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Managing Water in the West

Appraisal Report

Long Lake Valley Offstream Storage

Klamath Project, Oregon and California
Upper Klamath Basin Offstream Storage (UKBOS) Study

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Regional Office
Klamath Basin Area Office
Klamath Falls, Oregon

February 2010

Mission Statements

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

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

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Executive Summary

Demand for water has been steadily growing in the Klamath Basin. As a result, conflicts between competing interests over water in the basin continue to arise. Increasing the ability to store water for beneficial use is one of the many potential solutions to this increased demand for water, and so the Klamath Basin Water Supply Enhancement Act (Enhancement Act) was enacted in 2000 to give the Bureau of Reclamation (Reclamation) the authority to investigate different storage options. Pursuant to Section 3(a) of the Enhancement Act, Reclamation initiated the Upper Klamath Basin Offstream Storage (UKBOS) feasibility studies. The purpose of these studies is to offer potential offstream storage options for water in the Klamath Basin.

Reclamation has completed reconnaissance studies as the first phase of UKBOS feasibility studies. The reconnaissance phase resulted in an early version of the Initial Alternatives[1] Investigation Report (IAIR), which presented, described, and discussed a number of alternatives, including options developed in the late 1990s with stakeholder involvement (the Klamath Basin Water Supply Initiative [KBWSI]). The early version of the IAIR recommended that the planning process should move forward to the appraisal phase to further investigate the Long Lake Valley (LLV) storage reservoir alternative and its variations. A reservoir in LLV, located just west of Klamath Falls, Oregon, could store water that nearby Upper Klamath Lake would otherwise spill during certain times of the year.

For many years, the local stakeholder community has believed that a surface water storage reservoir at LLV would be the best solution to many of the current water issues in the Upper Klamath Basin. Due to the unique political and stakeholder support for this alternative, Reclamation believed that the planning studies of LLV alternatives needed to be advanced enough to address several key issues affecting water management within the Upper Klamath Basin known to the water-issue stakeholder community. These issues included, but were not limited to water quality, and compliance with the Endangered Species, Clean Air, and Clean Water Acts.

This appraisal report further identifies available information, clarifies issues, and clearly identifies data gaps with respect to a surface water storage reservoir at LLV. It then compares the implementation of LLV to the No-Action alternative that will be described in the next version of the IAIR. This revised IAIR will recommend whether studies should continue on alternatives other than LLV.

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[1] The term “alternative” is used in this report to express the option being evaluated in this appraisal report. This term is not used in the same context as it is used in the National Environmental Policy Act (NEPA) and should not be construed as so.

This appraisal study has found that a reservoir at LLV capable of storing 350,000 acre-feet of water may reduce the number of years in which there would be a shortage to the Klamath Project or other environmental resources because there is opportunity for high water yield as compared to the IAIR-defined No-Action alternative. As a result of the studies discussed in this report, the surface water reservoir located in LLV, has been identified as a technically viable alternative for meeting the purpose and objectives of the appraisal phase of the UKBOS feasibility study. However, while this project may be technically viable, preliminary benefit/cost ratios do not show a positive result; therefore, Reclamation does not recommend that the LLV alternative move forward to feasibility-level studies at this time.

Introduction

Reclamation has completed some reconnaissance studies as the first phase of Upper Klamath Basin Offstream Storage (UKBOS) planning studies. The reconnaissance phase resulted in an early version of the Initial Alternatives[2] Investigation Report (IAIR), which presented, described, and discussed a number of alternatives, including options developed in the late 1990s with stakeholder involvement (the Klamath Basin Water Supply Initiative [KBWSI]). The early version of the IAIR recommended that the planning process move forward to the appraisal phase to further investigate the Long Lake Valley (LLV) storage reservoir alternative and its variations. A reservoir in LLV, located just west of Klamath Falls, Oregon, would store water that nearby Upper Klamath Lake (UKL) would otherwise spill during certain times of the year, in accordance with preliminary discussions with the Oregon Water Resources Department.

In 2006, the Bureau of Reclamation (Reclamation) initiated the UKBOS feasibility study under the authority of the Klamath Basin Water Supply Enhancement Act of 2000 (P.L. 106-498) (Enhancement Act). This appraisal report is an interim product of the UKBOS feasibility study. It presents the results of preliminary analyses that specifically focus on Long Lake Valley offstream storage options as compared to the No-Action alternative. The No-Action alternative was not described in the early version of the IAIR but will be described in a later version of the IAIR. During the initial phases of the UKBOS feasibility study, team members in Reclamation's Klamath Basin Area Office (KBAO) in Klamath Falls, Oregon, and Technical Service Center (TSC, located in Denver) identified opportunities to increase surface water storage in Long Lake Valley. The team found that the planning objectives and constraints that were produced by the KBWSI public scoping meetings in the 1990s are still viable. These objectives and constraints resulted in a range of options (preliminary alternative plans) to potentially store up to 350,000 acre-feet of water in Long Lake Valley. The LLV alternative is technically viable, albeit poorly fiscally viable, and is the basis for this report. The additional water storage available in the potential Long Lake Valley Reservoir could reduce the number of years in which there would be a water shortage to the Klamath Project or other ecological resources.

The alternatives presented and discussed in the early IAIR version did not include a No-Action alternative, but the alternatives were developed as potential solutions to the purpose and objective developed for the UKBOS studies. In the later version of the IAIR, the No-Action alternative will be defined as the March 2008

[2] The term "alternative" is used in this report to express the option being evaluated in this appraisal report. This term is not used in the same context as it is used in the National Environmental Policy Act (NEPA) and should not be construed as so.

Proposed Action for Klamath Project operations included in Reclamation's Biological Assessment, occurring at the point in time (roughly the year 2016) when the Upper Klamath Basin as a system includes the breaching of the existing boundary levees of Agency Lake Ranch.

The purpose and objective of the UKBOS feasibility study, through the authority and direction of the Enhancement Act, are to investigate the potential for increased water supply to help meet the growing and competing water demands in the Klamath Basin, and to reduce future conflicts over water between the Upper and Lower Klamath Basins. The study is under way to determine if there is a Federal interest in the proposed actions included in sections 2 and 3 of the Enhancement Act. Those proposed actions would improve water supply and reliability to upstream and downstream water uses (possibly in furtherance of Reclamation's tribal trust responsibilities), provide fish and wildlife benefits, and provide water for agriculture in the basin for Reclamation's Klamath Project.

The purpose and scope of this appraisal report are to document the results of appraisal-level studies (e.g., planning, engineering, economic, and environmental) that address the potential options for, and effects of, surface water storage of surplus flows in Long Lake Valley, based on review of available information. The report also addresses the type and extent of Federal and/or Reclamation interest in a potential water storage conceptual plan in Long Lake Valley, identifies unresolved issues and data gaps, and presents findings, conclusions, and recommendations. In particular, this document addresses:

- Problems and needs regarding water storage in Long Lake Valley
- Definition of the study area and description of existing conditions
- Federal/Reclamation planning process
- Development of planning objectives and constraints
- Examination of measures considered to address objectives and constraints
- Formulation of initial alternatives
- Summary of potential effects of alternatives compared to No Action
- Summary and comparison of potential effects of alternatives to each other
- Rationale for alternatives to be carried forward, or not, for further analyses
- Unresolved issues
- Findings and conclusions

- Recommendations
- Next steps

At the appraisal level of investigation, Long Lake Valley Reservoir was investigated, as presented in this report, to determine if it is a viable alternative that meets the purpose and objective of the UKBOS study without any unmitigatable impacts to the Endangererd Species, Clean Water, and Clean Air Acts.

Early in the UKBOS planning process, it was held that potential conceptual plan features would comprise a very large portion of any of the scoped KBWSI and that further costs associated with mitigation features and other issues costs would be compared at a later date. Mitigation features involve wetlands, land acquisition, reservoir lining, energy, water quality, fish and wildlife species of concern and their habitat protection, easements, rights-of-way, relocations, and other social impacts. Based on this information, it was then held that the most cost-effective studies would be those that determined benefit-cost ratios (BCR) of conceptual plan features first. If the conceptual plan features BCR studies showed positive results, then a more thorough determination of the costs of mitigation and other issues would be undertaken as adding more costs would only serve to make a BCR worse.

Further justification for performing appraisal-level studies for an offstream surface water storage reservoir and its variations at LLV comes from the water stakeholder community. This comunity has, for many years, held that a surface water storage reservoir at LLV would be the best solution to many of the water issues in the Upper Klamath Basin. It was determined that studies of LLV alternatives must be advanced enough to address several key issues. These are issues affecting water management within the Upper Klamath Basin known to the water-issue stakeholder community within the basin such as water quality, and Endangered Species, Clean Air, and Clean Water Act compliance.

