,529	**13**	**169,113**	HRF
Mentzelia laevicaulis	Proposed	Custom field	BFI	2020 Wild collect, Yurok	0	*300*	450	400,960	**750**	**300,720,000**	BFI
Penstemon roezlii	Current	Commercial	BFI	Box O	0	*165*	0	650,000	**165**	**107,250,000**	BFI
Penstemon speciosus	Proposed	Custom field	JHS	2020 Wild collect, Yurok	0	0	15	445,879	**15**	**6,688,185**	JHS
Poa secunda	Current	Commercial	BFI	Fremont 5850	5,585	0	0	912,500	**5,585**	**5,096,312,500**	BFI
Solidago elongata	Current	Custom field	BFI	2018 Wild collect, PCS	93	*220*	0	4,600,000	**313**	**1,439,800,000**	BFI
Stipa lemmonii	Proposed	Custom field	JHS	2020 Wild collect, Yurok & BLM Medford	0	0	760	108,474	**760**	**82,440,392**	JHS
Trichostema lanceolatum	Completed	Custom field	S&S	2018 Wild collect, PCS	116	0	0	126,400	**116**	**14,662,400**	CPMC
				TOTALS	**23,515**	***19,523***	**8,795**		**51,833**	**19,847,026,750**	

Table H-5.2 Wild Collected Seed Inventory

Species	Lot #	Collection year	Seed Source	Collector	Pure Live Seed per lb	Clean seed weight (bulk lbs)	Approximate # Pure live seed	Storage location	Seed plan	Notes
Achillea millifolium	YT19-ACHMIL	2019	Klamath watershed	YT	2,790,000	2.480	6,919,200	HRF	Seed to be directly added to upland seed mixes	
Acmispon americanus	KP1002	2018	Klamath watershed	PCS	75,750	1.300	63,753	CPMC	Propagate into plugs or directly added to seed mixes	
Amelanchier utahensis	YT21-AMEUTA-IG	2021	Iron Gate/Copco area	YT	26,628	1.286	34,244	JHS	Propagate into bare root plants	
Artemisia douglasiana	YT19-ARTDOU	2019	Klamath watershed	YT	340,000	0.480	163,200	HRF	Directly add to riparian seed mixes	
Artemisia tridentata	KP1049A	2018	Klamath watershed	PCS	1,382,732	150.000	18,708,364	JHS	To be sown for bare root production	
Artemisia tridentata	KP1049B	2018	Klamath watershed	PCS	1,382,732	116.000	19,055,153	JHS	To be sown for bare root production	
Ascelpias fascicularis	YT21-ASCFAS	2021	Ashland/Iron Gate area	YT	71,863	0.489	35,141	RNPP	Propagate into plugs or directly added to seed mixes	
Balmsamerhiza deltoidea	YT20-BALDEL	2020	Klamath watershed	YT	39,185	0.552	21,626	RNPP	Seed to be directly added to upland seed mixes	
Balmsamerhiza deltoidea	YT21-BALDEL	2021	Klamath watershed	YT	39,185	3.269	128,096	RNPP	Seed to be directly added to upland seed mixes	
Berberis aquifolium	YT20-BERAQU-IG	2020	Iron Gate/Copco area	YT	48,743	0.651	31,732	JHS	Sown at JHS, fall of 2020 for 2yr bare root production	
Berberis aquifolium	YT20-BERAQU-JCB	2020	JC Boyle area	YT	51,382	0.788	40,489	JHS	Sown at JHS, fall of 2020 for 2yr bare root production	
Bidens frondosa	KP1005	2018	Klamath watershed	PCS	195,300	12.900	2,159,856	CPMC	Propagate into plugs or directly added to seed mixes	
Bidens frondosa	KP1005A	2018	Klamath watershed	PCS	195,300	4.610	611,956	CPMC	Propagate into plugs or directly added to seed mixes	
Bidens frondosa	YT19-BIDFRO	2019	Klamath watershed	YT	195,300	5.200	1,015,560	HRF	Directly add to riparian seed mixes	
Bromus sitchensis var *carinatus*	YT19-BROSIT	2019	Klamath watershed	YT	103,453	0.150	15,518	HRF	Seed to be directly added to upland seed mixes	
Calocedrus decurrans	YT21-CALDEC-JCB	2021	Pinehurst, OR	SBS	11,999	0.618	7,415	JHS	Propagate into bare root plants	
Carex nebrascensis	KP1007	2018	Klamath watershed	PCS	534,100	1.250	98,541	CPMC	Propagate into plugs; excess seed added to seed mixes	
Carex nebrascensis	KP1007A	2018	Klamath watershed	PCS	534,100	0.650	62,629	CPMC	Propagate into plugs; excess seed added to seed mixes	
Carex praegracilis	KP1009	2018	Klamath watershed	PCS	664,900	2.760	1,553,065	CPMC	Propagate into plugs; excess seed added to seed mixes	
Carex simulata	KP1044	2018	Klamath watershed	PCS	1,043,000	1.400	464,782	CPMC	Propagate into plugs; excess seed added to seed mixes	
Carex simulata	KP1044A	2018	Klamath watershed	PCS	1,043,000	0.880	409,540	CPMC	Propagate into plugs; excess seed added to seed mixes	
Carex utriculata	KP1045	2018	Klamath watershed	PCS	360,000	3.950	1,422,000	CPMC	Propagate into plugs; excess seed added to seed mixes	
Ceanothus cuneatus	YT21-CEACUN-IG	2021	Iron Gate/Copco area	YT	41,189	0.319	13,139	JHS	Sown at JHS, fall of 2020 for 2yr bare root production	
Ceanothus integerrimus	YT20-CEAINT-IG	2020	Iron Gate/Copco area	YT	63,183	0.103	6,508	JHS	To be sown for bare root production	
Ceanothus integerrimus	YT21-CEAINT-IG	2021	Iron Gate/Copco area	YT	71,267	0.213	15,180	JHS	To be sown for bare root production	
Cercocarpus betuloides	YT20-CERBET-IG	2020	Iron Gate/Copco area	YT	15,532	1.750	27,181	JHS	To be sown for bare root production	
Cercocarpus betuloides	YT20-CERBET-JCB	2020	JC Boyle area	YT	13,804	1.075	14,839	JHS	To be sown for bare root production	
Cornus glabrata	YT20-CORGLA-IG	2020	Iron Gate/Copco area	YT	9,422	0.447	4,214	JHS	To be sown for bare root production	
Cornus sericea	YT20-CORSER-JCB	2020	JC Boyle area	YT	17,888	1.848	33,057	JHS	To be sown for bare root production	
Deschampsia danthoides	YT19-DESDAN	2019	Klamath watershed	YT	900,000	0.160	144,000	HRF	Propagate into plugs or directly added to seed mixes	
Distichlis spicata	KP1014	2018	Klamath waterdshed	PCS	520,000	8.130	292,127	CPMC	Propagate into plugs or directly added to seed mixes	
Distichlis spicata	YT19-DISSPI	2019	Klamath watershed	YT	520,000	3.850	2,002,000	HRF	Propagate into plugs or directly added to seed mixes	
Elymus cinereus	YT19-ELYCIN	2019	Klamath watershed	YT	131,000	42.850	5,613,350	HRF	Directly add to riparian seed mixes	
Elymus elymoides	YT19-ELYELY	2019	Klamath watershed	YT	165,836	5.000	829,180	HRF	Seed to be directly added to upland seed mixes	
Elymus glaucus	YT19-ELYGLA	2019	Klamath watershed	YT	134,000	0.400	53,600	HRF	Directly add to riparian seed mixes	
Elymus triticoides	YT19-ELYTRI	2019	Klamath watershed	YT	172,000	8.100	125,667	HRF	Directly add to riparian seed mixes	
Ericameria bloomeri	YT20-ERIBLO-JCB	2020	JC Boyle area	YT	149,215	0.619	92,364	JHS	To be sown for bare root production	
Ericameria nauseosa	YT20-ERINAU-IG	2020	Iron Gate/Copco area	YT	14,657	0.077	1,121	JHS	To be sown for bare root production	
Ericameria nauseosa	YT20-ERINAU-JCB	2020	JC Boyle area	YT	194,704	2.474	481,698	JHS	To be sown for bare root production	
Euthamia occidentalis	YT19-EUTOCC	2019	Klamath watershed	YT	2,500,000	2.100	5,250,000	HRF	Directly add to riparian seed mixes	
Festuca idahoensis	YT19-FESIDA	2019	Klamath watershed	YT	442,500	0.400	177,000	HRF	Seed to be directly added to upland seed mixes	
Grindelia nana	YT20-GRINAN	2020	Iron Gate/Copco area	YT	128,000	17.340	2,219,520	RNPP	Seed to be directly added to upland seed mixes	
Hordeum brachyantherum	KP1022	2018	Klamath watershed	PCS	85,000	0.250	12,822	CPMC	Establish seed increase field or propagate into plugs	
Hordeum brachyantherum	YT19-HORBRA	2019	Klamath watershed	YT	85,000	0.020	1,026	HRF	Directly add to riparian seed mixes	
Lomatium californicum	YT21-LOMCAL	2021	Klamath watershed	YT	49,293	2.688	132,500	RNPP	Seed to be directly added to upland seed mixes	
Lomatium dissectum	YT21-LOMDIS	2021	Klamath watershed	YT	45,000	0.013	585	RNPP	Seed to be directly added to upland seed mixes	
Lomatium nudicaule	YT21-LOMNUD	2021	Klamath watershed	YT	42,000	2.519	105,798	RNPP	Seed to be directly added to upland seed mixes	
Lomatium species	YT20-LOMsp	2020	Klamath watershed	YT	40,000	12.950	518,000	RNPP	Seed to be directly added to upland seed mixes	
Lomatium triternatum	YT21-LOMTRI	2021	Klamath watershed	YT	45,000	0.025	1,125	RNPP	Seed to be directly added to upland seed mixes	
Lonicera interrupta	YT20-LONINT-IG	2020	Iron Gate/Copco area	YT	26,285	0.074	1,953	JHS	To be sown for bare root production	
Lupinus albifrons	YT20-LUPALB	2020	Iron Gate/Copco area	YT	15,000	0.413	6,188	RNPP	Seed to be directly added to upland seed mixes	
Lupinus albifrons	YT20-LUPALB-GC	2020	Ashland, OR (2100 ft)	SBS	15,419	4.437	68,414	RNPP	Seed to be directly added to upland seed mixes	
Lupinus albifrons	YT21-LUPALB	2021	Iron Gate/Copco area	YT	15,000	4.344	65,160	RNPP	Seed to be directly added to upland seed mixes	
Lupinus albifrons	YT21-LUPALB-GC	2021	Ashland, OR (2100 ft)	SBS	18,000	6.044	108,792	RNPP	Seed to be directly added to upland seed mixes	
Lupinus argenteus	YT19-LUPARG	2019	Klamath watershed	YT	12,500	0.200	2,500	HRF	Seed to be directly added to upland seed mixes	Likely *L. albifrons*
Monardella odoratissima	YT20-MONODO	2020	Iron Gate/Copco area	YT	600,000	0.289	173,280	RNPP	Seed to be directly added to upland seed mixes	
Monardella odoratissima	YT21-MONODO	2021	Iron Gate/Copco area	YT	600,000	0.044	26,400	RNPP	Seed to be directly added to upland seed mixes	

Table H-5.2 Wild Collected Seed Inventory, con't.