KBAO led this appraisal study in coordination with the TSC and the Mid-Pacific Region Office, located in Sacramento, California. Additionally, the KBAO coordinated with other public agencies, private consulting contractors, and other entities.

Study Authority

The Klamath Basin Water Supply Enhancement Act of 2000, P.L. 106-498 (Enhancement Act), authorized the UKBOS studies, specifically Sections 2 and 3(a):

> SEC. 2. AUTHORIZATION TO CONDUCT FEASIBILITY STUDIES.
> In order to help meet the growing water needs in the Klamath Basin, to improve water quality, to facilitate the efforts of the State of Oregon to resolve water rights claims in the Upper Klamath Basin including facilitation of Klamath tribal water rights claims, and to reduce conflicts over water between the Upper and Lower Klamath Basins, the Secretary of the Interior (hereafter referred to as the "Secretary") is authorized and directed, in consultation with affected State, local and tribal interests, stakeholder groups and the interested public, to engage in feasibility studies of the following proposals related to the Upper Klamath Basin and the Klamath Project, a Federal reclamation project in Oregon and California:
>
> (1) Increasing the storage capacity, and/or the yield of the Klamath Project facilities while improving water quality, consistent with the protection offish and wildlife.
>
> (2) The potential for development of additional Klamath Basin groundwater supplies to improve water quantity and quality, including the effect of such groundwater development on nonproject lands, groundwater and surface water supplies, and fish and wildlife.
>
> (3) The potential for further innovations in the use of existing water resources, or market-based approaches, in order to meet growing water needs consistent with State water law.
>
> SEC. 3. ADDITIONAL STUDIES.
>
> (a) NONPROJECT LANDS.—The Secretary may enter into an agreement with the Oregon Department of Water Resources to fund studies relating to the water supply needs of nonproject lands in the Upper Klamath Basin.
>
> (b) SURVEYS.—To further the purposes of this Act, the Secretary is authorized to compile information on native fish species in the Upper Klamath Basin, upstream of Upper Klamath Lake. Wherever possible, the Secretary should use data already developed by Federal agencies and other stakeholders in the Basin.
>
> (c) HYDROLOGIC STUDIES.—The Secretary is directed to complete ongoing hydrologic surveys in the Klamath Basin currently being conducted by the United States Geological Survey.
>
> (d) REPORTING REQUIREMENTS.—The Secretary shall submit the findings of the studies conducted under section 2 and section 3(a) of this Act to the Congress within 90 days of each study's completion, together with any recommendations for projects.

Federal/Reclamation Planning Process

While conducting the UKBOS study and associated investigations, Reclamation, to the extent practicable, is following its defined "planning process" consistent with Reclamation planning directives, standards, and policies, and the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G; Water Resources Council, 1983). Reclamation planning directives and standards are described in the *Reclamation Manual*, "Directives and Standards," CMP 05-02. At the same time, Reclamation is attempting to interject enough flexibility in the planning process to accommodate the dynamics of ongoing water discussions pertaining to the Upper Klamath Basin.

Reclamation's planning process contains four phases of study, implemented as successive, increasingly detailed levels: reconnaissance, appraisal (consisting of two phases, preplan formulation and plan formulation), and feasibility. Should an appraisal- or higher-level study show that a UKBOS alternative is not viable for meeting the purpose and objective of the UKBOS study, Reclamation would revisit the reconnaissance-level studies to investigate the feasibility of other alternatives. The process would be reiterated until all viable alternatives had been determined and the rest eliminated through screening.

The planning process for the appraisal-level assessment of potential options for surface storage in Long Lake Valley generally followed the P&G process with limited resources. This process:

- Identified problems, needs, and opportunities
- Specified planning objectives and constraints
- Described existing and likely future conditions in the study area
- Conducted the plan formulation process (including collaboration with stakeholders, agencies, and public involvement) and identified and developed management measures, physical and institutional, to address specified objectives and constraints
- Refined and combined measures into conceptual preliminary alternative plans
- Evaluated alternatives compared to No Action, including identification of potential effects (benefits, costs, environmental impacts, and social impacts)
- Compared alternatives against each other and No Action, including identification of potential effects
- Addressed the results of the comparison of alternatives and identified those that appear ripe for further analysis (if any) in the next phase of the feasibility study and report(s)

- Described the study findings and conclusions to date, including a determination and rationale that further action is in the Federal interest and identification of unresolved issues

- Described the next steps in the feasibility study process

The objective of a feasibility study is to determine the desirability of seeking congressional authorization for implementation of an alternative. Congress requires acquisition of primary data and participation of public agencies and entities and the general public to develop a preferred plan from a range of alternative courses of action to meet recognized needs, problems, and opportunities associated with the planning area of concern.

For an action to be federally implementable, it must be identified as the alternative plan with the greatest net economic benefits consistent with protecting the Nation's environment. The Secretary may grant exceptions consistent with with section 404 of the Clean Water Act, which requires identification of the least environmentally damaging practicable alternative, and with other pertinent Federal laws and policy.

For Long Lake Valley, the planning process involved reconnaissance-level coordination, review, and assessment, which has led to the current appraisal-level studies summarized in this report, which focused on Long Lake Valley storage alternatives and variations. These studies could, in turn, lead to higher-level studies, such as post-appraisal and/or feasibility level investigations and studies. Each of these "phases" has a succeeding level of study being supported by data of increasing accuracy.

Should the appraisal- or higher-level studies show that LLV is not a viable alternative for meeting the needs of water storage in the Upper Klamath Basin, Reclamation would revisit the reconnaissance studies to investigate other alternatives to a greater extent than completed previously. The Enhancement Act, as interpreted through the Regional Solicitor's Office, allows Reclamation this flexibility. This process could be reiterated until all viable alternatives have been identified and the rest eliminated through screening. Only then would a concluding report for all UKBOS studies be developed.

The Enhancement Act allows Reclamation the authority to proceed with the UKBOS study up to and including feasibility-level studies and investigations. Additionally, a waiver of the pertinent Reclamation Directives and Standards (CMP 05-01 Section D.5) has been granted by the Regional Director through the Office of the Solicitor.

In addition, current drafts of the Klamath Basin Restoration Agreement call for Reclamation to continue the search for viable water storage alternatives in the Upper Klamath Basin.

Early in the UKBOS planning process, it was held that potential conceptual plan features would comprise a very large portion of any of the scoped KBWSI and that further costs associated with mitigation features and other issues costs would be compared at a later date. Mitigation features involve wetlands, land acquisition, reservoir lining, energy, water quality, fish and wildlife species of concern and their habitat protection, easements, rights-of-way, relocations, and other social impacts. Based on this information, it was then held that the most cost-effective studies would be those that determined conceptual plan features BCRs first. If the conceptual plan features BCR studies showed positive results, then a more thorough determination of mitigation and other costs would be undertaken to determine the effects of those additional costs on the BCRs.

Reconnaissance Study Phase

The first phase of the planning study involved reconnaissance-level coordination, review, assessment, and compilation of existing information and previous studies in order to assess the need for additional information.

Some minor outstanding study issues and data gaps were investigated during this phase. The resulting early version of the IAIR presented, described, and discussed a number of alternatives, not including a No-Action alternative. The action alternatives, however, were developed as potential solutions to the purpose and objective developed for the UKBOS studies.

In the later version of the IAIR, the No-Action alternative will be defined as the point in time (roughly the year 2016) when the Upper Klamath Basin as a system includes the breaching of the existing boundary levees of Agency Lake Ranch. The No-Action alternative would not provide additional water storage in the Upper Klamath Basin. The later version IAIR will conclude that the No-Action alternative would not be a viable alternative. The earlier IAIR concluded that the planning process should continue to move forward to the next planning phase, the appraisal-level studies, focusing on the Long Lake Valley storage reservoir alternative and its variations.

Appraisal Study Phases

Appraisal studies consist of two phases, preplan formulation and plan formulation. These studies are brief, preliminary investigations to determine the desirability of proceeding to the third phase, a feasibility-level study. Appraisal-level studies have been conducted to develop objectives, preliminary Long Lake Valley storage alternatives, and initial evaluation of potential effects to determine if feasibility-level studies are warranted

Due to the high level of interest in LLV as a potential solution to water storage needs in the Upper Klamath Basin, KBAO staff intend to present to water user and local government officials the results of the appraisal- and any post-appraisal-level studies.

At the appraisal level of investigation, Long Lake Valley Reservoir was investigated, as presented in this report, to determine if it is a viable alternative to meet the purpose and objective of the UKBOS study. LLV was compared to the No-Action alternative, which is defined as the March 2008 Proposed Action for Klamath Project operations included in Reclamation's Biological Assessment.