Species	Lot #	Collection year	Seed Source	Collector	Pure Live Seed per lb	Clean seed weight (bulk lbs)	Approximate # Pure live seed	Storage location	Seed plan	Notes
Penstemon deustus	YT20-PENDEU	2020	Klamath watershed	YT	3,376,508	2.467	8,328,495	RNPP	Seed to be directly added to upland seed mixes	
Penstemon deustus	YT21-PENDEU	2021	Klamath watershed	YT	3,376,508	1.827	6,168,880	RNPP	Seed to be directly added to upland seed mixes	
Penstemon laetus	YT20-PENLAE	2020	Klamath watershed	YT		0.212	0	RNPP	Seed to be directly added to upland seed mixes	Unk seeds per pound
Penstemon laetus	YT21-PENLAE	2021	Klamath watershed	YT		2.869	0	RNPP	Seed to be directly added to upland seed mixes	Unk seeds per pound
Penstemon speciosus	YT20-PENSPE	2020	Iron Gate/Copco area	YT	445,879	4.936	2,200,692	RNPP	Propagate into plugs or directly added to seed mixes	
Penstemon speciosus	YT21-PENSPE	2021	Iron Gate/Copco area	YT	445,879	5.450	2,430,041	RNPP	Propagate into plugs or directly added to seed mixes	
Persicaria amphibia	KP1046	2018	Klamath watershed	PCS		0.520	0	CPMC	Propagate into plugs or directly added to seed mixes	Unk seeds per pound
Phacelia heterophylla	YT20-PHAHET	2020	Klamath watershed	YT	490,915	2.688	1,319,334	RNPP	Establish seed increase field or propagate into plugs	
Philadelphus lewisii	YT20-PHILEW-IG	2020	Iron Gate/Copco area	YT	5,462,404	0.537	2,933,311	FCN	To be sown for bare root production	
Philadelphus lewisii	YT20-PHILEW-JCB	2020	JC Boyle area	YT	5,462,404	0.022	120,173	FCN	To be sown for bare root production	
Physocarpus capitatus	YT20-PHYCAP-IG	2020	Iron Gate/Copco area	YT	499,763	0.108	53,974	FCN	To be sown for bare root production	
Pinus contorta var. murryana	Seed Zone 681	2017	Klamath Co, 4,500 ft	SS	67,013	1.000	67,013	JHS	To be sown for bare root production	98% viability, 2017 test
Pinus ponderosa	Seed Zone 721	2014	Klamath watershed, 4,500 ft	SS	8,584	1.000	8,584	JHS	To be sown for bare root production	94% viability, 2014 test
Poa secunda	YT19-POASEC	2019	Klamath watershed	YT	925,000	0.550	45,889	HRF	Seed to be directly added to upland seed mixes	
Prunus subcordata	YT20-PRUSUB-JCB	2021	JC Boyle area	YT			0	JHS	Not cleaned as of 12/1/21	
Prunus virginiana	YT20-PRUVIR-IG	2020	Iron Gate/Copco area	YT	4,402	3.460	15,231	JHS	To be sown for bare root production	
Prunus virginiana	YT21-PRUVIR-IG	2021	Iron Gate/Copco area	YT	3,880	1.330	5,160	JHS	To be sown for bare root production	
Prunus virginiana	YT20-PRUVIR-JCB	2020	JC Boyle area	YT	4,078	0.621	2,532	JHS	To be sown for bare root production	
Pseudotsuga menziesii	Seed Zone 512	2017	Josephine Co, 1,500 ft	SS	25,738	1.000	25,738	JHS	To be sown for bare root production	77% viability, 2017 test
Pseudotsuga menziesii	Seed Zone 502	2017	Jackson Co, 4,000 ft	SS	22,700	1.000	22,700	JHS	To be sown for bare root production	79% viability, 2017 test
Purshia tridentata	YT20-PURTRI-IG	2020	Iron Gate/Copco area	YT	9,506	0.483	4,593	JHS	To be sown for bare root production	
Purshia tridentata	YT21-PURTRI-IG	2021	Iron Gate/Copco area	YT	11,807	1.228	14,499	JHS	To be sown for bare root production	
Purshia tridentata	YT20-PURTRI-JCB	2020	JC Boyle area	YT	12,052	0.063	759	JHS	To be sown for bare root production	
Purshia tridentata	YT21-PURTRI-JCB	2021	JC Boyle area	YT	19,031	6.721	127,907	JHS	To be sown for bare root production	
Rhus aromatica	YT20-RHUARO-IG	2020	Iron Gate/Copco area	YT	12,918	1.514	19,558	JHS	To be sown for bare root production	
Ribes cereum	YT20-RIBCER-JCB	2020	JC Boyle area	YT	352,779	0.078	27,623	JHS	To be sown for bare root production	
Ribes velutinum	YT20-RIBVEL-IG	2020	Iron Gate/Copco area	YT	173,160	0.141	24,329	JHS	To be sown for bare root production	
Ribes velutinum	YT21-RIBVEL-IG	2021	Iron Gate/Copco area	YT	146,024	0.931	135,948	JHS	To be sown for bare root production	
Ribes velutinum	YT20-RIBVEL-JCB	2020	JC Boyle area	YT	201,000	0.007	1,467	JHS	To be sown for bare root production	
Ribes velutinum	YT21-RIBVEL-JCB	2021	JC Boyle area	YT	176,335	0.258	45,494	JHS	To be sown for bare root production	
Rosa woodsii	YT20-ROSWOO-JCB	2020	JC Boyle area	YT	40,115	0.330	13,238	JHS	In stratification for spring 2021 sow, 2 yr bare root	
Sambucus nigra	YT21-SAMNIG-IG	2021	Ashland/Iron Gate area	YT	179,255	0.661	118,488	JHS	To be sown for bare root production	
Sambucus nigra	YT21-SAMNIG-JCB	2021	JC Boyle area	YT	130,626	0.039	5,094	JHS	To be sown for bare root production	
Spiraea douglasii	YT20-SPIDOU-JCB	2020	JC Boyle area	YT	15,260,228	0.374	5,707,325	JHS	To be sown for bare root production	
Stipa lemmonii	YT19-STILEM	2019	Klamath watershed	YT	84,278	0.130	10,956	HRF	Seed to be directly added to upland seed mixes	
Symphoricarpos albus	YT21-SYMALB-IG	2021	Iron Gate/Copco area	YT	48,162	0.125	6,020	FCN	To be sown for bare root production	
Symphoricarpos albus	YT21-SYMALB-JCB	2021	JC Boyle area	YT	48,162	0.190	9,151	FCN	To be sown for bare root production	
Xanthium strumarium	YT19-XANSTU	2019	Klamath watershed	YT	1,219	14.000	17,066	HRF	Directly add to riparian seed mixes	
					TOTALS	502.096	101,679,411			

CPMC: Corvallis Plant Material Center, Corvallis, OR
FNC: Fourth Corner Nursery, Bellingham, WA
HRF: Hedgerow Farms, Winters, CA
JHS: J Herbert Stone Nursery, Central Point, OR
RNPP: Rogue Native Plant Partnership, Sampson Creek Reserve, Ashland, OR
SBS: Siskiyou Biosurvey

Appendix H-6: Bare Root Plant Summary and Production Plan

Species	Reservoir	PLS stored	PLS Target	Proposed Vendor	2023 number	2024 number	TOTAL number	Bare root or Container	Min age of bare root	Max age of bare root	Notes
Abies concolor	JC Boyle	To be collected 2022	3,450	JHS	500	0	500	77/170 Styro	1	3	
Acer macrophyllum	Iron Gate/Copco	To be collected 2022	10,350	JHS	0	0	0	Bareroot	1	1	
Alnus rhombifolia	Iron Gate/Copco	To be collected 2022	8,970	JHS	600	700	1,300	Bareroot	1	1	
Amelanchier alnifolia	JC Boyle	To be collected 2022	3,450	JHS	300	200	500	Bareroot	1	2	2021 collection not yet cleaned as of 12/3/21
Amelanchier utahensis	Iron Gate/Copco	26,628 PLS	17,250	JHS	3,350	2,650	6,000	Bareroot	1	2	
Artemisia tridentata	JC Boyle	266 lbs	13,800	JHS	2,500	1,500	4,000	Bareroot	1	1	Sent out for viability testing, November 2021.
Berberis aquifolium	Iron Gate/Copco	31,722 PLS	13,800	JHS	400	2,600	3,000	Bareroot	2	3	
Berberis aquifolium	JC Boyle	40,489 PLS	3,450	JHS	0	500	500	Bareroot	2	3	
Calocedrus decurrens	Iron Gate/Copco	Collected in 2021	6,900	JHS	600	0	600	Bareroot	1	2	2021 collection not yet cleaned as of 12/3/21
Calocedrus decurrens	JC Boyle	9,970 PLS	1,560	JHS	1,000	300	1,300	Bareroot	1	2	
Ceanothus cuneatus	Iron Gate/Copco	41,189 PLS	110,400	JHS	15,000	15,000	30,000	Bareroot	1	2	
Ceanothus integerrimus	Iron Gate/Copco	21,688 PLS	126,000	JHS	4,000	18,000	22,000	Bareroot	1	1	
Cercocarpus betuloides	Iron Gate/Copco	30,682 PLS	103,500	JHS	9,100	5,900	15,000	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Cercocarpus betuloides	JC Boyle	14,839 PLS	6,900	JHS	700	300	1,000	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Cornus glabrata	Iron Gate/Copco	4,215 PLS	10,350	JHS	1,500	1,500	3,000	Bareroot	1	1	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Cornus sericea	Iron Gate/Copco	33,058 PLS	3,450	JHS	250	250	500	Bareroot	1	1	
Ericameria nauseosa	Iron Gate/Copco	67,078 PLS	124,200	JHS	12,000	6,000	18,000	Bareroot	1	2	Seed from this species loses viability in storage after 9 months. Will need fresh collection annually.
Ericameria nauseosa	JC Boyle	4,425,955 PLS	20,700	JHS	2,000	1,000	3,000	Bareroot	1	2	Seed from this species loses viability in storage after 9 months. Will need fresh collection annually.
Ericameria bloomeri	JC Boyle	92,364 PLS	13,800	JHS	1,500	0	1,500	Bareroot	1	2	Seed from this species loses viability in storage after 9 months. Will need fresh collection annually.
Fraxiunus latifolia	Iron Gate/Copco	Sown fall 2020	6,900	JHS	700	1,800	2,500	Bareroot	1	2	Seed from this species does not store and must be collected annually.
Lonicera interrupta	Iron Gate/Copco	1,953 PLS	62,100	JHS	1,700	6,800	8,500	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Pinus contorta var latifolia	JC Boyle	67,013 PLS	22,338	JHS	1,000	500	1,500	Bareroot or 77/170	2	3	

Bare Root Plant Summary and Production Plan (Con't)

Species	Reservoir	PLS stored	PLS Target	Proposed Vendor	2023 number	2024 number	TOTAL number	Bare root or Container	Min age of bare root	Max age of bare root	Notes
Pinus ponderosa	Iron Gate/Copco	Collected in 2021	5,040	JHS	1,500	1,700	3,200	Bareroot	1	2	2021 seed collection not yet cleaned as of 12/3/21
Pinus ponderosa	JC Boyle	8,584 PLS	5,880	JHS	2,600	1,600	4,200	Bareroot	1	2	
Prunus subcordata	Iron Gate/Copco	Sown fall 2020	62,100	JHS	5,900	3,100	9,000	Bareroot	1	2	No wild seed produced in 2021 likely due to drought and heat.
Prunus subcordata	JC Boyle	Sown fall 2020	10,350	JHS	750	750	1,500	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Prunus virginiana	Iron Gate/Copco	20,393 PLS	8,625	JHS	1,000	1,500	2,500	Bareroot	1	1	
Prunus virginiana	JC Boyle	2,307 PLS	6,900	JHS	600	400	1,000	Bareroot	1	1	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Pseudotsuga menziesii	Iron Gate/Copco	25,438 PLS	8,280	JHS	800	600	1,400	Bareroot	1	2	
Pseudotsuga menziesii	JC Boyle	22,700 PLS	7,590	JHS	800	300	1,100	Bareroot	1	2	
Purshia tridentata	Iron Gate/Copco	19,091 PLS	96,600	JHS	8,200	5,800	14,000	Bareroot	1	2	
Purshia tridentata	JC Boyle	128,666 PLS	27,600	JHS	2,500	1,500	4,000	Bareroot	1	2	
Quercus garryana	Iron Gate/Copco	Sown fall 2020, 2021	14,000	JHS	0	2,500	2,500	MT2510 pot	2	3	~7,000 plants currently in containers from 2020 & 2021 planting.
Quercus kelloggii	Iron Gate/Copco	Sown fall 2020, 2021	5,000	JHS	0	900	900	MT2510 pot	2	3	~2,000 plants currently in containers from 2020 & 2021 planting.
Rhus aromatica	Iron Gate/Copco	19,558 PLS	172,500	JHS	15,800	10,200	26,000	Bareroot	1	2	No wild seed produced in 2021 likely due to drought and heat.
Ribes cereum	JC Boyle	27,623 PLS	3,450	JHS	300	200	500	Bareroot	1	2	
Ribes velutinum	Iron Gate/Copco	160,277 PLS	124,200	JHS	10,800	7,200	18,000	Bareroot	1	2	
Ribes velutinum	JC Boyle	46,962 PLS	13,800	JHS	1,500	500	2,000	Bareroot	1	2	
Rosa woodsii	Iron Gate/Copco	Sown spring 2021	8,280	JHS	500	500	1,000	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Rosa woodsii	JC Boyle	Sown spring 2021	4,140	JHS	500	500	1,000	Bareroot	1	2	Additional seed collection in 2021 not yet cleaned as of 12/3/21.
Spiraea douglasii	Iron Gate/Copco	Collected in 2021	12,075	JHS	600	2,900	3,500	Bareroot	1	2	2021 seed collection not yet cleaned as of 12/3/21
Spiraea douglasii	JC Boyle	5,707,325 PLS	6,900	JHS	700	300	1,000	Bareroot	1	2	
Philadephus lewisii	Iron Gate/Copco	942,485 PLS	75,900	FCN	9,000	1,000	10,000	Bareroot	1	2	
Philadephus lewisii	JC Boyle	38,785 PLS	15,252	FCN	2,250	0	2,250	Bareroot	1	2	
Physocarpus capitatus	Iron Gate/Copco	31,701 PLS	6,900	FCN	1,200	800	2,000	Bareroot	1	2	
Sambucus nigra	Iron Gate/Copco	122,082 PLS	24,000	FCN	0	3,500	3,500	Bareroot	2	3	2020 seed sown at FCN in fall 2020, PLS reflects 2021 wild seed.
Sambucus nigra	JC Boyle	34,921 PLS	3,000	FCN	0	500	500	Bareroot	2	3	2020 seed sown at FCN in fall 2020, PLS reflects 2021 wild seed.

Bare Root Plant Summary and Production Plan (Con't)

Species	Reservoir	PLS stored	PLS Target	Proposed Vendor	2023 number	2024 number	TOTAL number	Bare root or Container	Min age of bare root	Max age of bare root	Notes
Symphoricarpos albus	Iron Gate/Copco	5,618 PLS	10,350	FCN	0	3,000	3,000	Bareroot	2	3	2020 seed sown at FCN in summer 2020, PLS reflects 2021 wild seed.
Symphoricarpos albus	JC Boyle	7,326 PLS	3,450	FCN	0	1,000	1,000	Bareroot	2	3	2020 seed sown at FCN in summer 2020, PLS reflects 2021 wild seed.
				TOTALS	126,850	119,200	247,850				

Appendix H-7: Nurseries, Seed Cleaners, and Seed Collectors

NURSERY	CONTACT	CITY/STATE	FACILITY TYPE	STATUS
Forth Corner Nursery	Dylan Levy-Boyd	Bellingham, WA	Private nursery	No contract yet but seed has been provided to them
J. Herbert Stone Nursery	John Justin or Andrew Colyer	Central Point, OR	USFS facility that only contacts with tribes or other government agencies (local, state or federal)	No contract yet but propagation underway
BFI Native Seed	Matthew Benson	Moses Lake, WA	Private nursery	Active contracts – 2019-2022
Hedgerow Farms	Patrick Reynolds	Winters CA	Private nursery	Active contracts – 2020-2022
Corvallis Plant Material Center	Amy Bartow	Corvallis, OR	USDA facility that only contracts with tribes or other gov entities	They will be storing seed and have a 0.5 acre field in production at no cost
S&S Seeds	Jody Miller	Carpinteria, CA	Private nursery	Currently cleaning seeds from 2020. No contract beyond this year.
Pacific Coast Seed	David Gilpin	Tracy, CA	Private nursery	Remaining seeds collected November 2020. No future contracts.
Bend Seed Extractory	Kayla Herriman	Bend, OR	USFS facility (can only contract with tribes or other government agencies) – seed cleaners, no storage	Provides services as needed

NURSERY	CONTACT	CITY/STATE	FACILITY TYPE	STATUS
Rogue Native Plant Partnership	Kathryn Prive	Southern Oregon	Not a nursery. Seed cleaners, provide connections with local small-scale seed providers and store seed at their facility	Provides services as needed
Siskiyou Biosurvey	Greg Carey	Eagle Point, OR	Botany consultation and seed collection	Provides services as needed

Appendix I

Habitat Restoration Group

Habitat Restoration Group Members

- Renewal Corporation Team
  - McMillen Jacobs
  - Camas, LLC
  - RES
  - Stantec Consulting Services Inc.
- Agencies
  - State Water Resources Control Board
  - Oregon Department of Environmental Quality
  - California Department of Fish and Wildlife
  - Oregon Department of Fish and Wildlife
  - North Coast Regional Water Quality Control Board
  - National Marine Fisheries Service
  - United States Bureau of Land Management (Klamath Falls Field Office)
  - United States Fish and Wildlife Service
- Tribes
  - The Karuk Tribe
  - The Yurok Tribe
  - The Klamath Tribes