Feasibility Study Phase

Should appraisal-level studies recommend moving forward, feasibility-level studies would be conducted to refine alternative plans for Long Lake Valley storage. These studies would occur to complete detailed technical analyses to determine potential engineering, environmental, economic, and financial feasibility, and recommend a preferred plan (or No Action) to Congress. The results of the feasibility-level study process would be addressed in a planning/ feasibility report with supporting environmental documentation and a related Record of Decision (ROD) for processing to Congress for action to authorize a project or not. Unless and until Congress authorizes project construction after the feasibility-level study process and ROD, there is no promise or expectation that such a proposed action or project(s) will automatically progress to implementation.

Analysis of the potential impacts resulting from the range of alternatives would begin during this phase based on a predetermined level of the design process. Activities in support of National Environmental Policy Act (NEPA) compliance would also take place in this phase. Such activities would include stakeholder and public involvement through workshops and presentations.

Interim documents may be developed, at the discretion of the responsible office, to highlight important decision points and facilitate team review. The need for interim documents would be determined during scoping and documented.
It is anticipated that a concluding feasibility report would include the proper NEPA compliance document. Other items that would likely need to be addressed at this level are Endangered Species Act compliance, National Historic Preservation Act Section 106 compliance, and other environmental laws, regulations, and compliance needs.

Development of Long Lake Valley Water Storage Alternatives

This section includes discussions of issues and needs, history and background, planning objectives, approach, assumptions and constraints, formulation of measures and preliminary alternative plans, evaluation of potential effects, comparison of plans, determination of feasibility, findings and conclusions, and rationale for further actions.

Introduction

The early version of the IAIR recommended that studies for LLV advance to the appraisal level. This appraisal report clarifies some of the key topics discussed in the early version of the IAIR as they apply to the appraisal-level planning process:

- Definition of the study and study area, including background information
- Outstanding issues and problems addressed
- Development of planning objectives and constraints
- Planning process and study approach
- Summary of potential effects of alternatives compared to No Action
- Summary and comparison of potential effects of alternatives
- Conceptual features
- Estimated costs
- Uncertainties of conceptual plan features, findings, and recommendations
- Summary

Study Area

The UKBOS study area (figure 1) as outlined and discussed in the IAIR is the portion of the Klamath Basin above Keno Reservoir, known as the Upper Klamath Basin, which encompasses approximately 4,250 square miles or 2.7 million acres. This area is part of the East Cascades Ecologic Region that spans the eastern slope of the Cascade mountain range from south central Washington to northern California.

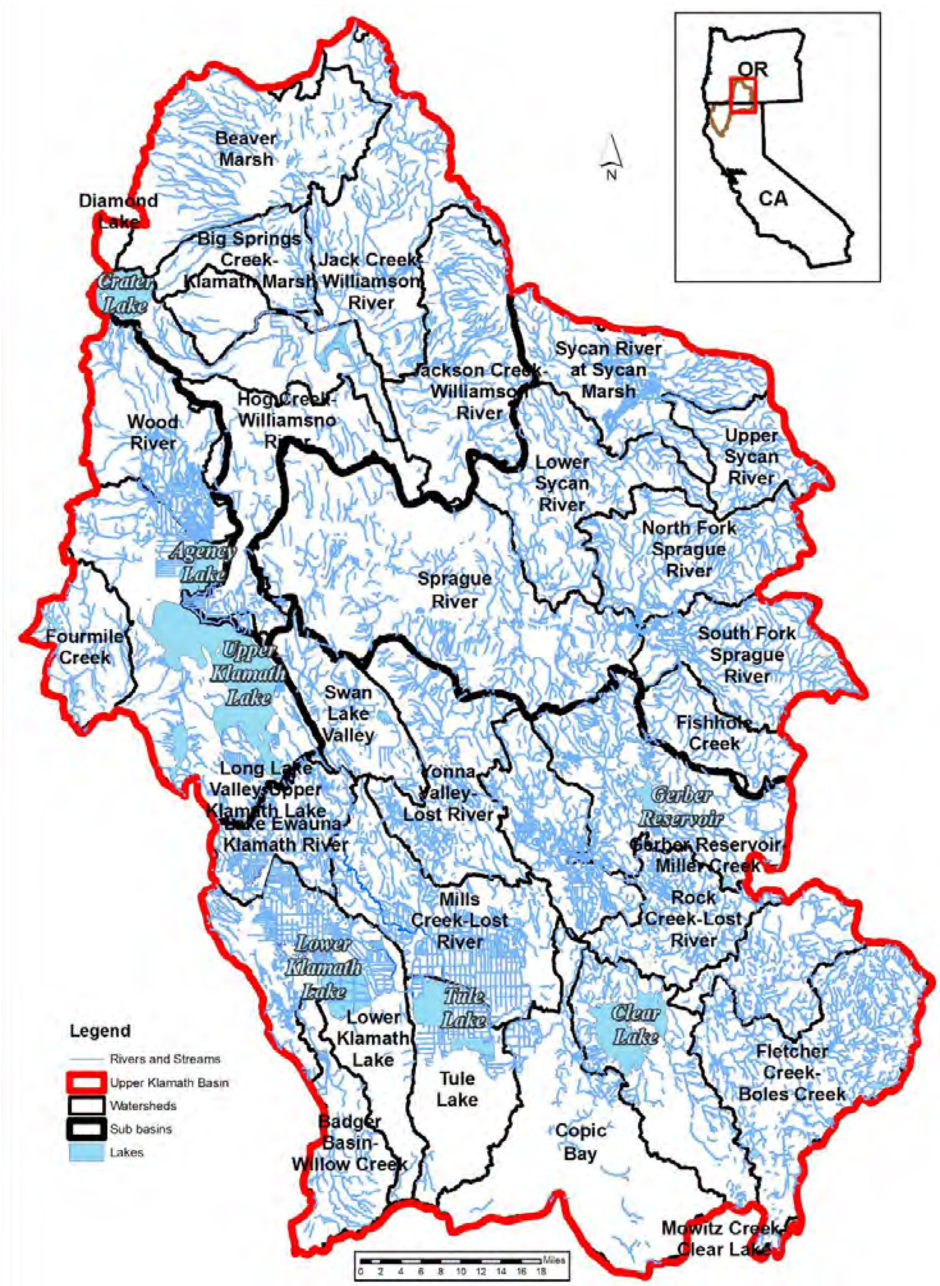

Figure 1.—The UKBOS study area.

Outstanding Issues and Problems, and Purpose and Need for Studies and Investigation

An example of conflict over Klamath Basin water occurred in 2001, when the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) issued multiyear biological opinions concerning the Klamath Project's (Project) operational effects on listed species. The issuance of these biological opinions, along with a drier water year, forced Reclamation to withhold nearly all irrigation water from Project water users and the National Wildlife Refuges in 2001.

The UKBOS study and associated investigations have been undertaken to study options that could meet identified management issues of growing demand and competition for water in the entire Klamath Basin and reduce future conflicts over water between the Upper and Lower Klamath Basins.

Storage of excess winter/spring runoff, whether short term or long term, is a potential solution to water shortages in the Klamath Basin and is the purpose for conducting studies with planning objectives that meet the directives contained in the Enhancement Act. This report documents that the investigations and studies discussed here meet the directives of Section 2 of the Enhancement Act by the studies' efforts to find viable options for additional surface and/or groundwater storage. Carryover storage, storage of water in water years when surplus water supplies occur for use in subsequent years/irrigation seasons when the natural water supplies are less than optimal, could be obtained via many alternatives, including Long Lake Valley. This carryover storage would essentially "create" water supplies for use when no surplus flows or less-than-optimal water supplies are available for use in any given year.

Development of Planning Objectives and Constraints

The purpose of the UKBOS study is to identify preliminary alternatives that provide the ability to create significant storage potential for water and that have met preliminary screening criteria in the Upper Klamath Basin. This final appraisal report is an interim document of the feasibility study process and identifies, discusses, and examines measures to address the need for increased water storage for years when there may be surplus water supplies in the Upper Klamath Basin for use in years when there is less than optimal water supplies. A surface water storage reservoir at LLV and variations had been identified in the early version of the IAIR as the option which passed initial screening criteria and which most met the purpose and need of the UKBOS studies.

The next steps could include completion of a feasibility-level study. If the results of the feasibility-level studies were acceptable, Reclamation and/or stakeholder groups would use the final feasibility report and environmental compliance document as a basis for receiving Congressional approval and authority. Reclamation and/or stakeholder groups could proceed with preparation of final specifications and construction of the preferred alternative.[3] If the results of the feasibility-level studies were not viable, Reclamation would begin an iterative process of studying other alterntives.