Appendix J

List of Preparers

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Appendix K

60 Percent Assisted Sediment Evacuation Design for Copco Reservoir

LEGEND

- EDGE OF RESERVOIR
- PRIMARY ASSISTED EVACUATION AREA
- SECONDARY ASSISTED EVACUATION AREA
- 3–6 FT ESTIMATED RESIDUAL SEDIMENT THICKNESS

NOTES:

1. SEDIMENT DEPTHS ARE PROVIDED FOR GUIDANCE IN SELECTING AREAS TO CONCENTRATE ASSISTED SEDIMENT EVACUATION EFFORTS DURING DRAWDOWN. DEPTHS SHOWN REFLECT PROBABLE REMAINING RESERVOIR SEDIMENT IN THE EVENT OF MINIMAL EVACUATION BY THE KLAMATH RIVER (I.E. DRAWDOWN OCCURS IN A DRY YEAR).
2. RESIDUAL SEDIMENT THICKNESS ESTIMATED FROM SEDIMENT CONSOLIDATION SURFACES FOR A POST–DRAWDOWN CONDITION. BASE DATA ARE GEOREFERENCED SEDIMENT DEPTH ISOLINE MAPS TAKEN FROM US BUREAU OF RECLAMATION 2011 HYDROLOGY, HYDRAULICS, AND SEDIMENT TRANSPORT STUDIES FOR THE SECRETARY'S DETERMINATION ON KLAMATH RIVER DAM REMOVAL AND BASIN RESTORATION (TECHNICAL REPORT NO. SRH–2011–02). A SEDIMENT SHRINKAGE FACTOR OF 0.4, BASED ON SEDIMENT MATERIAL PROPERTIES DESCRIBED IN THE DEFINITE PLAN, WAS APPLIED TO THE SEDIMENT THICKNESS DATA TO ACCOUNT FOR ANTICIPATED VOLUMETRIC CHANGES FROM DRYING POST–DRAWDOWN.
3. RESIDUAL SEDIMENT DEPOSITS ARE DEPICTED WITHIN THE KLAMATH RIVER CHANNEL EXTENDING OUT TO THE APPROXIMATE 100–YR FLOOD LIMIT.
4. PRIORITY AREAS FOR TARGETED ASSISTED SEDIMENT EVACUATION ARE SHOWN WHERE POTENTIAL RESIDUAL SEDIMENT DEPOSITS COULD PRESENT A BARRIER TO VOLITIONAL FISH PASSAGE IN THE KLAMATH RIVER AND SELECT TRIBUTARIES WITHIN THE PROJECT AREA.
5. ASSISTED EVACUATION TO BE CONDUCTED DURING JANUARY 1 TO MARCH 15 DRAWDOWN WINDOW.
6. ASSISTED SEDIMENT EVACUATION ACTIONS MAY INCLUDE, BUT ARE NOT LIMITED TO, EXCAVATION WITH BOAT MOUNTED WATER CANNONS, ACTIVE REMOVAL UTILIZING BOAT WAKES AND/OR PROP WASH DURING DRAWDOWN, AND MANUAL, HYDRAULIC, OR MECHANICAL EXCAVATION POST–DRAWDOWN.
7. ASSISTED SEDIMENT EVACUATION ACTIVITIES WILL BE LIMITED ON A DAILY BASIS, IN PART, BY ACCESSIBILITY OF BOATS AND OTHER EQUIPMENT TO AREAS OF ACCUMULATED SEDIMENT. WHERE CONFLICTS ARISE BETWEEN ACCESSIBILITY TO BEAVER CREEK AND DEER CREEK VERSUS SECONDARY AREAS, PRIORITY WILL BE GIVEN TO BEAVER CREEK AND DEER CREEK BUT REASONABLE EFFORTS WILL BE MADE TO ASSIST WITH SEDIMENT EVACUATION AT THE SECONDARY AREAS SHOWN, AS WELL.

PRELIMINARY DESIGN (NOT FOR CONSTRUCTION) 60% PLAN

REV	DESCRIPTION	BY	CHK	APP	DATE

WARNING
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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

PREPARED BY: res / Kiewit

DESIGNED	GH/KB
DRAWN	SMS
REVIEWED	JFS
IN CHARGE	SDP
APPROVED	MFA

PREPARED FOR: KLAMATH RIVER RENEWAL CORPORATION

PROJECT: KLAMATH RIVER RENEWAL PROJECT

SHEET TITLE: COPCO RESERVOIR-ASSISTED SEDIMENT EVACUATION AREAS

PROJ #	VA103-640/1
DATE	2020.02.07
DWG	R2705

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Appendix L

60 Percent Assisted Sediment Evacuation Design for Iron Gate Reservoir

NOTES:

1. SEDIMENT DEPTHS ARE PROVIDED FOR GUIDANCE IN SELECTING AREAS TO CONCENTRATE ASSISTED SEDIMENT EVACUATION EFFORTS DURING DRAWDOWN. DEPTHS SHOWN REFLECT PROBABLE REMAINING RESERVOIR SEDIMENT IN THE EVENT OF MINIMAL EVACUATION BY THE KLAMATH RIVER (I.E. DRAWDOWN OCCURS IN A DRY YEAR).
2. RESIDUAL SEDIMENT THICKNESS ESTIMATED FROM SEDIMENT CONSOLIDATION SURFACES FOR A POST–DRAWDOWN CONDITION. BASE DATA ARE GEOREFERENCED SEDIMENT DEPTH ISOLINE MAPS TAKEN FROM US BUREAU OF RECLAMATION 2011 HYDROLOGY, HYDRAULICS, AND SEDIMENT TRANSPORT STUDIES FOR THE SECRETARY'S DETERMINATION ON KLAMATH RIVER DAM REMOVAL AND BASIN RESTORATION (TECHNICAL REPORT NO. SRH–2011–02). A SEDIMENT SHRINKAGE FACTOR OF 0.4, BASED ON SEDIMENT MATERIAL PROPERTIES DESCRIBED IN THE DEFINITE PLAN, WAS APPLIED TO THE SEDIMENT THICKNESS DATA TO ACCOUNT FOR VOLUMETRIC CHANGES FROM DRYING POST–DRAWDOWN.
3. RESIDUAL SEDIMENT DEPOSITS ARE DEPICTED WITHIN THE KLAMATH RIVER CHANNEL EXTENDING OUT TO THE APPROXIMATE 100–YR FLOOD LIMIT.
4. PRIORITY AREAS FOR TARGETED ASSISTED SEDIMENT EVACUATION ARE SHOWN WHERE POTENTIAL RESIDUAL SEDIMENT DEPOSITS COULD PRESENT A BARRIER TO VOLITIONAL FISH PASSAGE IN THE KLAMATH RIVER AND SELECT TRIBUTARIES WITHIN THE PROJECT AREA.
5. ADAPTIVE MANAGEMENT SEDIMENT EVACUATION WORK MAY BE NECESSARY IN FALL CREEK AND BOGUS CREEK POST DRAWDOWN TO PROMOTE VOLITIONAL FISH PASSAGE.
6. ASSISTED EVACUATION TO BE CONDUCTED DURING JANUARY 1 TO MARCH 15 DRAWDOWN WINDOW.
7. ASSISTED SEDIMENT EVACUATION ACTIONS MAY INCLUDE, BUT ARE NOT LIMITED TO, EXCAVATION WITH BOAT MOUNTED WATER CANNONS, ACTIVE REMOVAL UTILIZING BOAT WAKES AND/OR PROP WASH DURING DRAWDOWN, AND MANUAL, HYDRAULIC, OR MECHANICAL EXCAVATION POST–DRAWDOWN.
8. ASSISTED SEDIMENT EVACUATION ACTIVITIES WILL BE LIMITED ON A DAILY BASIS, IN PART, BY ACCESSIBILITY OF BOATS AND OTHER EQUIPMENT TO AREAS OF ACCUMULATED SEDIMENT. WHERE CONFLICTS ARISE BETWEEN ACCESSIBILITY TO SCOTCH CREEK, CAMP CREEK AND JENNY CREEK VERSUS SECONDARY AREAS, PRIORITY WILL BE GIVEN TO SCOTCH CREEK, CAMP CREEK AND JENNY CREEK BUT REASONABLE EFFORTS WILL BE MADE TO ASSIST WITH SEDIMENT EVACUATION AT THE SECONDARY AREAS SHOWN, AS WELL.

PRELIMINARY DESIGN (NOT FOR CONSTRUCTION) 60% PLAN

REV	DESCRIPTION	BY	CHK	APP	DATE

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

PREPARED BY: res, Kiewit

DESIGNED JM
DRAWN CW
REVIEWED JFS
IN CHARGE SDP
APPROVED MFA

PREPARED FOR: KLAMATH RIVER RENEWAL CORPORATION

PROJECT: KLAMATH RIVER RENEWAL PROJECT
SHEET TITLE: IRON GATE RESERVOIR-ASSISTED SEDIMENT EVACUATION AREAS

PROJ # VA103-640/1
DATE 2020.02.07
DWG R4708

sshelton Apr 08, 2021 - 12:08pm

Appendix M

Large Wood Stability Calculations

Large Wood Stability Calculations for the Klamath Dam Removal 60% Design

Stability calculations were performed to evaluate large wood placement stability for the five primary tributaries within the project reach. The 60% Design calls for wood elements placed along the priority tributaries within the Iron Gate, Copco, and JC Boyle Reservoirs including Beaver, Scotch, Camp, Jenny, and Spencer Creeks. Full length trees, 50-100 feet in length placed with a helicopter and rootwads, 35-50 feet in length will be placed using ground based heavy equipment.

2D hydraulic models were developed for each reservoir and tributary to evaluate the 10 year discharge in order to determine hydraulic parameters (depth, velocity, etc.) that are necessary to evaluate the forces acting on the large wood placement conditions. Hydraulic parameters from the model were applied to determine the stability and force-balance for large wood design conditions at each tributary. Using a risk assessment based on Bureau of Reclamation – Risk Based Guidelines (USBR 2014) for tributaries within the reservoir footprints coupled with 2D hydraulic modeling a Factor of Safety (FOS) rating resulted in a risk level of Low for horizontal, vertical, and overturning forces on wood features. The FOS of low risk corresponds to the 10 Year discharge (USBR 2014) with corresponding values of 1.25 for sliding (horizontal forces); 1.5 for bouncy (vertical forces); and 1.25 for rotation or overturning forces.

The stability evaluation method used, and associated calculations were based from the National Large Wood Manual (Bureau of Reclamation 2016) and Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement (Rafferty 2013) and USBR 2014 Risk Based Guidelines. Each of the tools uses planform and cross-section inputs along with site specific geometry, hydraulic parameters, wood dimension, orientation and other factors to determine forces acting against each wood element. Initial stability calculations were performed at two potential design scenarios for each of the tributaries hydraulic conditions. Jenny Creek which is the largest tributary has a 10 year discharge of 4,000 cfs. This tributary was used as the worse-case scenario to determine the most appropriate arrangement that would result in stable conditions and still providing the maximum amount of habitat value within the tributary.

The two different scenarios and methods correspond to both ground and helicopter placed large wood. Scenario 1 is for a single helicopter placed wood using whole tree placed with dimensions of approximately 80 feet in length and 18 inch diameter should be oriented with rootwad placed in the active channel at 1-3 depth of flow. The larger volume area of the tree including the base and top should be positioned within the floodplain bench to provide the counteracting weight against bouncy forces. Scenario 2 was to evalute ground placed material using two single 35 foot long rootwad elements buried approximately 3 feet into the bank and extending approximately 10 feet directly into the flow field. Each scenario used separate stability calculation spreadsheets, but with the same hydraulic parameters. The results of the calculations resulted in both scenarios being stable at the 10 year event. Although, flows above 4,000 cfs or the 10 year event has the potential for the wood to become mobile within the active channel. To view the calculations and the hydraulic parameters used for the Jenny Creek, see the scenario examples located at the end of this document. The section immediately below describes the hydraulic modeling framework developed to support the large wood stability calculations.

Hydraulic Modeling to Support Large Wood Stability Calculations

Current restoration plans for the Iron Gate, Copco, and JC Boyle reservoir areas include the potential for large wood placements in reservoir arms corresponding to six tributary streams. Large wood stability calculations require estimates of the flow depths and velocities that placed wood could be subjected to during floods. As the tributary channels are currently submerged beneath the reservoirs, hydraulic modeling is necessary to estimate potential flow conditions in those channels. That modeling was performed using SRH-2D, a publically-available 2-dimensional hydraulic modeling system developed by the U.S. Bureau of Reclamation. Hydraulic model development consists of four general steps: selecting an appropriate model domain, constructing a computational mesh spanning the selected domain, determining mesh boundary conditions, and applying surface topography and roughness to the mesh. Each of those steps and the methods used are summarized below.

Model Domains

Tributary channels evaluated for wood placement within the Iron Gate reservoir footprint consist of Jenny Creek and Camp Creek/Scotch Creek. Jenny Creek is the largest tributary entering any of the three reservoirs by a wide margin, whereas Camp Creek and Scotch Creek are much smaller tributaries that join at the upstream end of the Camp Creek arm of the reservoir (Figure 1). Two relatively small tributaries within the Copco 1 footprint are evaluated for wood placement, those being Beaver Creek and Deer Creek (Figure 2). One important tributary, Spencer Creek, is considered for wood placement within the JC Boyle reservoir footprint (Figure 3). Although Spencer Creek has only about 40% of the watershed area of Jenny Creek, it offers by far the greatest length of tributary channel accessible to migrating fish (9 miles) of any tributary in the reach spanning the three reservoirs.