The viable LLV alternatives identified in this report for potential feasibility studies could enhance water resources management flexibility. Such alternatives could address issues and planning objectives in providing for Project purposes; improved water quality where possible; fish and wildlife purposes; furtherance of Reclamation's tribal trust responsibilities; and groundwater development. This could be accomplished by increasing the reliability of water supplies through maximizing additional storage as well as offering other potential operational benefits both to the Klamath Project and the Upper Klamath Basin as a whole. Furthermore, carryover storage capability, which could be available through LLV or its variations, could potentially provide additional water supply during short periods of drought. Addition of power production features to the alternatives was not investigated but additional studies could show where the opportunity was potentially feasible.

Justification for Federal Action

For an action to be federally implementable, it must be feasible as defined by the *Economic and Environmental Principles and Guidelines (Principles and Guidelines).* The *Principles and Guidelines* require Federal actions contribute to the national economic development (NED). However, since this report documents the pre-appraisal level of the UKBOS investigation, the requirement for a net positive contribution to the Nation's economy has not been investigated and quantified for the below discussed options and alternatives. This report includes details of the analysis surrounding a preliminary review of the economic factors of two of the leading investigated options and the conclusion supporting the advancement of the leading option.

Current and Future Activities Related to Klamath Basin Water Resources

The following activities have, or could have, impacts on the water supply or its management in the Klamath Basin. The agencies responsible for these actions are listed in parenthesis:

- Return of the Agency Lake Ranch/Barnes Ranch properties to UKL by restoring the hydraulic connection (Reclamation and Fish and Wildlife Service)

- Return of Wood River Ranch to UKL by restoring the hydraulic connection (BLM)

- Water Supply Enhancement Act studies (Reclamation)

[3] The stage of the process for this investigation is equivalent to "pre-appraisal."

- Williamson River Delta Restoration (The Nature Conservancy)
- Federal Energy and Regulatory Commission relicensing of four hydroelectric dams located on the Klamath River (PacifiCorp)
- ESA Section 7 Consultation for the Operation of the Klamath Project (Reclamation)
- Klamath Basin Restoration Agreement (numerous stakeholder groups)

LLV Planning Process and Study Approach

KBAO, in collaboration with other offices within Reclamation, are developing the UKBOS investigation with the expectation of involvement of the Regional Director, Commissioner, and cooperating agencies, and concerned stakeholders, tribes, and citizens.

This final appraisal report documents the completion of Phase 2 of the several identified phases of the UKBOS investigations conducted as shown in the study phases described below. The phases conform to the process described in Reclamation Directives and Standards CMP 05-01. This report identifies and discusses conceptual plan features for a surface water storage reservoir at LLV and variations as alternatives and determines which alternatives meet the purpose and need of the appraisal-level study objectives and screening criteria.

In the appraisal-level studies, only LLV and variations from the list of alternatives studied in the early IAIR version were studied because they best met preliminary screening criteria and the purpose and needs identified in the IAIR. In the appraisal-level studies, a “future without (water storage) project” scenario (i.e., the No-Action alternative) and “future with (water storage) project” scenario will be identified. In addition, alternative plans will be formulated, evaluated, and compared to LLV and its variations.

LLV Study Phases

Phase 1—Organization and Development of a Plan of Study and Performance of Pre-Appraisal-Level Investigations

Activities were undertaken to:

- Identify priority activities fundamental to the study that were initiated after the Klamath Basin Water Supply Initiative
- Define the scope of work, schedule, and budget for the accomplishment of the studies

- Identify alternatives and determine which alternatives meet the purpose and need of the pre-appraisal or phase study objectives and screening criteria

The early version of the IAIR documents the first phase of the feasibility study. Initial screening criteria focused on those alternatives brought forward from the KBWSI process that optimized water storage at a minimum of life-cycle cost. A surface water storage reservoir at LLV best met those initial preliminary screening criteria.

Phase 2—Preplan Formulation—Early Appraisal-Level Studies Activities
Basic data and information generally common to storage alternatives are collected, compiled, and analyzed. This includes conducting limited studies to define:

- Irrigation and normative instream flow criteria
- The identifying water supply needs for agricultural, fishery, municipal, and industrial purposes
- The shortage of water supply to meet the identified needs
- The availability of water for additional short and long term storage from UKL resources
- The ability of Long Lake Valley to hold water

Klamath Basin entities capable of receiving water from offstream storage are identified to the extent possible. *(Most Phase 2 activities have been completed, and others are under way as authorized by the Enhancement Act. These activities are also discussed for Phases 3 and 4.)*

Phase 3—Plan Formulation—Final Appraisal-Level Studies Activities
Potential plan elements for consideration in the "future without (water storage) project" (i.e., the No-Action alternative) and "future with (water storage) project" scenarios would be identified in this phase, and alternative plans would be formulated, evaluated, and compared. A viable alternative plan(s) could possibly be selected to carry forward for further analysis into the more detailed feasibility-level phase. An appraisal report (or plan formulation report) would be prepared in this phase to serve as an interim document of the authorized feasibility study process and advise Congress under Section 3(d) of the Enhancement Act of completion of this portion of the studies

Phase 4—Feasibility-Level Analysis, Environmental Impact Statement (EIS), ROD, and potential Congressional Action Activities
This and subsequent phases would only take place given the recommendation to proceed from appraisal-level studies. The components of Phase 4 are:

- Phase 4a and 4b—Alternatives analysis—The viable alternative plan(s) would be further developed and analyzed. Feasibility-level and engineering design studies would be conducted.

- Phase 4c—Development of draft final report/EIS-EIR—The feasibility report/EIS would be prepared. EIS preparation would include public review and comment and agency staff responses to comments.

- Phase 4c—Development of final report/EIS-EIR—The final report/EIS-EIR would be reviewed and certified according to Reclamation directives and standards.

- Phase 4d—Record of Decision and Congressional action—The Department of the Interior and Office of Management and Budget would review the report and submit to Congress under Section 3(d) of the Enhancement Act to request funding and authority to construct and implement the project. Potential project beneficiaries (stakeholders) may also seek to obtain congressional authorization.

Implementation Phases

(It must be recognized that unless and until Congress authorizes project construction after the feasibility-level study process and the ROD is complete, there is no promise or expectation that such a project(s) would automatically progress to implementation "phases.") The implementation phases are:

- Phase 5—Property purchase (as necessary)

- Phase 6—Final specifications design

- Phase 7—Construction

- Phase 8—Begin operations and delivery of water

Previous Studies

This section provides an overview of studies completed prior to the undertaking of the current Upper Klamath Basin Offstream Storage studies. The planning objectives for many of the studies appear to be to establish the feasibility and technical viability of a number of offstream water storage schemes. Previous studies, for purposes of the discussion in this section, are divided into pre- and post-KBWSI.

The KBWSI is a consortium of agricultural water users, Native American tribes, local residents, and many other parties affected by or interested in Project operations. Since its 1997 inception, KBWSI has suggested numerous potential solutions to water resource development and use in the Klamath Basin. A "No-

Action" alternative/option would involve the continuation of demand growth and competition for water in the entire Klamath Basin and future conflicts over water between the Upper and Lower Klamath Basins.

Alternatives and Results from Pre-KBWSI Planning Level Studies

Both government and private organizations have conducted offstream storage studies in the Upper Klamath Lake area. A review of these studies is presented in Reclamation's *Upper Klamath Offstream Storage Study, Appraisal Report* (February 1987). The report concluded that a project involving Long Lake Valley, Aspen Lake, and Round Lake was not economically viable due to the presence of geological problems investigated at that time.

In 1959 and 1960, the California-Oregon Power Company—currently known as PacifiCorp—contracted with Dames and Moore to conduct geotechnical investigations for offstream storage in the greater Aspen-Round-Long Lake area. Pacific Power and Light Co. (a subsidiary of PacifiCorp) contracted with Shannon and Wilson, Inc., in 1982 to conduct an independent geotechnical review of offstream storage in the greater Aspen-Round-Long Lake area. Building on previous investigations by Dames and Moore, Shannon and Wilson drilled ten additional holes and excavated several test pits to better determine subsurface geology and hydraulic conductivity of individual units. Like their predecessors, they focused most of their drilling and test pit work in the Aspen Lake area located about 4 miles northwest of LLV, with less work in Round and Long Lake Valleys. Findings from their 1982 investigations are presented in *Shannon and Wilson, Report to Pacific Power and Light Co., Independent Geotechnical Review Upper Klamath Offstream Storage Study, Klamath Falls, Oregon* (1983). The report, although discussing seepage problems at each potential reservoir site, did not conclusively eliminate Long Lake, Round Lake and Aspen Lake from the technical feasibility standpoint.

Alternatives and Results from KBWSI and Post-KBWSI Planning Level Studies

In July 1998, Reclamation's KBAO developed a KBWSI draft options report that included 96 options for increasing water supplies to the Klamath Basin. This report included screening criteria used to narrow the list of options. In September 2004, KBAO updated the KBWSI draft options report, and the *Klamath Basin Water Supply Options Status Report* (2004) was developed.

Twenty-six options (Reclamation, 1998, table 4) were recommended for additional study. Of those 26, seven involved water storage options. Of those seven, six involved water storage scenarios in the Upper Klamath Basin: No. 34—Agency Lake North and West, No. 37—Boundary Dam, No. 60—Lower Klamath National Wildlife Refuge for storage, No. 61—Sump rotation—Tule Lake National Wildlife Refuge, No. 70—Raise Gerber Dam, and No. 72—Raise Link River Dam.

In addition to those six, five options were carried forward for additional study to determine if they held promise for storage upon updated information and political interest. Those five options were KBWSI option No. 23—Klamath River Valley groundwater—in-lieu pumping, No. 24—Klamath River Valley groundwater—pumping with recharge; No. 40—Long/Round/Aspen Lake Valleys pumped storage, No. 41—a new storage facility at Swan Lake, and No. 80—Dredge deep pools at Upper Klamath Lake.

Locations of the UKBOS alternatives are shown in figure 2.

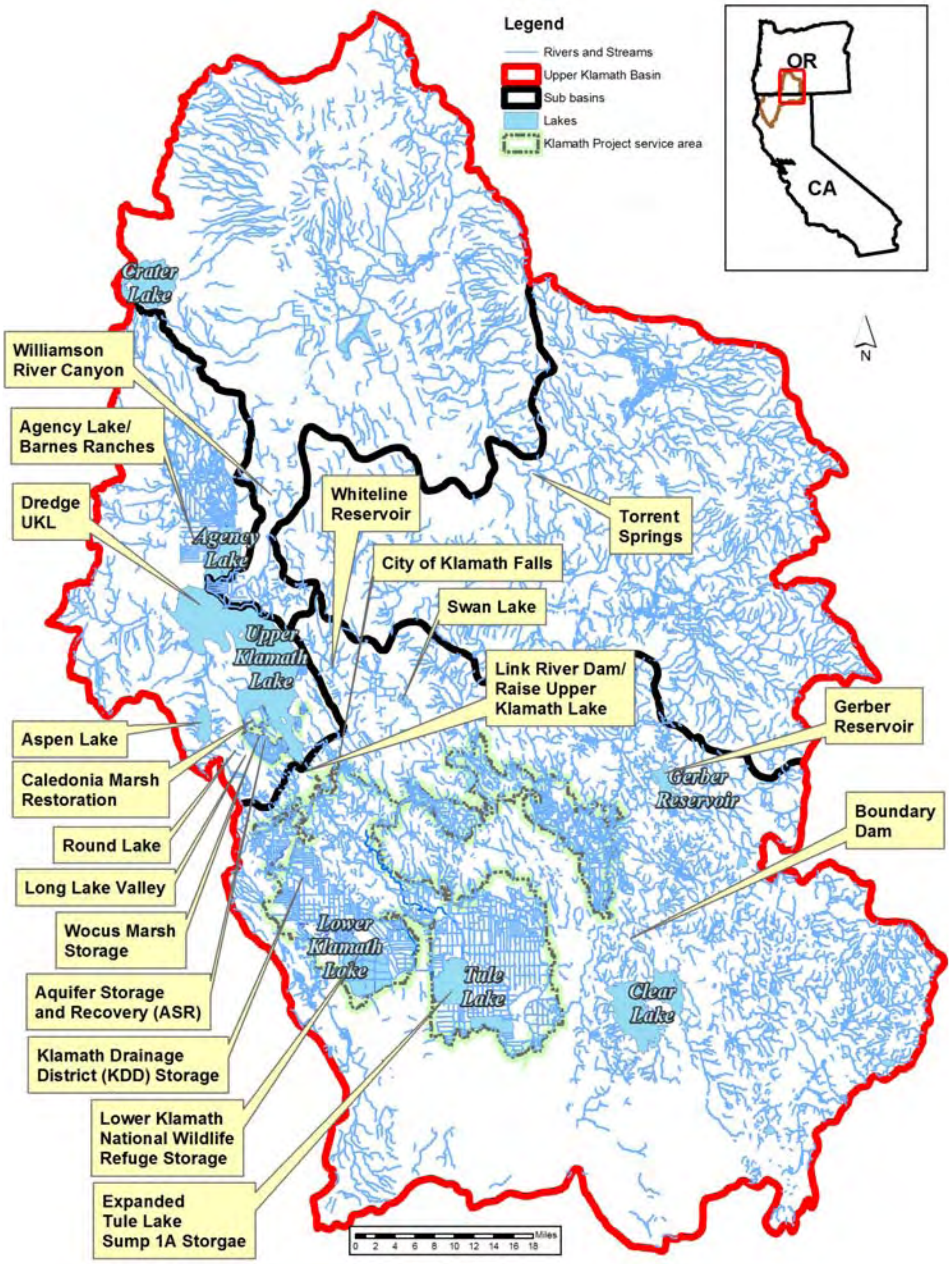

Figure 2.—Locations of UKBOS alternatives.

Political interest has developed post-KBWSI in several additional options that were studied under UKBOS, namely, Klamath Drainage District storage, Caledonia Marsh Restoration storage, Whiteline Valley pumped storage, Torrent Springs damsite, and Williamson River Canyon and Falls Area damsites.

The UKBOS investigation's reconnaissance-level study phase focused on the No-Action option, the eight KBWSI options listed above, and other options that have been re-examined or developed since the September 2004 report. Table 1 of the early version IAIR lists all the options that were examined in the UKBOS study.

Description of the No-Action Alternative

As described in the hydrology discussion section elsewhere in this document, the No-Action scenario is the March 2008 Proposed Action for Klamath Project operations included in Reclamation's Biological Assessment. The with-project alternatives are consistent with the proposed action assumptions, but also include Long Lake Valley Reservoir and use the additional stored water in meeting conceptual plan operating goals and enhanced Iron Gate flow augmentation. The with-project alternatives differ only in the conveyance capacity assumed between Long Lake Valley Reservoir and Upper Klamath Lake.

	Long Lake Valley Reservoir storage capacity (TAF*)	Canal capacity (ft^3/s)
Proposed action	0	0
LL350 1K	350	1,000
LL350 2K	350	2,000

* Thousand acre-feet

Input data and operating rules for both scenarios are consistent with the criteria for the Klamath Project 2008 Proposed Action, and these are described below.

The Barnes Ranch (BR) and Agency Lake Ranch (ALR) site is located on the northwest shoreline of Agency Lake, which is directly connected to the northern end of UKL (figure 3). Reclamation undertook preliminary studies to evaluate options for restoring and enhancing lacustrine wetlands at the site. Site characteristics are examined and the potential benefits of different restoration options are weighed against practical considerations to identify important constraints and opportunities that could influence effective site planning.

Historically, the BR and ALR site lands comprised mixed emergent and floating aquatic wetlands lying within the high water levels of Agency/UKL. Reclamation purchased the BR and ALR properties to provide additional water storage and