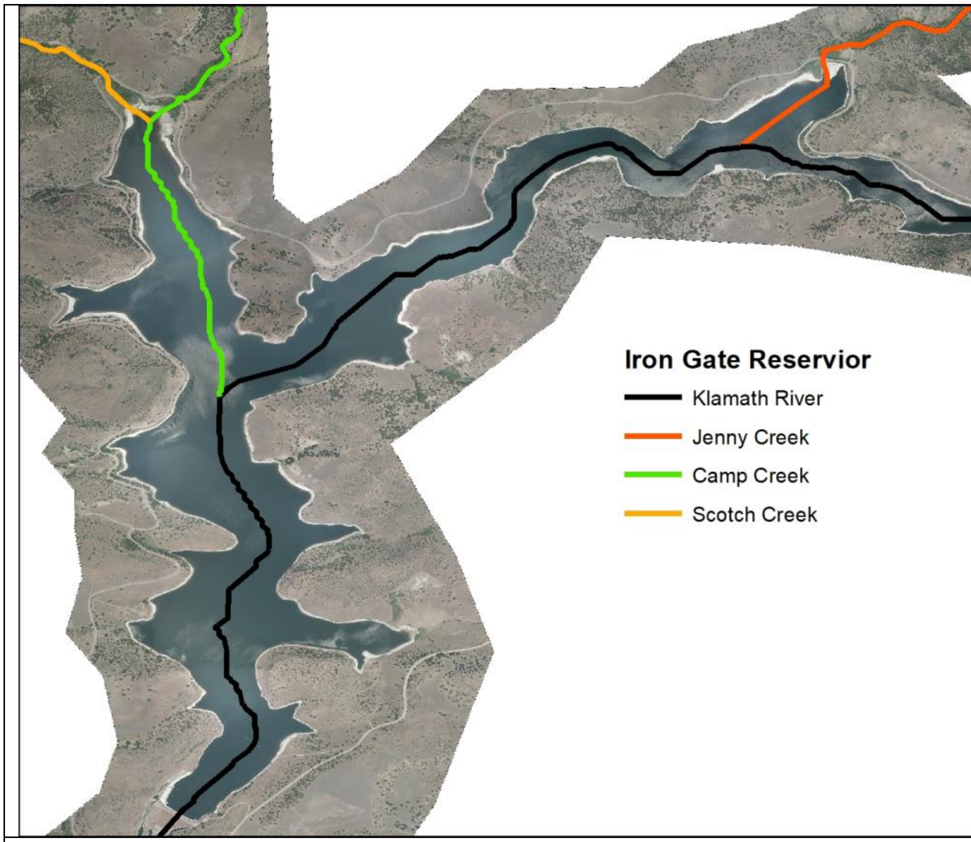


Figure 1: Iron Gate reservoir with Scotch, Camp, and Jenny Creeks highlighted.

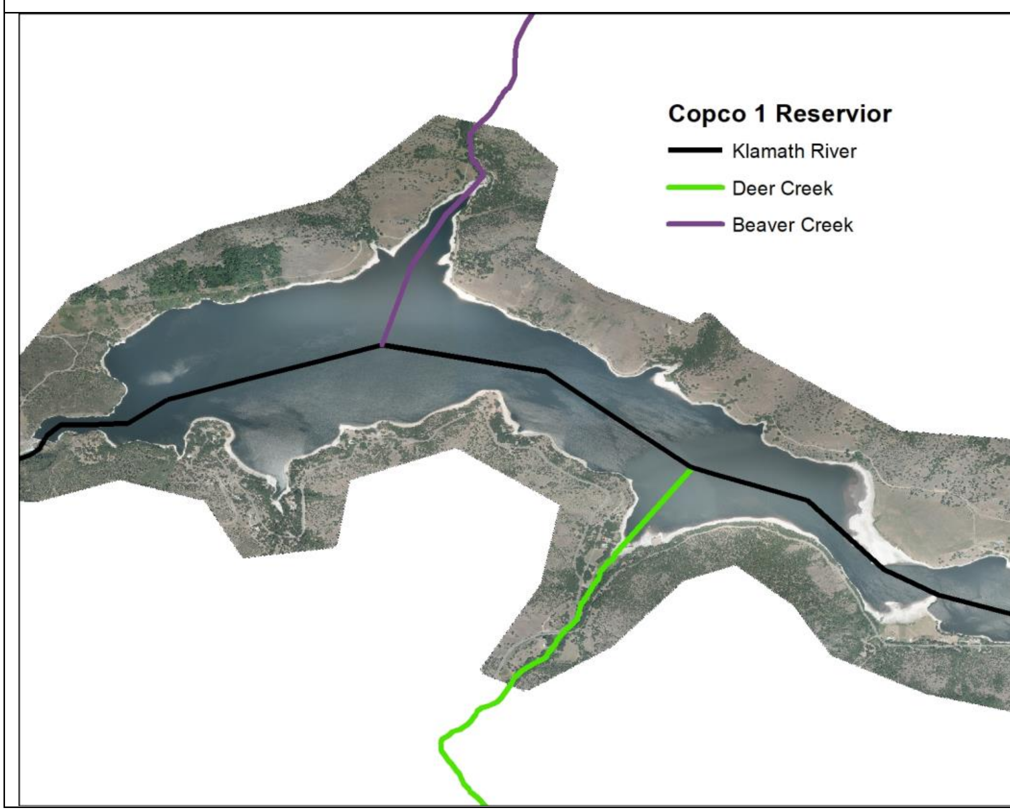


Figure 2: Copco 1 reservoir with Beaver and Deer Creeks highlighted.

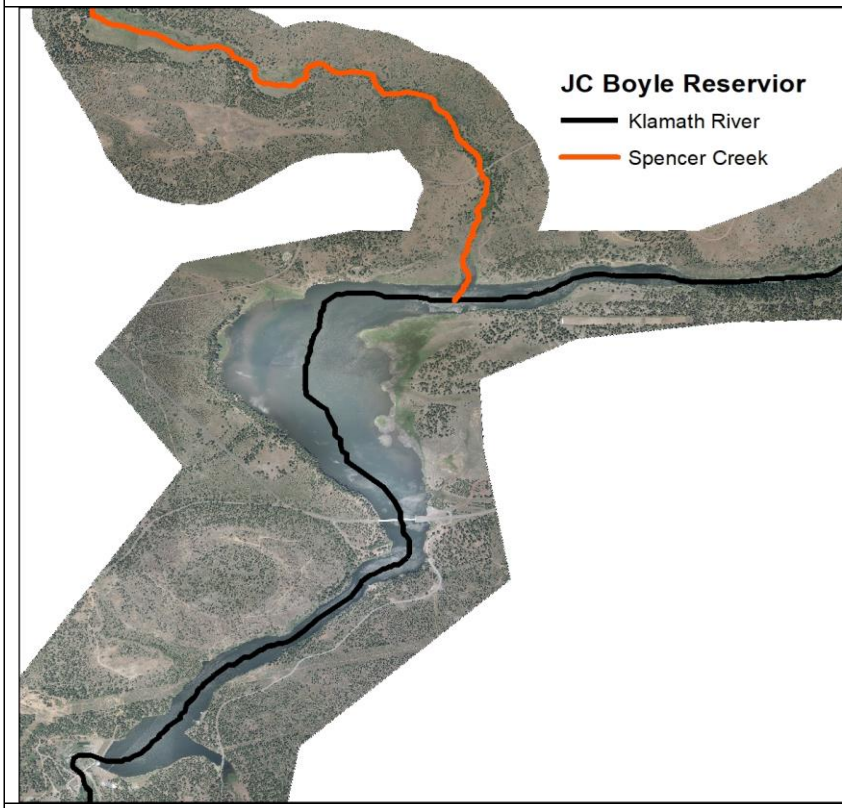


Figure 3: JC Boyle reservoir with Spencer Creek highlighted.

Rather than modeling each of these five tributary arms separately, we chose model domains spanning each of the three reservoirs. One reason to model the entire reservoirs is that water surface elevations in the mainstem Klamath River exert downstream control on hydraulics in the tributaries, particularly near their confluences with the Klamath. It would therefore be necessary to model some part of the Klamath River even if each tributary model were modeled separately. A second reason to model the entire reservoirs is that reservoir models will likely be useful for other purposes in the future as dam removal planning and implementation proceeds. For example, it could be helpful to model hydraulic conditions at various stages of reservoir drawdown to assess the feasibility of deploying watercraft to help manage sediment evacuation.

Computational Meshes

SRH-2D permits the use of an unstructured mesh composed of a combination of triangular and quadrilateral elements of various sizes. This makes it possible to spatially vary mesh resolution and geometry to provide greater resolution in areas where complex flow fields are anticipated and reduce computational demands in less sensitive areas. For example, Figure 4 shows a portion of the Copco 1 mesh at the confluence of Deer Creek with the mainstem Klamath River. The mesh along the sinuous Klamath floodway and in a swath of valley surrounding the course of Deer Creek consists of mostly quadrilateral elements about 10 ft wide. The higher floodplain areas are represented by triangular elements that are small near the floodways but become larger with increasing elevation and distance from the main flow paths. For scale, note that the largest triangular elements at the edges of the mesh farthest from a stream channels are 90 to 100 ft wide along their longest edges. Those large edge elements are inundated only when the reservoir is at full pool, and many are even beyond the bounds of full pool. The meshes for all three reservoir models are constructed in this way.

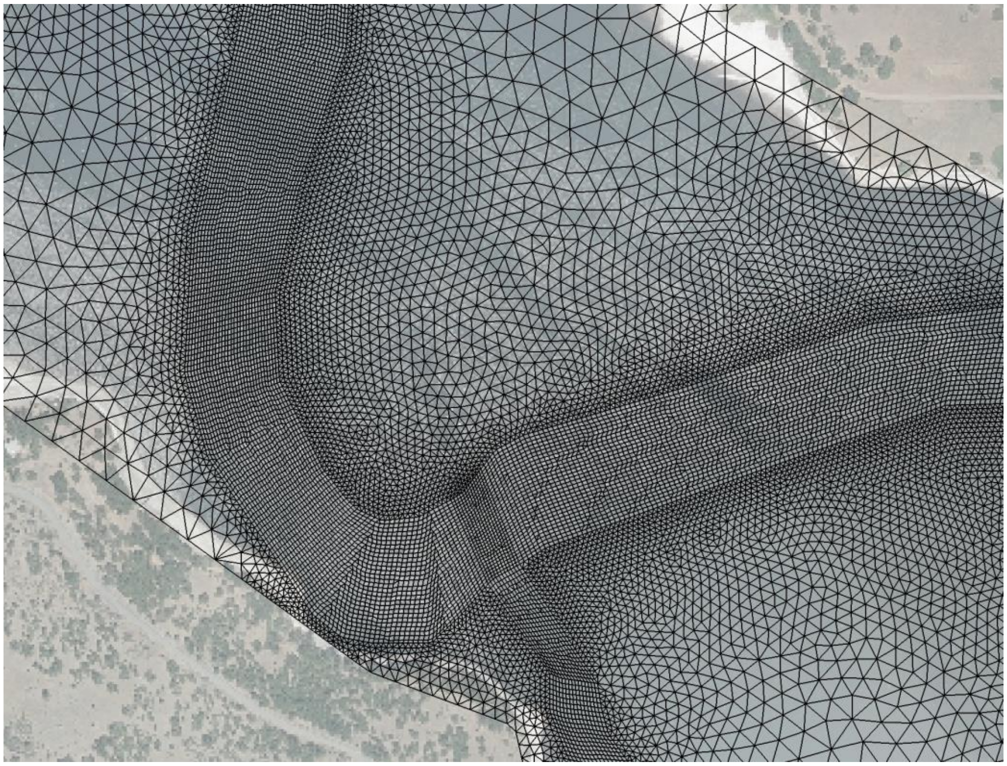


Figure 4: Example of mesh structure; confluence of Deer Creek with the Klamath River.

Boundary Conditions

We chose the 10-yr flood as the benchmark event for assessing wood stability. Flood magnitudes for that event in the mainstem Klamath River are given in Appendix B5 of the Design Criteria Report and based on the 2019 BiOp flows for the Upper Klamath Irrigation Project. They are 9500 cfs at JC Boyle Dam, 11300 cfs at Copco 1 Dam, and 12000 cfs at Iron Gate Dam. Klamath River inflows at the upstream boundary of each model domain were computed by subtracting the tributary inputs within each reservoir (described below) from the 10-yr discharge, such that the discharge at the downstream boundary of each model is equal to the 10-yr flood.

Estimates of water surface elevations corresponding to those flood discharges are also required to define boundary conditions at the downstream end of the model domains. Those water surface elevations were estimated by extracting channel/valley cross sections at the downstream boundaries of the model domains from the available digital terrain models, assigning reasonable assumed roughness values, and computing normal flow via the Manning equation. The downstream boundaries of the models are located far enough downstream that errors in the downstream water surface elevations have no effect on model results at the tributary confluences or in the tributaries themselves.

Flood magnitudes for several of the individual tributaries considered here are available in Table 4.2 and Table 4.3 in Appendix B5 of the Design Criteria Report. That table contain estimates for the 10-yr flow magnitude for Scotch Creek, Camp Creek, Jenny Creek, and Beaver Creek. Of those tributaries, the flood hydrology estimates are based on actual gage records only at Jenny Creek. For all other locations, Appendix B5 indicates that flood magnitudes were estimated using methods developed by the USGS (Cooper 2005). Appendix B5 provides no estimates of flood magnitudes for Deer Creek or Spencer Creek. It was therefore necessary to evaluate methods for assessing flood magnitudes in those tributaries.

We first consulted Cooper (2005) and found that the methods described in that document require extensive detailed information regarding watershed topography, climate, and soil characteristics, and that the precise parameters required varies according to watershed location. Due to that complexity, Cooper (2005) directs the reader to an interactive website hosted by the Oregon Water Resources Department where the user can click on a location and receive a report of flood frequencies for that location (*http://www.wrd.state.or.us/OWRD/SW/peak_flow.shtml*). Upon engaging that website, we found that it would not return results for the locations in California, presumably because those streams are outside of the region the methods were developed for. Rather, it returned flood magnitude estimates only for Spencer Creek.

In addition to estimates for various flood recurrence intervals, the report for Spencer Creek included the mathematical model used to generate those estimates. The model, which the report identifies as being for "East Slope Cascade Mountains watersheds," depends on just three watershed parameters: drainage area (A), mean slope (S), and mean elevation (Z). Those factors are raised to powers that depend on recurrence interval, with the 10-yr event being given by:

$$Q_{10} = 10^{4.875} A^{0.8181} S^{1.992} Z^{-1.454}$$

The report also lists sets of exponents for the 2-, 5-, 20-, 25-, 50-, 100-, and 500-yr events. Surprisingly, no region corresponding to the "East Slope Cascade Mountains" exists in Cooper (2005), which discusses only Region 1 (coastal watersheds), Region 2A (western interior with mean elevation greater than 3000 ft), and Region 2B (western interior with mean elevation less than 3000 ft). It is therefore unclear how Cooper (2005) relates to the OWRD website or what methods are appropriate for Klamath River tributaries in California or near the state border.

We evaluated the equations contained on the OWRD report for Spencer Creek by applying them to the tributaries listed in Table 4.3 of Appendix B5, which gives estimates for the 2-, 5-, 10-, and 25-year flood magnitudes. We found that the OWRD method gives very different results than those reported in Appendix B5. For example, the OWDR equation gives estimates for the 10-yr events in Scotch and Camp Creeks of 1844 and 1849 cfs, whereas Appendix B5 reports 10-yr floods of 320 and 360 cfs. In addition, the OWDR method produces flood magnitudes for Spencer Creek that seem anomalously small – the OWDR 10-yr event on Spencer Creek is just 581 cfs. That is less than a third of the OWDR flows on Scotch and Camp Creeks even though the Spencer Creek watershed is more than four time larger in terms of watershed area.