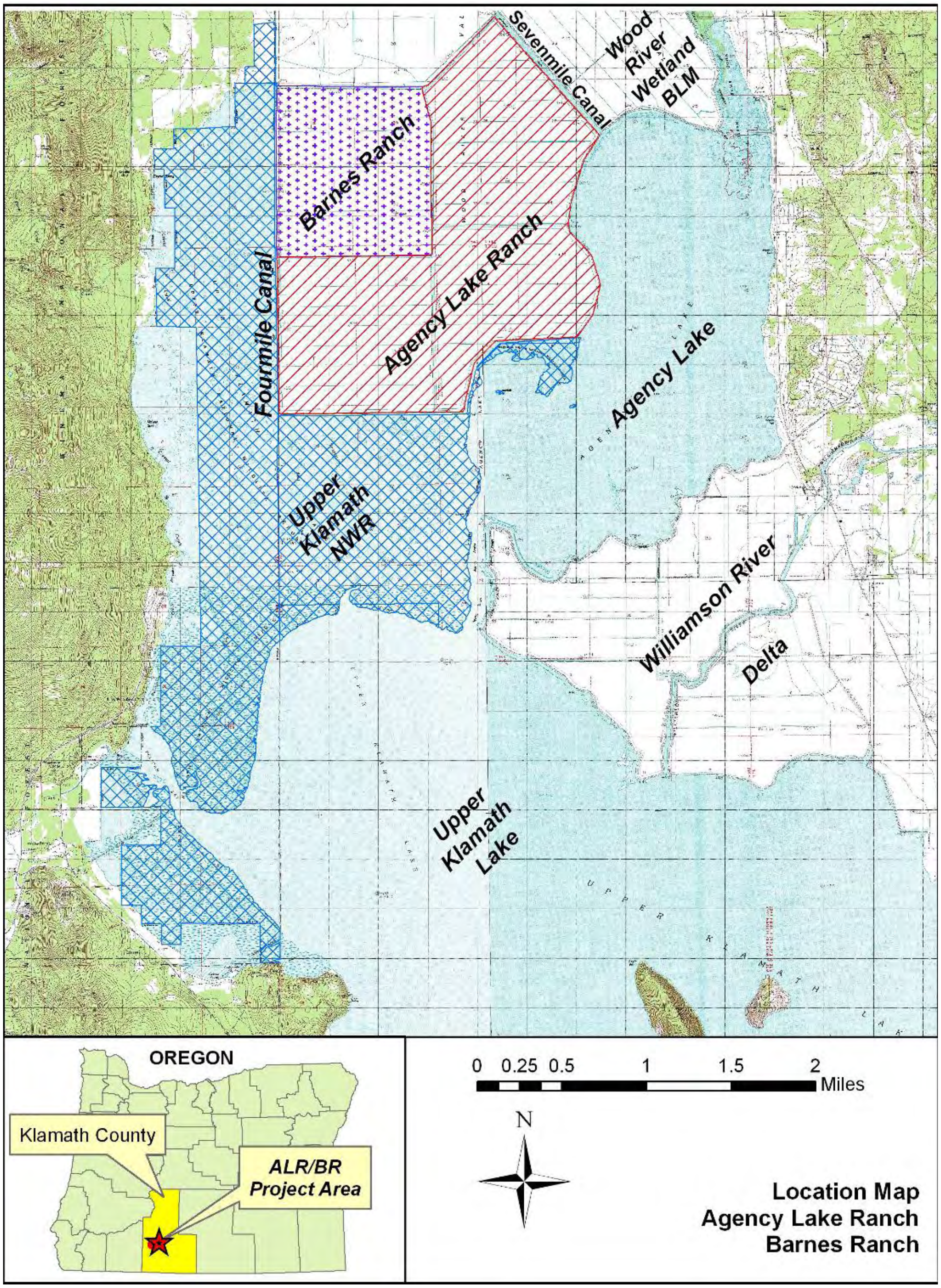

Figure 3.—The Barnes Ranch and Agency Lake Ranch sites border Agency Lake, which is directly connected to the northern end of Upper Klamath Lake.

contribute to the ongoing UKL wetlands restoration goals (FWS, 2008). Reclamation has operating agreements with the Fish and Wildlife Service and The Nature Conservancy that involve the goal of "restoring" the BR/ALR site by re-establishing a hydraulic connection to UKL water levels. However, under existing conditions, most of the site lands are submerged by UKL lake levels even during relatively dry water years. This raises questions concerning what options might be most practical to restore or enhance beneficial site functions and how the resulting site values are balanced effectively between storage, wildlife habitat, and other vital resource needs in the Klamath Basin.

As for the conceptual plan features of the No-Action alternative, the resulting framework of site options and initial planning considerations is summarized in table 1 in the ALR/BR report (Reclamation, May 2009) and its interim updates up to January 4, 2010. General categories described in this report concerning site construction work and water control operations indicate definitive actions for restoration. These categories form an array outlined in the first four site options in the table that encompass open-to-lake versus water control and minimum site work to work required to enhance restoration benefits.

In effect, the last two options in the table represent mechanisms to account for uncertainties, and although important considerations, definitive actions cannot be developed at this time and they are set aside for later planning stages.

As a result, the first four site options are considered potentially viable options and are carried through subsequent evaluations. This array of options is compounded by each option assessed with respect to the different units within the ALR/BR complex such as BR, ALR-A, ALR-B, and ALR-C unit areas individually and all four unit areas combined to identify the most promising options and formulate comprehensive plans for the entire BR-ALR site.

Description of the Long Lake Valley Alternative

In 2006, the Bureau of Reclamation (Reclamation) initiated the UKBOS Investigation study under the authority of the Klamath Basin Water Supply Enhancement Act of 2000 (P.L. 106-498; Enhancement Act). Earlier, in December 2005, the Bureau of Reclamation's Klamath Basin Area Office requested the Mid-Pacific Region, Division of Design and Construction, Engineering Branch (MP-210) to perform an appraisal-level study to evaluate using Long Lake Valley as an offstream storage reservoir. Due to the limited time, staff availability, and minimal available design data, MP-210 proposed and was approved to complete a reconnaissance level construction cost estimate instead. This study examined costs to pump water from Upper Klamath Lake and store it in Long Lake Valley during the winter months. Water would be released back into Upper Klamath Lake during the drier months. Two pumping plant capacities were evaluated: 1,000 and 2,000 cubic feet per second (ft^3/s). The water would be stored to maximum water surface elevation 4430 feet in Long

Lake Valley Reservoir, which was reported to provide 350,000 acre-feet of offstream storage.

The Mid-Pacific Region previously completed an appraisal report in February 1987 titled *Upper Klamath Offstream Storage Study* (Reclamation, 1987). The 1987 study examined the potential of constructing and operating an offstream storage conceptual plan involving a system of three reservoirs: Long Lake Valley Reservoir, Round Lake, and Aspen Lake. The reservoirs would be hydraulically connected by tunnels, which would be filled by a single pump-generating plant called Aspen Lake Pumping-Generating Plant. In September 2003, the 1987 study findings were revised and cost indexed. The revision included a new cost breakdown for a "Long Lake Only" storage scenario and an alternative approach to lining the reservoir. Since the 2003 re-evaluation of the 1987 study, the Geology Branch (MP-230) conducted additional geologic investigations in 2004 (Reclamation, 2004a) and 2005. These investigations indicated that the water-holding capability of Long Lake Valley is more promising than originally estimated.

The reconnaissance estimate completed in March 2006 and entitled *Upper Klamath Offstream Storage Study at Long Lake Valley, Reconnaissance Level Cost Estimate* (referred to in this appraisal report as the reconnaissance design report) (Reclamation, 2006a) differs from the previous estimates in several areas:

- To comply with fishery issues in Upper Klamath Lake, a fish screen structure would be incorporated upstream of any new pumping plant intake.

- Construction of a dam and dikes is unnecessary since maximum water surface for the 350,000 acre-foot reservoir is set at elevation 4430 feet, and the three identified low spots around the Long Lake Valley rim are at approximately elevation 4500 feet. It was further assumed that an emergency overflow spillway would not be necessary for this scenario.

- The pumping plant is designed for pumping only, not pumping-generating.

- Geologic findings indicate that less of the total reservoir area needs lining than was previously thought in the 1980s study. Geologic and hydrogeologic modeling studies are ongoing to further refine lining needs.

The appraisal-level offstream storage conceptual plan configuration described in the following section incorporates many of the reconnaissance level considerations, but there may be other factors that are not addressed. The reconnaissance level study uses data that was available at that time, but may not reflect all factors that need to be taken into account to determine the feasibility of the conceptual plan.

The appraisal-level design for the proposed conceptual plan remains essentially the same as that which was described in the reconnaissance design report with some alterations. To minimize study costs, the conceptual plan configuration was minimally changed due to the uncertainty of the outcome of the current Klamath Basin Restoration Agreement discussions and negotiations and the eventual determination of the LLV conceptual plan participating entities. Alternatives to the reconnaissance design report configuration were investigated for delivery of water from a water quality benefits perspective.

Reclamation staff conducted a constructability review in November 2007 that reviewed the reconnaissance planning level design that was intended for use as the appraisal level design. Several recommendations were made and incorporated into the final appraisal level design, where possible, or carried forward as uncertainties to be clarified in a potential final feasibility-level design process. The uncertainties are described in the following sections.

The following discussion sections contain recommendations and findings that are captured in parentheses and indexed to the particular feature or issue for capture and display in a summary listing later in this document.