Due to the uncertainties surrounding the Cooper/OWDR methods, we also evaluated the potential of scaling flood magnitudes with watershed area relative to Jenny Creek, the only gaged tributary. This approach assumes that the watershed are close enough to one another that climatic differences are relatively small. This seems reasonable, as the confluences of Spencer Creek and Jenny Creek with the Klamath River are within 24 miles of one another and the mean elevations of the two watersheds differ by just 850 ft.

Table 2 lists 10-yr flood magnitudes obtained by scaling the Jenny Creek magnitudes according to watershed area compared to the magnitudes reported in Appendix B5. For the three tributaries for which two estimates exist, they differ by just 7% and 4% for Scotch and Camp Creeks, and by 30% for Beaver Creek. This level of variability is considered acceptable, and the scaled flood magnitudes were adopted as tributary influx boundary conditions for modeling.

Table 2: Estimated 10-yr flood magnitudes in tributaries estimated by scaling Jenny Creek flows by watershed area (Scaled) and as reported in Appendix B5 (B5).

	Jenny Ck cfs	Scotch Ck cfs	Camp Ck cfs	Beaver Ck cfs	Spencer Ck cfs	Deer Ck cfs
Scaled	4000	344	376	130	1614	157
B5	4000	320	360	100		
% difference	0	7	4	30		

Topography and Roughness

Topography was mapped to the model meshes from existing terrain models. First, the new digital terrain model provided by Quantum Spatial in November 2019 was mapped to all three reservoir models to incorporate the most complete topographic data available for the Klamath River. Then, Post drawdown surfaces for each reservoir developed by Stantec and collaborators were overlain on the model meshes to incorporate the best available estimates regarding the locations and dimensions of channels within the reservoir footprints following drawdown. Finally, surfaces supplied by Stantec depicting reconstructed channels in areas that are currently occupied by the dams were overlain to provide flow conveyance through the dam footprints.

Roughness values assigned to the meshes in the vicinity of the dams are based on those used for earlier modeling to assess fish passage through the dam footprint areas, and are described in a series of memos submitted to Stantec and collaborators over the past few months. Those areas, however, are very small compared to the reservoirs as a whole and have little effect on the hydraulics farther upstream. Only two roughness values are used over the vast majority of the reservoir areas. Areas in and adjacent to where actual stream channels are expected were assigned Manning's n values of 0.041. This values is appropriate for a substrate composed of a combination of gravel, cobble, and occasional boulders. Other areas (floodplains, terraces, hillslopes, etc.) were assigned $n = 0.038$. This slightly lower value was selected in the expectation that many surfaces outside the main flow paths will be draped in fine sediments, at least initially. It should be understood that no roughness parameterization can be correct for drawdown and the initial phases of restoration work because the surface materials and vegetative cover will be constantly and rapidly evolving for several years. Likewise, actual channel configurations and upland surface geometries will certainly deviate substantially from what is indicated by the post drawdown surfaces, and they will be subject to rapid evolution for some time.

Results

Flow depths and velocities expected during the 10-yr event as described above are presented visually in Figures 5 through 10. The results are presented in order from downstream to upstream beginning with the north half of Camp/Scotch Creeks (Figure 5), followed by the south half Camp/Scotch Creeks (Figure 6), Jenny Creek (Figure 7), Beaver Creek (Figure 8), Deer Creek (Figure 9), and Spencer Creek (Figure 10). The color ramps used in the figures are consistent throughout, with the lowest depths or velocities (0 ft or 0 ft/s) shown in blue and the greatest depths or velocities (10+ ft or 10+ ft/s) shown in red.

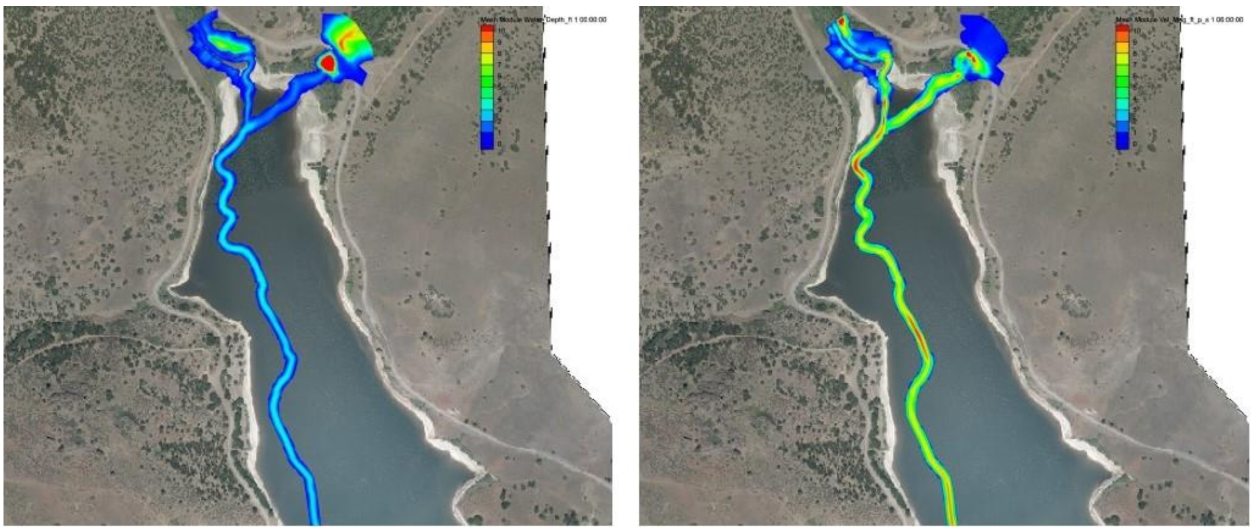


Figure 5: Modeled depths (left) and flow velocities (right) in the north half of the Camp Creek/Scotch Creek arm of Iron Gate reservoir.

The Camp/Scotch Creek results (Figure 5 and 6) are typical for most of the tributaries modeled in that flow depths are small compared to flow velocities. Modeled depths in that stream rarely exceeding 3 ft, whereas velocities are generally near 6 ft/s and in some locations exceed 10 ft/s and near-critical or supercritical flow conditions are common. Depths are greater (>5 ft) through much of Jenny Creek due to its much larger 10-yr discharge, but flow velocities are also very large and supercritical flow is widespread throughout the tributaries length. The small depths and high velocities reflect the fact that most of the tributary valleys are rather steep, with slopes through the modeled reaches between 1.3% (Beaver Creek) and 2.1% (Jenny Creek). The exception is Spencer Creek with a reach averaged slope of about 0.8%, velocities mostly less than twice the depth, and Froude numbers mostly less than 0.6.

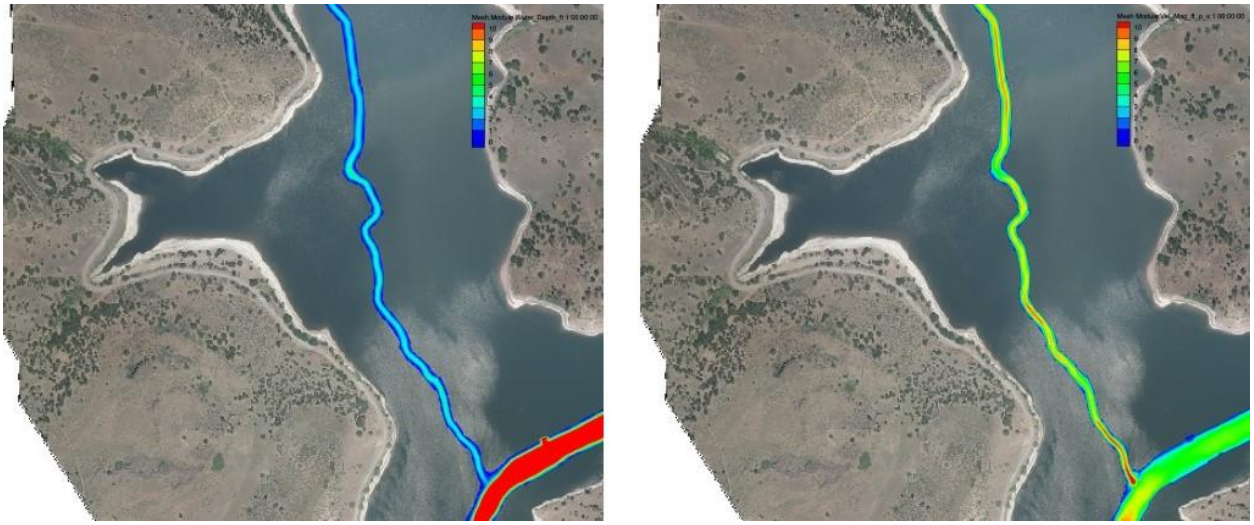


Figure 6: Modeled depths (left) and flow velocities (right) in the south half of the Camp Creek/Scotch Creek arm of Iron Gate reservoir and Klamath River confluence area.

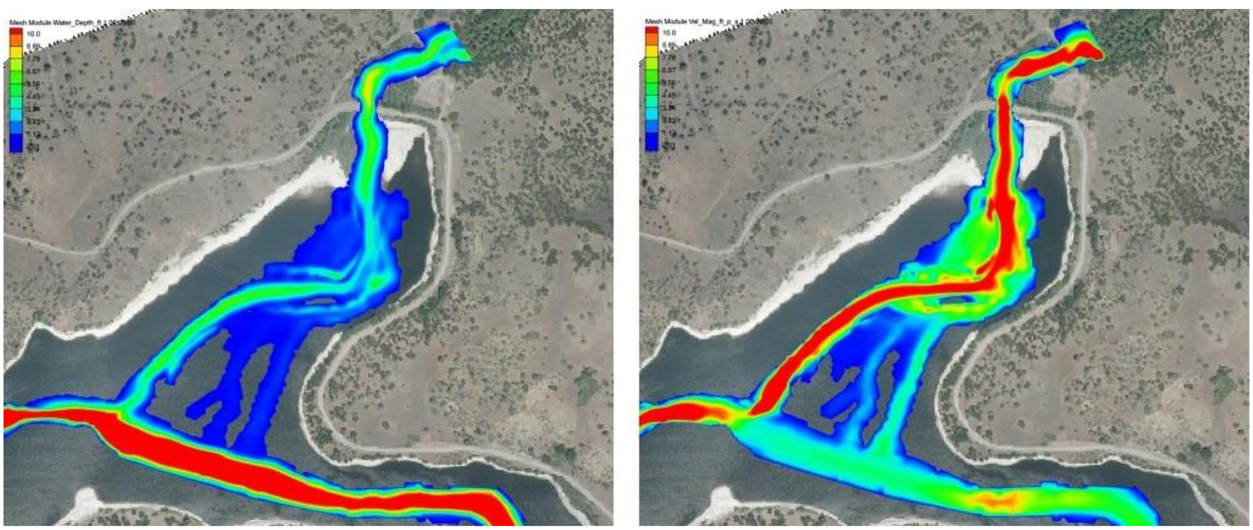


Figure 7: Modeled depths (left) and flow velocities (right) in Jenny Creek and Klamath River confluence area within the Iron Gate reservoir footprint.

As a final observation on these modeling results, it can be noted that neither the Jenny Creek nor the Spencer Creek channels contain their respective modeled 10-yr flood discharges, whereas the channels graded into the postdrawdown surfaces do contain those events. In the case of Spencer Creek, almost all of the modeled tributary is currently exposed subaerially and therefore reflect actual conditions on the ground rather than hypothetical graded geometry, as is the case with the other tributaries.

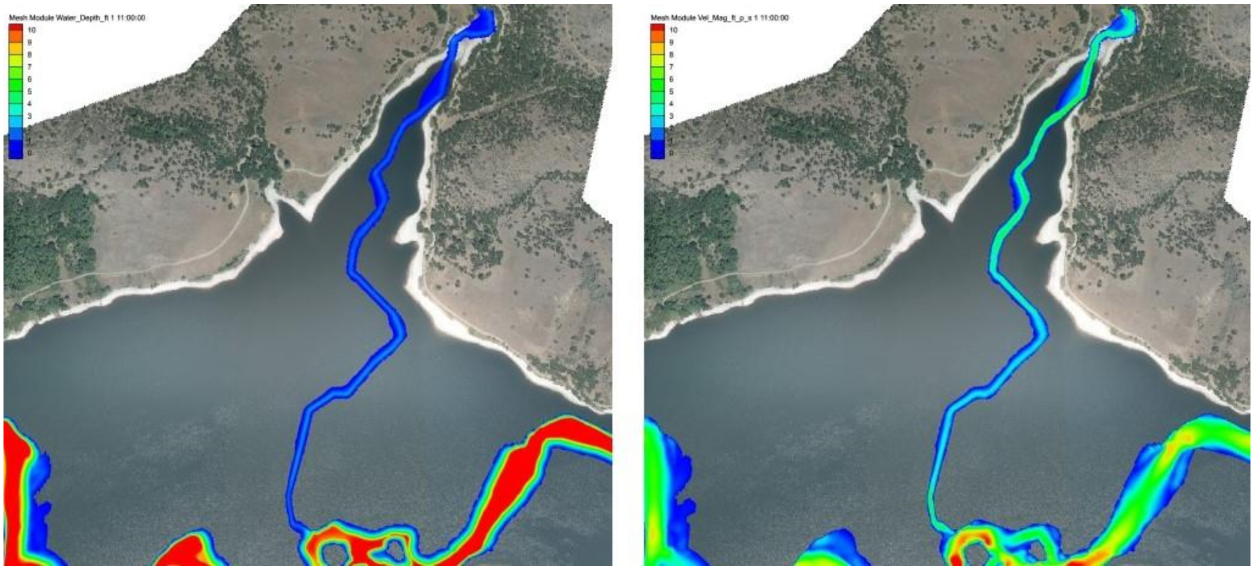


Figure 8: Modeled depths (left) and flow velocities (right) in Beaver Creek and Klamath River confluence area within the Copco 1 reservoir footprint.