Conceptual Plan Features

Refer to figure 4 for the general location of conceptual plan features. The offstream storage conceptual plan consists of ten primary conceptual plan features to be constructed:

1. Canal conveyance system
2. New fish facility and check structures
3. Intake channel and bypass release structures
4. Pumping plant
5. Concrete-lined tunnel
6. Surge shaft
7. Outlet works tower and access bridge
8. Access roads
9. Reservoir lining
10. Electrical power to conceptual plan features

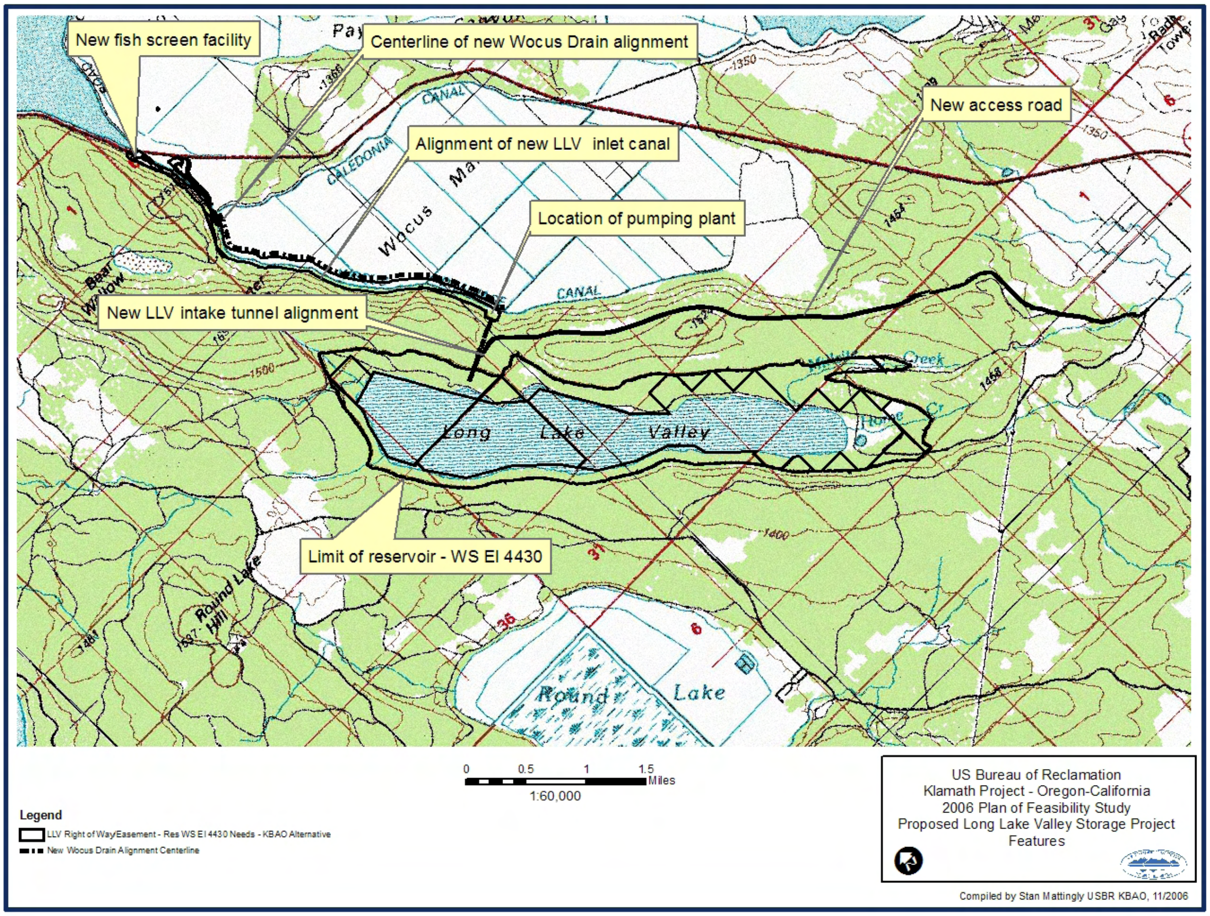

Figure 4.—Proposed Long Valley Reservoir and conceptual plan features.

These features are considered to comprise the appraisal-level design of the conceptual plan.

A water treatment facility was investigated separately to study benefits and construction and life-cycle costs for the delivery of Long Lake Valley water in a water quality aspect.

Canal Conveyance System and Fish Facility

Refer to figures 4 and 5.

For both the 1,000- and 2,000-ft^3/s pumping capacity, the existing Caledonia Canal and Wocus Drainage Canal alignments would be improved to convey flow from Upper Klamath Lake at Wocus (Howard) Bay to the new pumping plant, which would lift the water into Long Lake Valley Reservoir. The new pumping plant would draw water from Wocus Bay under the Highway 140 Bridge, and through a new canal intake structure. The intake structure would include trash racks, a fish screen facility, and head works. The fish screen facility would be similar to the A-Canal Fish Screen with a trash rack that has an automatic cleaning facility and six manually operated bulkheads. However, the remote location of the Caledonia Canal inlet area may warrant a different arrangement of these facilities. The precise location and arrangement of the fish bypass facility would need much more refinement. (CCSFF-3)

Construction of the v-shaped fish screen facility and bypass system would include several parts including stainless steel wedge wire fish screens, a flow control baffle system, a screen cleaning system; a bypass flow control weir, a backup engine generator set, a bifurcation structure, a fish-friendly pump and motor system, and a pressure fish bypass pipeline discharging back into Upper Klamath Lake.

Both the fish screen and bypass system would be computer and electrically controlled. The head gate structure would consist of six gates that would also be electric motor operated. The fish screen structure for these alternatives would consist of cast-in-place concrete structures with three bays. Two bays would house the "V" configuration fish screens, and the third bay would serve as a return channel bypassing the fish screen when water flow is reversed from Long Lake Valley Reservoir back to Upper Klamath Lake.

The structure would include trash racks on the intake side from Upper Klamath Lake, radial gates upstream of the fish screens, fish bypass pipe entrances dropping through the invert of the structure floor, and downstream radial gates. The radial gates in both the two fish screen bays and the return flow channel bay would serve to isolate the compartments under the different operation scenarios. If the pumping plant was drawing water from Upper Klamath Lake to Long Lake Valley, the fish screen bay channels would be in operation, and the radial gates would isolate the return flow channel bay. If the return flows were made from Long Lake Valley back into Upper Klamath Lake, then the radial gates would isolate the fish screen bays, and the return flow channel would bypass the flow.

All fish screens would be designed to meet the National Marine Fisheries Service, Northwest Region, screen criteria for juvenile salmonids. For this appraisal study, Reclamation used salmonid fry criteria (shorter than 2.36 inches [60 mm]) for fish screens located both at the intake/screening structures located upstream of the plants and also for the fish screens located on the intake structures within Long Lake Valley Reservoir. The criteria state that for salmonid fry, the approach velocity shall not exceed 0.40 feet per second (ft/s). Approach velocity is defined as the water velocity component perpendicular and approximately 3 inches in front of the screen face. The total submerged screen area required (excluding the area affected by structural components) was then calculated by dividing the maximum diverted flow by the allowable approach velocity. The criteria include channel velocities, screen approach velocities, sweeping velocities, exposure time along the screen, maximum fish bypass pipe flow velocity, and minimum radius of fish bypass pipe bends.

Following the original 1970 appraisal report parameters, the canal would be earth lined with a trapezoidal section and 70-foot wide bottom and would be riprap reinforced on both side slopes with the sloping at a horizontal-to-vertical ratio of 2:1. The canal bottom slope would be set at elevation 4124.8 feet and the top banks at elevation 4150.0 feet, which result in a 25.2-foot deep canal. The original ground surface is assumed to be at elevation 4138.0 feet, so there would be 13.2 feet of excavation and 12 feet of fill for the compacted embankments. Since Upper Klamath Lake's water surface elevation varies between elevations 4136.0 and 4143.3 feet, the assumed normal water surface in the canal would be at an approximate elevation of 4140.0 feet.

Overall, the canal would be approximately 19,000 feet long with paved, 25-foot wide service roads on both sides of the canal. Both roads would connect to Highway 140 and would be approximately 3.5 miles long. The canal would be designed to be bidirectional, with water pumped from Upper Klamath Lake for storage in Long Lake Valley during the winter months and then released back into Upper Klamath Lake during the drier summer months against the adverse slope of the canal. Per an email forwarded from the Reclamation Hydrology Group on June 26, 2008, the high water surface (WS) at Klamath Lake is the normal water surface at elevation 4143.30 feet, and the low water surfaces are at elevation 4139.0 feet (optimal minimum level), elevation 4138.0 feet (dry condition minimum level), and elevation 4137.50 feet (emergency level). On the Upper Klamath Lake side, with the bidirectional flow, the initial flow WS was sited to match the low elevation of 4137.50 feet, and the return flow WS was sited to match the high elevation of 4143.30 feet.

Interpretation of recommendations in the November 2007 constructability review led to a sub-feasibility-level optimization study to determine alternative conveyance facility combination types and alignment configurations. This optimization study took into consideration any and all existing design data and would be the basis for the final feasibility level design decisions and the subsequent conceptual plan configuration. (CCSFF-1)

When water is released back into Upper Klamath Lake, the flow would be directed through a check structure located adjacent to the intake/fish screen structure. Redirecting these return flows would help protect the fish facility. The check structure would have two radial gates with motor-operated hoists, similar to the ones constructed in the Tehama-Colusa Canal. For the 1,000-ft^3/s flow, the two radial gates would be sized for 14-foot wide by 14-foot high gate openings with a 7,500-pound hoisting capacity, whereas the 2,000-ft^3/s openings would be 18 feet wide by 15.5 feet high with a 15,000-pound capacity.