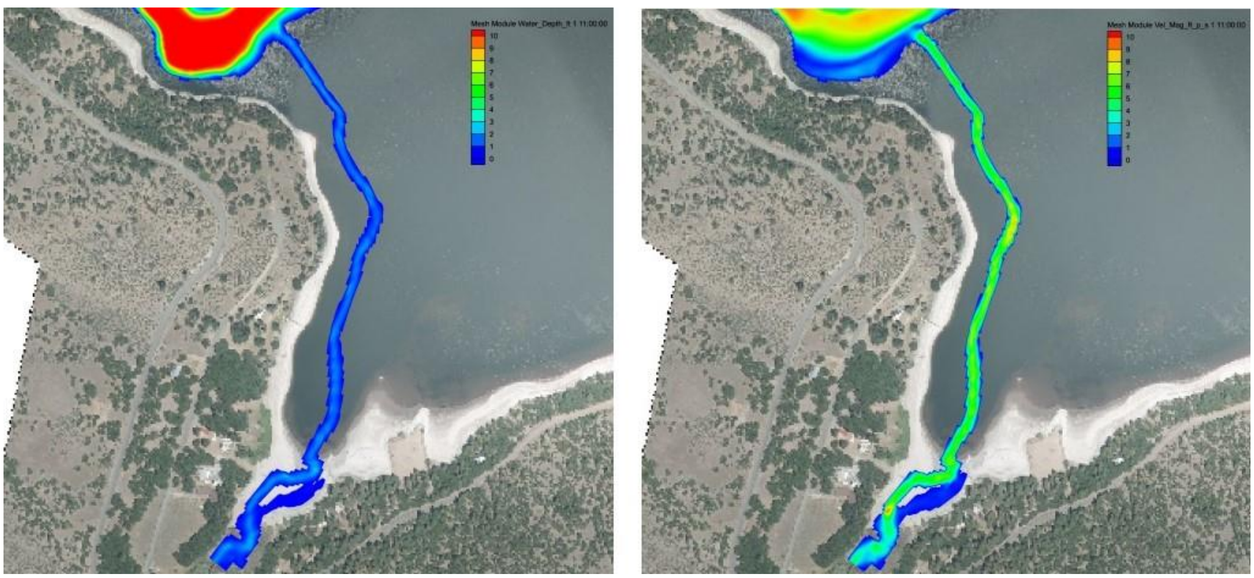


Figure 9: Modeled depths (left) and flow velocities (right) in Deer Creek and Klamath River confluence area within the Copco 1 reservoir footprint.

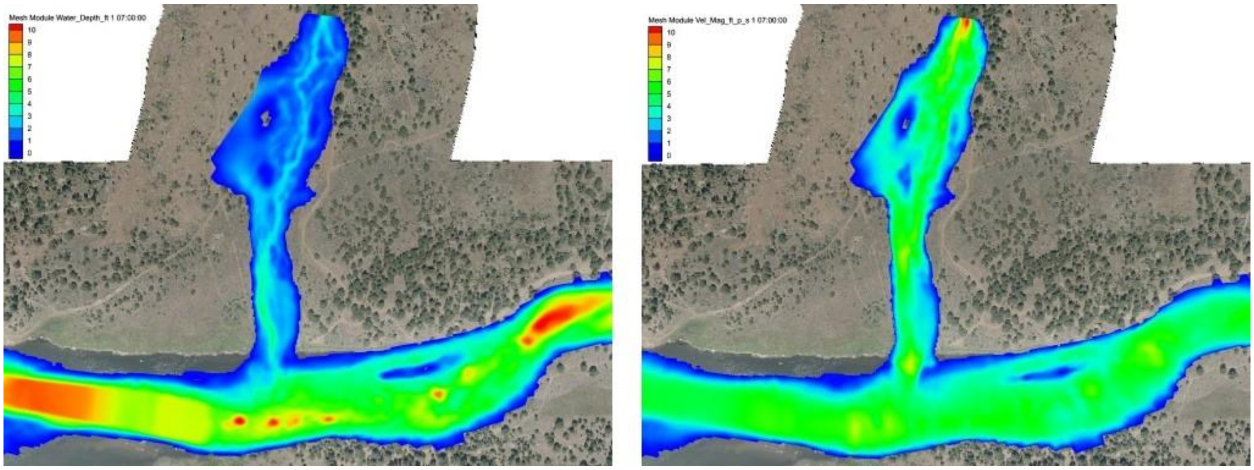


Figure 10: Modeled depths (left) and flow velocities (right) in Spencer Creek and Klamath River confluence area within the JC Boyle reservoir footprint.

References

Cooper, R.M., 2005. Estimation of peak discharges for rural, unregulated streams in western Oregon. US Geological Survey Scientific Investigations Report 2005-5116, 134 pp.

Bureau of Reclamation, M. Knutson and J. Fealko, 2014. Large Woody Materials Risk Based Guidelines. Pg. 14-25.

Bureau of Reclamation and U.S. Army Engineer Research and Development Center (USBR and ERDC), 2016. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure.

Rafferty, M., 2013. Development of a Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement. Masters of Science Thesis, Colorado State University.

LARGE WOOD STABILITY CALCULATIONS

SCENARIO 1

(SINGLE WHOLE TREE WITH ROOTWAD – 80 FT. LONG / 30” DIA. HELICOPTER PLACED)

Klamath Dam Removal - 60% Design

Large Wood Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: December 5, 2019

Designer:
DJ Bandrowski

Reviewed by:
Yurok Tribe

Reference for Design Method of Large Wood Structures:
NRCS NEH 654 Technical Supplement 14J (2007)

Reference for Companion Paper:
Rafferty, M. (2013). *Development of a Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement*. Masters of Science Thesis, Colorado State University.

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.0

Klamath Dam Removal - 60% Design
Factors of Safety and Design Constants

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.75**
FS_H	Factor of Safety for Horizontal Force Balance	**1.50**
FS_M	Factor of Safety for Moment Force Balance	**1.50**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Klamath Dam Removal - 60% Design
Hydrologic and Hydraulic Inputs

Average Return Interval (ARI) of Design Discharge: 10 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
Iron Gate	Jenny Creek	4,000	4.90	9.10	95.0	345	870

Klamath Dam Removal - 60% Design
Stream Bed Substrate Properties

Klamath Dam Removal - 60% Design
Bank Soil Properties

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
Iron Gate	Jenny Creek	15.00	Medium gravel	5	121.9	75.9	36	Coarse sand, loose	6	98.0	61.0	31

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Klamath Dam Removal - 60% Design
Large Wood Properties

Project Location: West Coast

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Douglas-fir, Coast**	Pseudotsuga menziesii var. menzi.	33.5	38.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

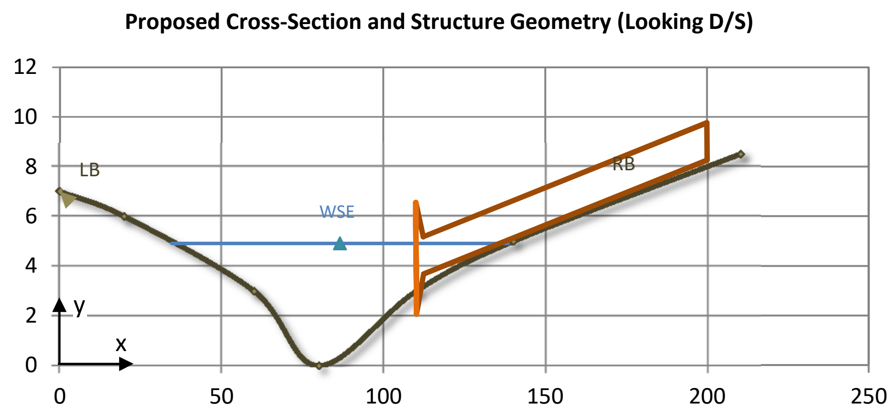
Klamath Dam Removal - 60% Design

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Iron Gate	Rootwad	Right bank	Inside	Jenny Creek	4.90	9.16	9.10

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.0	7.00
Top LB	20.0	6.00
Toe LB	60.0	3.00
Thalweg	80.0	0.00
Toe RB	110.0	3.00
Top RB	140.0	5.00
Fldpln RB	210.0	8.50

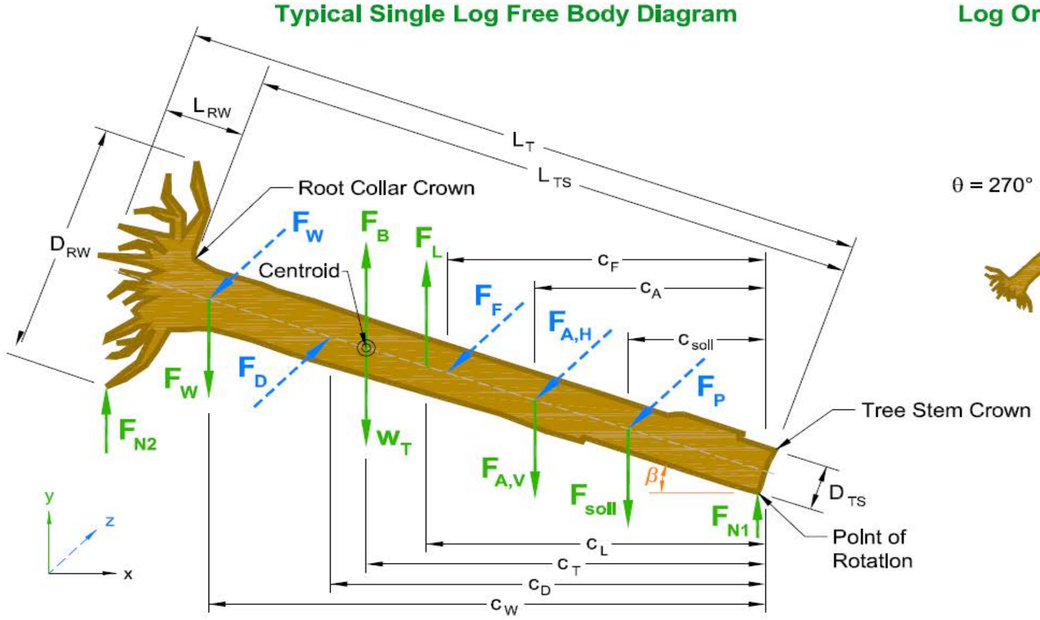


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	90.0	1.50	2.25	4.50	33.5	38.0

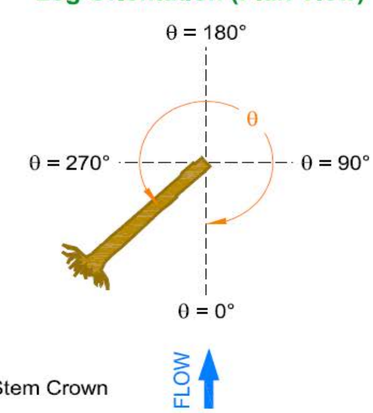
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.0	3.0	Rootwad: Crown	110.00	6.55	2.06	9.76	17.49

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.9	75.9	36.0	5	0.00	0.00	0.00
Bank	Coarse sand, loose	98.0	61.0	31.0	6	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	138.4	4.0	142.4	4,777	0
↓WS↑Thw	16.6	9.8	26.4	887	1,650
↓Thalweg	0.0	0.0	0.0	0	0
Total	155.1	13.8	168.9	5,664	1,650

Lift Force

C_{LT}	0.23
F_L (lbf)	323

Vertical Force Balance

F_B (lbf)	1,650	↑
F_L (lbf)	323	↑
W_T (lbf)	5,664	↓
F_{soil} (lbf)	0	
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
Σ F_V (lbf)	3,691	↓
FS_V	2.87	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	0.0	0.0	0
Total	0.0	0.0	0.0	0

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.05	1.31	1.10	0.00	1.22	1,715

Horizontal Force Balance

F_D (lbf)	1,715	→
F_P (lbf)	0	
F_F (lbf)	2,682	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
Σ F_H (lbf)	967	←
FS_H	1.56	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	2,682
Bank	3.12	0	0.00	0.60	0
Total	-	0	2.00	-	2,682

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
47.6	77.2	77.2	47.6	0.0	90.0	0.0

*Distances are from the stem tip

Point of Rotation: Rootwad

Moment Force Balance

M_d (lbf)	95,987
M_r (lbf)	239,969
FS_M	2.50 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Klamath Dam Removal - 60% Design
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

LARGE WOOD STABILITY CALCULATIONS

SCENARIO 2

(DOUBLE LOG IN COMBINATION – PARTIALLY BURRIED 35 FT. LONG / 20” DIA. GROUND PLACED)

SUMMARY SHEET - LARGE WOOD STABILITY CALCULATIONS Version 3.0 - updated 2-17

PROJECT	Klamath Dam Removal			DATE
STRUCTURE TYPE	Multiple Log (Ground Placed)	ANALYSTS	DJB	2/3/2020
RIVER & REACH	Jenny Creek (Tributary)		-	-
SPREADSHEET DEVELOPER	Bureau of Reclamation/Yurok Tribe	REVIEWER	Yurok Tribe	2/3/2020
PUBLIC SAFETY RISK	Low			
PROPERY DAMAGE RISK	Low			
DESIGN FLOW	4,000 cfs			
DESIGN FLOW RETURN INTERVAL	10-year			
STRUCTURE PURPOSE	Habitat			

RESULTS SUMMARY

	Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	FOS sliding	FOS bouyancy	FOS rotation[2]	FOS overturning[2]	FOS Pile Breakage	FOS Pile Overturning
MINIMUM FACTOR OF SAFETY[1]	Low	Low	10-year	1.25	1.5	1.25	1.25	1.5	1.5
PROPOSED FACTOR OF SAFETY	Low	Low	10-year	1.3	1.5	1.72	N/A	N/A	N/A
FACTOR OF SAFETY CHECK			OK	OK	OK	OK	OK	OK	OK

Notes

[1] minimum factor of safety from Table 4, Large Woody Material - Risk Based Design Guidelines, Sep 2014

[2] Structure failure by rotation or overturning not applicable to: (a) mid-channel structures, or (b) structures not embedded in the bank.

STRUCTURE & HYDRAULICS - LARGE WOOD STABILITY CALCULATIONS					Version 3.0 - updated 2-17	
PROJECT	Klamath Dam Removal					DATE
STRUCTURE	Multiple Log (Ground Placed)				ANALYSTS DJB	2/3/2020
RIVER & REACH	Jenny Creek (Tributary)					
					REVIEWER Yurok Tribe	2/3/2020
HYDRAULIC INPUT						
FLOW		4,000	CFS			
RETURN INTERVAL		10-year	Note - Assume 2 Year			
				Notes (RM, model source etc.)		
UPSTREAM CONDITIONS						
LOCATION		**Jenny Creek - At Placement**				
APPROACH VELOCITY	Vchannel =	9.1	fps	From SRH-2D Hydraulic Model		
CHANNEL WIDTH		95.0	ft	From SRH-2D Hydraulic Model		
WATER SURFACE EL		2321.9	ft	From SRH-2D Hydraulic Model		
CHANNEL EL		2317.0	ft	From SRH-2D Hydraulic Model		
FLOW DEPTH (AVG)	Yu =	4.9	ft			
CROSS-SECTIONAL AREA	Au =	465.5	sf			
AT-STRUCTURE CONDITIONS						
LOCATION		**Jenny Creek - At Placement**				
VELOCITY AT STRUCTURE	Vc (Uc) =	9.1	fps	From SRH-2D Hydraulic Model		
WATER SURFACE EL		2321.9	ft	From SRH-2D Hydraulic Model		
CHANNEL EL		2317.0	ft	From SRH-2D Hydraulic Model		
SCOUR DEPTH	Ys =	0.0	ft			
SCOUR EL		2317.0	ft			
FLOW DEPTH (AVG)	Yc =	4.9	ft			
CONTRACTED CHANNEL WIDTH		95.0	ft	From SRH-2D Hydraulic Model		
AREA OF CONTRACTED FLOW	Ac =	465.5	sf			
DOWNSTREAM CONDITIONS						
LOCATION		**Jenny Creek - At Placement**				
WATER SURFACE EL		2321.9	ft	From SRH-2D Hydraulic Model		
CHANNEL EL		2317.0	ft	From SRH-2D Hydraulic Model		
FLOW DEPTH	Yd =	4.9	ft			
CHANNEL WIDTH		95.0	ft			
CROSS-SECTIONAL AREA	Ad =	465.5	sf			
STRUCTURE DIMENSIONS						
STRUCTURE UPSTREAM FACE TOP EL		2321.0	ft			
STRUCTURE CHANNEL EL		2317.0	ft			
STRUCTURE UPSTREAM FACE HEIGHT		4.0	ft			
STRUCTURE UPSTREAM WIDTH		10.0	ft	Distance of Rottwad from Bank (Typical)		
STRUCTURE UPSTREAM FACE AREA		40	sf			
OBSTRUCTED AREA	ALWM =	40	sf			
STRUCTURE LENGTH		15.0	ft			
TOTAL NUMBER OF PILES/POSTS	Npiles =	0.0		No Piles		
PILE/POST BOTTOM EL		2317.0	ft	Set Equal to cell E41 - Bottom El. of Structure		
PILE/POST LENGTH (INCL ROOTWAD IF APPLIC.)		0.0	ft	Set in order to keep Cell E50 at Zero		
PRE-SCOUR EMBEDDED LENGTH OF PILES	Tlpile =	0.0	ft	total embedded length, disregarding scour		
PILE/POST TOP EL		2317.0	ft			
STRUCTURAL FILL TOP EL		2320.5	ft	Approximately 3 Feet of Ballast		
STRUCTURAL FILL DEPTH		3.5	ft			

BOUYANCY, LIFT & PILE FRICTION - LARGE WOOD STABILITY CALCULATIONS				Version 3.0 - updated 2-17
PROJECT	Klamath Dam Removal			DATE
STRUCTURE	Multiple Log (Ground Placed)	ANALYSTS	DJB	2/3/2020
RIVER & REACH	Jenny Creek (Tributary)		-	-
		REVIEWER	Yurok Tribe	2/3/2020

LARGE WOOD MATERIAL FORCE			
STRUCTURAL MEMBERS			
UNIT WEIGHT OF WATER	$\gamma_w =$	62.4	lbs/ft^3
GRAVITATIONAL ACCELERATION	g =	32.2	ft/s2
SPECIES OF LARGE WOOD	DOUGLAS FIR	- COASTAL	
DRY UNIT WEIGHT OF WOOD	$\gamma_{wood} =$	34.0	lbs/ft^3
ROOTWAD POROSITY	$\eta_p =$	20%	
ROOTWAD DIAMETER	$D_{RW} =$	3.5	ft
ROOTWAD LENGTH	$L_{RW} =$	3	ft
LOG TAPER (Inches per 10 ft)		1	in
PILES / ROOTWAD POSTS			
SPECIES OF LARGE WOOD	DOUGLAS FIR	- COASTAL	
DRY UNIT WEIGHT OF WOOD	$\gamma_{wood} =$	34.0	lbs/ft^3
ROOTWAD POROSITY	$\eta_p =$	20%	
ROOTWAD DIAMETER	$D_{RWp} =$	3.5	ft
ROOTWAD LENGTH	$L_{RW} =$	3	ft
LOG TAPER (Inches per 10 ft)		1	in

Log Type	No. Logs	Piece Length	Diam (DBH)	Diam (avg)	Rootwad	Log Length	Vol log (ea)	Rootwad vol	Log & Rootwad vol	Total Log Vol	Total Weight	submerged	VLWMs submerged volume of LWM	VLWMd Dry volume of LWM
	ea	ft	in	in	-	ft	cf	cf	cf	cf	lbs	%	cf	cf
NO PILES	0	0	0	0.0	NO	0	0.0	0.0	0.0	0	0	0%	0	0
Layer-1: Rootwad Log - Ground Placed	1	35	20	18.8	YES	32	61.3	12.9	74	74	2,523	100%	74	0
Layer-2: Rootwad Log - Ground Placed	1	35	20	18.8	YES	32	61.3	12.9	74	74	2,523	100%	74	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	100%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	0%	0	0
				0.0	NO	0	0.0	0.0	0	0	0	0%	0	0
TOTAL	2									**148**	**5,046**		**148**	**0**

LARGE WOOD MATERIAL FORCE SUBMERGED	**FLWMs**	**(4,219)**	**lbs**
LARGE WOOD MATERIAL FORCE DRY	**FLWMd**	**-**	**lbs**
LIFT FORCE			
LIFT COEFFICIENT	CL =	0.2	Range 0.1 - 0.2
AREA OF LARGE WOODY MATERIAL PERPENDICULAR TO FLOW	ALWM =	40	ft^2
UPSTREAM CHANNEL VELOCITY AT DESIGN EVENT	Uu =	9.1	ft/sec
LIFT FORCE	**FL =**	**(642)**	**lbs**

BALLAST - LARGE WOOD STABILITY CALCULATIONS							Version 3.0 - updated 2-17	
PROJECT	Klamath Dam Removal							DATE
STRUCTURE	Multiple Log (Ground Placed)					ANALYSTS	DJB	2/3/2020
RIVER & REACH	Jenny Creek (Tributary)						-	-
						REVIEWER	Yurok Tribe	2/3/2020
<u>SOIL BACKFILL</u>								
TYPE					MEDIUM GRAVEL			
DRY UNIT WEIGHT OF SOILS				γ_{soil} =	120	lbs/cf		
SOIL SPECIFIC GRAVITY				SG =	2.65			
HEIGHT OF SUBMERGED SOIL ABOVE LOG				hsoilsub =	3	ft		
HEIGHT OF DRY SOIL ABOVE LOG				hsoildry =	0	ft		
VOID RATIO OF SOILS				e=	0.38			
SATURATED UNIT WEIGHT OF SOILS				γ_{sat} =	137	lbs/cf		
EFFECTIVE BOUYANT UNIT WEIGHT OF SOILS				γ'_{soil} =	75	lbs/cf		
BURIED LOG SCHEDULE								
Log Type	No. Logs	Piece Length	Diam (avg)	Total Area	Embedded	Embedded Area	Embedded Area normal to flow	Embedded Normal Area
	ea	ft	in	sf	%	sf	%	sf
NO PILES	0.01	0	0	0	0%	0	0%	0
Layer-1: Rootwad Log - Ground Placed	1	35	18.75	55	10%	5	90%	5
Layer-2: Rootwad Log - Ground Placed	1	35	18.75	55	50%	27	50%	14
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
0	0	0	0	0		0		0
AREA OF EMBEDDED LWM					**ALWMe =**	**33**	**ALWMen =**	**19**
VOLUME OF SUBMERGED BOULDERS ABOVE LOG					Vbouldersub =	-	cf	
VOLUME OF DRY BOULDERS ABOVE LOG					Vboulderdry =	-	cf	
VOLUME OF SUBMERGED SOIL ABOVE LOG					Vsoilsub =	98	cf	Vbouldersub d
VOLUME OF DRY SOIL ABOVE LOG					Vsoildry =	-	cf	Vboulderdry d
SOIL BACKFILL FORCE TOTAL					**Fsoil =**	**7,355**	**lbs**	
<u>TOTAL BOUYANT FORCE</u>						Bouyant Forces	Ballast Forces	
FORCE OF LARGE WOODY MATERIAL SUBMERGED					FLWMs =	(4,219)		lbs
FORCE OF LARGE WOODY MATERIAL DRY					FLWMd =		-	lbs
FORCE OF LIFT					FL =	(642)		lbs
FORCE OF BOULDERS					Fboulder =		-	lbs
FORCE OF DOLOSSE					Fdolo =		-	lbs
FORCE OF SOIL					Fsoil =		7,355	lbs
FORCE OF PILES SKIN FRICTION					Fpiles-v =		-	lbs
FORCE OF ROOTWAD POST SOIL COLUMN SKIN FRICTION					Fpost-v=		-	lbs
FORCE OF ROOT WAD POST PULLOUT					Fpost-p =		-	lbs
						(4,861)	7,355	
					Sum of Bouyant Forces	(4,861)	lbs	
					Sum of Ballast Forces	7,355	lbs	
TOTAL BOUYANT FORCE					**Fb =**	**2,494**	**lbs**	
BOUYANCY FACTOR OF SAFETY					**FOSb =**	**1.51**		

DRAG, HYDROSTATIC AND IMPACT - LARGE WOOD STABILITY CALCULATIONS								Version 3.0 - updated 2-17			
PROJECT	Klamath Dam Removal							DATE			
STRUCTURE	Multiple Log (Ground Placed)					ANALYSTS	DJB	2/3/2020			
RIVER & REACH	Jenny Creek (Tributary)						-	-			
						REVIEWER	Yurok Tribe	2/3/2020			
DRAG FORCE											
FLOW AREA BLOCKED BY STRUCTURE				ALWM =	40	sf					
AREA OF CONTRACTED FLOW				Ac =	466	sf					
CONTRACTED FLOW VELOCITY				Vc (Uc) =	9.1	fps					
DEPTH IN CONTRACTED AREA (AVG)				Yc =	4.9	ft					
OBSTRUCTION RATIO				B =	0.08						
CONTRACTED FLOW FROUDE NUMBER				Frc =	0.72						
DRAG COEFFICIENT				Cd =	1.15						
DRAG FORCE				**Fd =**	**3,695**	**lbs**					
HYDROSTATIC FORCES											
UPSTREAM HYDROSTATIC FORCE				**Fhu =**	**4,283**	**lbs**					
DOWNSTREAM HYDROSTATIC FORCE				**Fhd =**	**(4,283)**	**lbs**					
NET HYDROSTATIC FORCE				**Fhn =**	**-**	**lbs**					
IMPACT FORCE											
PUBLIC SAFETY RISK					Low						
PROPERTY DAMAGE RISK					Low						
COEFFICIENT OF IMPORTANCE				Ci =	0.5						
WATER VELOCITY IN CHANNEL				Vchannel =	9.1	fps					
TIME FROM INITIAL TO ZERO VELOCITY				Δt =	0.03	sec					
COEFFICIENT OF ORIENTATION				Co =	0.08						
RESPONSE RATIO FOR IMPULSIVE LOADS				Rmax =	0.8						
UPSTREAM FLOW DEPTH					4.9	ft					
UPSTREAM CHANNEL WIDTH					95	ft					
COEFFICIENT OF DEPTH				Cd =	0.975						
COEFFICIENT OF BLOCKAGE				Cb =	1						
WEIGHT OF DEBRIS											
SPECIES OF LARGE WOOD				DOUGLAS FIR - COASTAL							
WET UNIT WEIGHT OF WOOD				γ_{wood} =	38.0	lbs/ft^3					
ROOTWAD POROSITY				η_p =	20%						
ROOTWAD DIAMETER				D_{RW} =	3.5	ft					
ROOTWAD LENGTH				L_{RW} =	2	ft					
LOG TAPER (Inches per 10 ft)					1	in					
Log Type	No. Logs	Piece Length	Diam (DBH)	Diam (avg)	Rootwad	Log Length	Vol log (ea)	Rootwad vol	Log & Rootwad vol	Total Log Vol	Total Weight
	ea	ft	in	in	-	ft	cf	cf	cf	cf	lbs
DEBRIS	2	20	20	19.5	Y	18	37.3	8.6	45.9	92	3,491
		WEIGHT OF DEBRIS		wdebris =	3,491	lbs					
IMPACT FORCE				**Fi =**	**1,611**	**lbs**					

FRICTION, PASSIVE & LATERAL RESISTANCE - LARGE WOOD STABILITY CALCULATIONS					Version 3.0 - updated 2-17	
PROJECT	Klamath Dam Removal				DATE	
STRUCTURE	Multiple Log (Ground Placed)		ANALYSTS	DJB	2/3/2020	
RIVER & REACH	Jenny Creek (Tributary)			-	-	
			REVIEWER	Yurok Tribe	2/3/2020	
FRICTION FORCE						
INTERNAL ANGLE OF FRICTION OF SOILS		ϕ =	32	degrees		
INTERNAL ANGLE OF FRICTION OF SOILS		ϕ =	0.56	radians		
COEFFICIENT OF FRICTION OF BED		μbed =	0.62			
TOTAL BOUYANT AND BALLAST FORCES			Bouyant Forces	Ballast Forces		
FORCE OF LARGE WOODY MATERIAL SUBMERGED		FLWMs =	(4,219)	-	lbs	
FORCE OF LARGE WOODY MATERIAL DRY		FLWMd =	-	-	lbs	
FORCE OF LIFT		FL =	(642)	-	lbs	
FORCE OF BOULDERS		Fboulder =	-	-	lbs	
FORCE OF DOLOSSE		Fdolo =	-	-	lbs	
FORCE OF SOIL		Fsoil =	-	7,355	lbs	
FORCE OF PILES SKIN FRICTION		Fpiles-v =	-	-	lbs	
FORCE OF ROOTWAD POST SOIL COLUMN SKIN FRICTION		Fpost-v=	-	-	lbs	
FORCE OF ROOT WAD POST PULLOUT		Fpost-p =	-	-	lbs	
			(4,861)	7,355		
	Sum of Bouyant Forces		(4,861)	lbs		
	Sum of Ballast Forces		7,355	lbs		
TOTAL BOUYANT FORCE		**Fb =**	**2,494**	**lbs**		
FORCE DUE TO FRICTIONAL RESISTANCE		**Ff =**	**(1,558)**	**lbs**		
PASSIVE FORCES						
DRY UNIT WEIGHT OF SOILS		γ_{soil} =	120	lbs/ft^3		
SATURATED UNIT WEIGHT OF SOILS		γ_{sat} =	137	lbs/ft^3		
UNIT WEIGHT OF WATER		γ_{w} =	62.4	lbs/ft^3		
HEIGHT OF SUBMERGED SOIL ABOVE LOG		Dsubi =	3	ft		
HEIGHT OF DRY SOIL ABOVE LOG		Ddryi =	0	ft		
AREA OF EMBEDDED LWM NORMAL TO FLOW		ALWMeN =	19	ft^2		
UNIT RESISTANCE AGAINST SLIDING		σvi =	224	lb/ft^2		
COEFFICIENT OF PASSIVE EARTH PRESSURE		Kp =	3.25			
PASSIVE FORCE		**Fpassive =**	**(6,782)**	**lbs**		
LATERAL RESISTANCE FROM PILES						
NUMBER OF PILES		Npiles =	0.01			
EMBEDDED LENGTH OF PILES BELOW SCOUR DEPTH		Lpile =	0	ft		
EFFECTIVE UNIT WEIGHT OF SOIL		γ_{e} =	57.6	lbs/ft^3		
PILE DIAMETER (AVERAGE)		dpile =	0.0	ft		
HEIGHT ABOVE SCOUR DEPTH LOAD IS APPLIED		hload =	2.5	ft		
LATERAL RESISTANCE FROM PILES		**Fpiles-h =**	**-**	**lbs**		
TOTAL SLIDING FORCE						
DRAG FORCE		**Fd =**	3,695	lbs		
UPSTREAM HYDROSTATIC FORCE		**Fhu =**	4,283	lbs		
IMPACT FORCE		**Fi =**	1,611	lbs		
LATERAL RESISTANCE FROM PILES		**Fpiles-h =**	-	lbs		
DOWNSTREAM HYDROSTATIC FORCE		**Fhd =**	(4,283)	lbs		
FORCE DUE TO FRICTIONAL RESISTANCE		**Ff =**	(1,558)	lbs		
PASSIVE FORCE		**Fpassive =**	(6,782)	lbs		
SUM OF DRIVING MOMENTS			9,589	lbs		
SUM OF RESISTING MOMENTS			(12,623)	lbs		
FACTOR OF SAFETY FOR SLIDING		**FOSsliding =**	1.32			

ROTATION, OVERTURNING - LARGE WOOD STABILITY CALCULATIONS		Version 3.0 - updated 2-17		
PROJECT	Klamath Dam Removal		DATE	
STRUCTURE	Multiple Log (Ground Placed)	ANALYSTS	DJB	2/3/2020
RIVER & REACH	Jenny Creek (Tributary)		-	
		REVIEWER	Yurok Tribe	2/3/2020
RESISTANCE TO ROTATION				
ROTATION SCREENING: IS ROTATION FORCE APPROPRIATE FOR THIS STRUCTURE?			YES	
POINT OF ROTATION LOCATION			10	
EMBEDDED LENGTH OF WOOD STRUCTURE		Lebp =	10	ft
NUMBER OF PILES		Npiles =	0.0	
LENGTH OF STRUCTURE FROM TIP TO ROTATION POINT		Lsp =	-5.1	ft
DISTANCE FROM PILE i TO POINT OF ROTATION		Lphi =	10	ft
IMPACT FORCE		Fi =	1,611	lbs
DRAG FORCE		Fd =	3,695	lbs
UPSTREAM HYDROSTATIC FORCE		Fhu =	4,283	lbs
DOWNSTREAM HYDROSTATIC FORCE		Fhd =	(4,283)	lbs
PASSIVE FORCE		Fpassive =	(6,782)	lbs
LATERAL RESISTANCE FROM PILES		Fpiles-h =	-	lbs
FORCE DUE TO FRICTIONAL RESISTANCE		Ff =	(1,558)	lbs
SUM OF DRIVING MOMENTS		MDrotation =	23,492	ft-lbs
SUM OF RESISTING MOMENTS		MRrotation =	40,430	ft-lbs
FACTOR OF SAFETY FOR ROTATION		**FOSrotation =**	**1.72**	
RESISTANCE TO OVERTURNING				
DEPTH FROM CHANNEL BOTTOM TO POINT OF ROTATION		dubury =	2.45	ft
LENGTH OF STRUCTURE		Ls =	15	ft
DISTANCE FROM PILE I TO POINT OF ROTATION		Lpvi =	10	ft
WATER DEPTH ON UPSTREAM SIDE OF STRUCTURE		Yu =	4.9	ft
WATER DEPTH ON DOWNSTREAM SIDE OF STRUCTURE		Yd =	4.9	ft
LIFT FORCE		FL =	(642)	lbs
TOTAL BOUYANT FORCE		Fb =	2,494	lbs
SUM OF DRIVING MOMENTS		MDoverturn =	57,060	ft-lbs
SUM OF RESISTING MOMENTS		MRoverturn =	42,423	ft-lbs
FACTOR OF SAFETY FOR OVERTURNING		**FOSoverturn =**	**0.74**	

INDEX	FACTOR OF SAFETY - Tables 4 & 6, Large Woody Material - Risk Based Design Guidelines, BOR, Sep 2014							
	Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	FOS sliding	FOS bouyancy	FOS rotation	FOS overturning	COEFFICIENT OF IMPORTANCE
HighHigh	High	High	100-year	1.75	2	1.75	1.75	1
HighModerate	High	Moderate	50-year	1.5	1.75	1.5	1.5	0.9
HighLow	High	Low	25-year	1.5	1.75	1.5	1.5	0.8
LowHigh	Low	High	100-year	1.75	2	1.75	1.75	0.7
LowModerate	Low	Moderate	25-year	1.5	1.75	1.5	1.5	0.6
LowLow	Low	Low	10-year	1.25	1.5	1.25	1.25	0.5

FLOW RETURN INTERVAL	VALUE
10-year	10
25-year	25
50-year	50
100-year	100

		VALUE
MINIMUM	10-year	10
PROPOSED	10-year	10

COEFFICIENT OF DRAG - Eqns 22 - 26, Large Woody Material - Risk Based Design Guidelines, BOR, Sep 2014

		Test Column	Test Column	INDEX	Cd	OBSTRUCTION RATIO B		CONTRACTED FROUDE NUMBER Frc	
		B	Frc			lower limit	upper limit	lower limit	upper limit
Eqn 22	DRAG COEFFICIENT Cd	TRUE	FALSE	TRUEFALSE	1.80	0	0.36	0	0.4
Eqn 23	DRAG COEFFICIENT Cd	TRUE	TRUE	TRUETRUE	1.15	0	0.36	0.4	0.8
Eqn 24	DRAG COEFFICIENT Cd	TRUE	FALSE	TRUEFALSE	1.00	0	0.36	0.8	4
Eqn 25	DRAG COEFFICIENT Cd	FALSE	TRUE	FALSETRUE	2.82	0.36	0.77	0	1
Eqn 26	DRAG COEFFICIENT Cd	FALSE	TRUE	FALSETRUE	1.29	0.77	1	0	1
			GOAL	TRUETRUE	1.15				

COEFFICIENT OF DEPTH - Figure 11, Large Woody Material - Risk Based Design Guidelines, BOR, Sep 2014

		INDEX	Cd	WATER DEPTH (FT) lower limit	upper limit
COEFFICIENT OF DEPTH Cd		FALSE	0.00	0	1
COEFFICIENT OF DEPTH Cd		TRUE	0.98	1	5
COEFFICIENT OF DEPTH Cd		FALSE	1.00	5	
	GOAL	TRUE			

COEFFICIENT OF BLOCKAGE - Figure 12, Large Woody Material - Risk Based Design Guidelines, BOR, Sep 2014

		INDEX	Cd	WATER DEPTH (FT) lower limit	upper limit
COEFFICIENT OF BLOCKAGE Cd		FALSE	0.00	0	1
COEFFICIENT OF BLOCKAGE Cd		FALSE	FALSE	1	30
COEFFICIENT OF BLOCKAGE Cd		TRUE	1.00	30	500
	GOAL	TRUE			

PILE INSTALLATION TECHNIQUE TO MODIFY COEFFICIENT OF LATERAL EARTH PRESSURE (Ks

TECHNIQUE	Ks Reduction
DRIVEN	1
VIBRATED	1
DRILLED	0.5
EXCAVATED	0.25

ROTATION FORCE SCREENING

YES	1.72
NO	N/A

PILE MATERIAL TYPE & BENDING

TYPE	BENDING (Fb) - PSI	DRY DENSITY lb/cf	
DOUGLAS FIR - COASTAL	2450	34	
PINE -LODGEPOLE	1700	29	
STEEL H-BEAM	5000		NEED TO CONFIRM THIS!

ROOTWAD POST PULLOUT RESISTANCE

YES	0.01
NO	0

BOULDER BALLAST

ON LOGS	1
ROCK COLLARS	0

BOUYANCY - ROOTWAD YES/NO SELECTION

YES
NO

PILE LOCATION

ROW	POSITION
FRONT	RIGHT EDGE
2ND	2ND FROM RIGHT EDGE
3RD	MIDDLE
4TH	2ND FROM LEFT EDGE
BACK	LEFT EDGE

	DENSITY	
SPECIES	Wet unit weight (lbs/ft³)	dry unit weight (12% moisture) (lbs/ft³)
DOUGLAS FIR - COASTAL	38	34
DOUGLAS FIR - ROCKY MTN	35	30
PINE - LODGPOLE	39	29
PINE - PONDEROSA	45	28
SPRUCE - SITKA	33	28
ALDER - RED	46	28
ASPEN - QUAKING	43	26
COTTONWOOD	58	28
CEDAR - ALASKA	36	31
CEDAR - WESTERN RED	27	23
FIR - GRAND	45	28
FIR - NOBLE	30	26
FIR - PACIFIC SILVER	36	27
HEMLOCK - EASTERN	50	28
HEMLOCK - WESTERN	41	29
LARCH - WESTERN	48	36
PINE - EASTERN WHITE	36	25
REDWOOD	50	28

SUBSTRATE AND SOIL PROPERTIES - Table 5, Large Woody Material - Risk Based Design Guidelines, BOR, Sep 2014

GRAIN SIZE (MM)		SEDIMENT (	AVERAGE D	INTERNAL FRICTION ANGLE		
MIN	MAX		LB/CF	DEGREES	RADIANS	tan 2/3 theta rad
BEDROCK		BEDROCK	165	-		
256	2048	BOULDER	146	42	0.733	0.5317094
128	256	LARGE COB	142	42	0.733	0.5317094
64	128	SMALL COB	137	41	0.716	0.5168755
32	64	VERY COAR	131	40	0.698	0.5022189
16	32	COARSE GR	126	38	0.663	0.4734098
8	16	MEDIUM GR	120	36	0.628	0.4452287
4	8	FINE GRAVI	115	35	0.611	0.4313579
2	4	VERY FINE	109	33	0.576	0.4040262
1	2	VERY COAR	103	32	0.559	0.3905541
0.5	1	COARSE SA	98	31	0.541	0.3772038
0.25	0.5	MEDIUM SA	94	30	0.524	0.3639702
0.125	0.25	FINE SAND	93	30	0.524	0.3639702
0.063	0.125	VERY FINE	92	30	0.524	0.3639702
0.004	0.063	SILT	82	30	0.524	0.3639702
0.0001	0.004	CLAY	78	25	0.436	0.2993803

Source: NAVFAC DM 7.2, Foundation and Earth Structures, U.S. Department of the Navy, 1984. http://www.finesoftware.eu/help/geo5/en/coefficient-of-lateral-earth-pressure-k-01/

Coefficient of lateral earth pressure K

The soil around a driven pile is compressed during construction and the lateral earth pressure of this soil acting on the pile skin is greater than the earth pressure at rest (given by coefficient K_0) and smaller than the maximum earth pressure (passive earth pressure given by coefficient K_p):

$$K_0 < K < K_p$$

Reference values of the coefficient of lateral earth pressure K are listed later in the table. The coefficient of lateral earth pressure K is approximated as follows:

$$K = \frac{K_a + K_p + K_0}{3}$$

where: K_0 - coefficient of earth pressure at rest

$$K_0 = 1 - sin\varphi$$

φ - angle of soil shear resistance

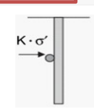
K_p - coefficient of passive earth pressure

$$K_p = tg^2\left(45^\circ + \frac{\varphi}{2}\right)$$

tg = tanger

K_a - coeffiecient of active earth pressure

$$K_a = tg^2\left(45^\circ - \frac{\varphi}{2}\right)$$



Pressure on the pile

Reference values of the lateral earth pressure coefficient K

Type of pile	K for compression piles	K for tensile - uplifted piles
Driven H-piles	0.5 - 1.0	0.3 - 0.5
Driven displacement piles (round and square)	1.0 - 1.5	0.6 - 1.0
Driven displacement tapered piles	1.5 - 2.0	1.0 - 1.3
Driven jetted piles	0.4 - 0.9	0.3 - 0.6
Bored piles (less than 70cm)	0.7	0.4

ϕ =	INTERNAL ANGLE OF FRICTION OF SOILS =	32	degrees
ϕ =	INTERNAL ANGLE OF FRICTION OF SOILS =	0.56	radians
	$(45-(\phi/2))$ =	29	degrees
	$(45-(\phi/2))$ =	0.5	radians
	$(45+(\phi/2))$ =	61	degrees
	$(45+(\phi/2))$ =	1.1	radians
K_o =	Coefficient of Earth Pressure at Rest =	0.5	
K_a =	Coefficient of Rankine's Active Earth Pressure =	0.3	
K_p =	Coefficient of Rankine's Passive Earth Pressure =	3.3	
$K = K_s$ =	Coefficient of Lateral Earth Pressure =	1.3	

Note: Higher K_s = higher lateral earth pressure. Assumption of K_s = 1.25 is conservative.

Table 3-1
Allowable Stress Values for Treated Round Timber Piles Graded in Accordance with ASTM D25

Species	Axial Compression (F_c) (psi)	Bending (F_b) (psi)	Shear Perpendicular to the Grain (F_v) (psi)	Compression Perpendicular to the Grain ($F_{c\perp}$) (psi)	Modulus of Elasticity (E) (psi)
Southern Pine[1]	1200	2400	110	250	1,500,000
Douglas Fir[2]	1250	2450	115	230	1,500,000
Lodgepole Pine	1150	1700	80	270	1,000,000
Red Oak[3]	1100	2450	135	350	1,250,000
Red Pine[4]	900	1900	85	155	1,280,000

1. Southern Pine design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.
2. Pacific Coast Douglas Fir design values apply to this species as defined in ASTM D 1760
3. Red Oak design values apply to Northern and Southern Red Oak
4. Red Pine design values apply to Red Pine grown in the United States

Additional Properties for Soil Ballast (DAS)

	Compaction	Average Dr	Low Dr	High Dr
1	Minimum	0	0	0
2	Very Loose	10	0	20
3	Loose	30	20	40
4	Medium	50	40	60
5	Dense	70	60	80
6	Very Dense	90	80	100
7	Maximum	100	100	100