Improvements may be required to protect the existing Highway 140 crossing. Pump stations, turnouts, and other infrastructure along Caledonia Canal would require relocation or modification. Present geologic and foundational conditions at and around the Highway 140 Bridge are unknown. The current reconnaissance estimate only includes cost-indexed values for relocating the bridge piers and two nearby pumping stations identified in the 1970 report. (CCSFF-2)

Intake Channel and Bypass Release Structures

Refer to figure 5 of the reconnaissance design report.

An intake channel would be constructed between the improved Caledonia Canal and the intake bays of the new pumping plant. Similar to the canal configuration, the channel would sit at the same elevation, but would have a greater width. The 200-foot long and 200-foot wide intake channel (250 feet wide for 2,000 ft^3/s) would be excavated and backfilled with 1-foot bedding and 2-foot thick riprap protection placed on each side. Water would be diverted from the canal into the channel and would be collected through the pumping plant units. The wide intake channel would aid in dissipating energy when water released from Long Lake Valley Reservoir would be bypassed around the pumping plant for release into the channel.

Water released from Long Lake Valley Reservoir would be directed through a bypass release structure incorporating a jet flow valve, which would help dissipate energy. The 1,000-ft^3/s pumping plant would have only one bypass release structure, while the 2,000-ft^3/s pumping plant would have two release structures located on each side of the pumping plant. Each bypass release structure would have a 60-inch jet flow valve enclosed by concrete walls.

To ensure that water released from Long Lake Valley Reservoir into Caledonia Canal would not back up into the Wocus Drainage Canal, a check structure would be constructed in the drainage canal, south of the pumping plant intake channel.

Pumping Plant

Refer to figures 4 and 6.

The 1,000-ft^3/s pumping plant would consist of an indoor pumping plant with six pumping units of equal capacity discharging into 78-inch diameter steel pipes. Each pumping unit discharge line would have a butterfly valve and a check valve. The discharge lines would manifold into a 16-foot diameter pipeline installed above grade. The 16-foot diameter pipeline would climb approximately 120 feet vertically up the hillside to its junction with the 16-foot diameter tunnel. The pumping plant and switchyard would be anticipated to be located near the base of the ridge at the same location identified in the 1970 study. A spread foundation for the plant is assumed to be adequate but would need to be verified with further geologic investigations. (PP-1)

Discharges from the reservoir would return down the hillside through a 16-foot diameter pipeline. At the pumping plant a 16-foot diameter bypass pipe would diverge from the 16-foot diameter pipeline to one side of the pumping plant and reduce to a 5-foot pipe, which would discharge through a 60-inch jet flow valve.

Energy not dissipated by the jet flow valve would be dissipated in the wide pumping plant intake channel before flowing into Caledonia Canal.

Similar to the 1,000-ft^3/s schematic, the 2,000-ft^3/s pumping plant would consist of nine pumping units discharging into 90-inch diameter steel pipes, which manifold into a 22.5-foot diameter pipeline, and finally into the 23-foot diameter tunnel. Return flow would be released into the tunnel and down the hillside through the 22.5-foot pipeline. The flow would then bifurcate into two 16-foot pipelines located on each side of the pumping plant. The two bypass pipelines would reduce to 5-foot pipes and discharge through 60-inch jet flow gates into the intake channel.

Interpretation of recommendations in the November 2007 constructability review led to a sub-feasibility-level optimization study to determine alternative pumping and/or pumping/generating facility combination types and size configurations. This optimization study took into consideration any and all existing design data and would be the basis for the final feasibility-level design decisions. The optimization study also took into consideration the possible power rates available to the Klamath Project.

One of the proposals within the agreement calls for the delivery of power to Klamath project water users at "project use" rates, and this scenario should be studied along with the supply of power at market rates. The potential for power generation should be explored more in depth should feasibility-level studies for LLV be undertaken. (PP-2)

Tunnel and Surge Shaft

Refer to figure 6.

A 3,000-foot long tunnel would carry water from Caledonia Canal and discharge into Long Lake Valley Reservoir. The tunnel would be lined with reinforced concrete and with a flat invert grade set at elevation 4270.0 feet. For the 1,000-ft^3/s flow scenario, the tunnel would have a 16-foot finished diameter, while the 2,000-ft^3/s flow would be sized at 23 feet. Rock excavation would be required to construct the tunnel and surge shaft, probably by means of blasting, perhaps supplemented with road header equipment. Use of a tunnel boring machine would not be expected due to the relatively short length of the tunnel. The tunnel alignment selected for this reconnaissance study is north of the 1970 penstock alignment. This north alignment has the advantage of steeper terrain and better rock foundation, which would reduce the length of the approach channel. However, the approach channel appears to be slightly longer. Selection of the final tunnel alignment would need to address these factors.

A 16-foot diameter (23 feet for 2,000 ft^3/s) surge shaft would be placed about a third of the way from the tunnel entrance nearest to the pumping plant to provide relief from water hammer pressure commonly associated with pumping plant operations. The surge shaft would be 230 feet high with the top "day-lighting" at elevation 4500.0 feet.

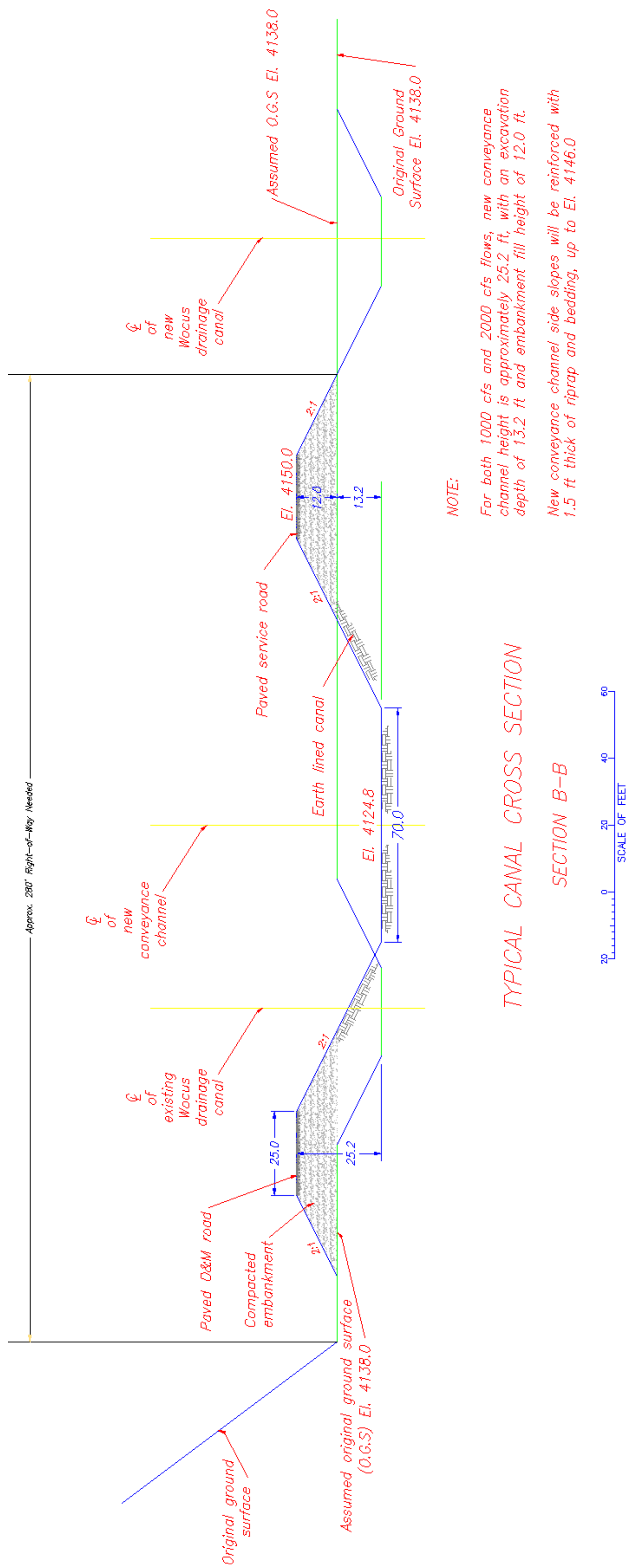

Figure 5.—Typical cross section of Long Lake Valley Reservoir Inlet Canal.

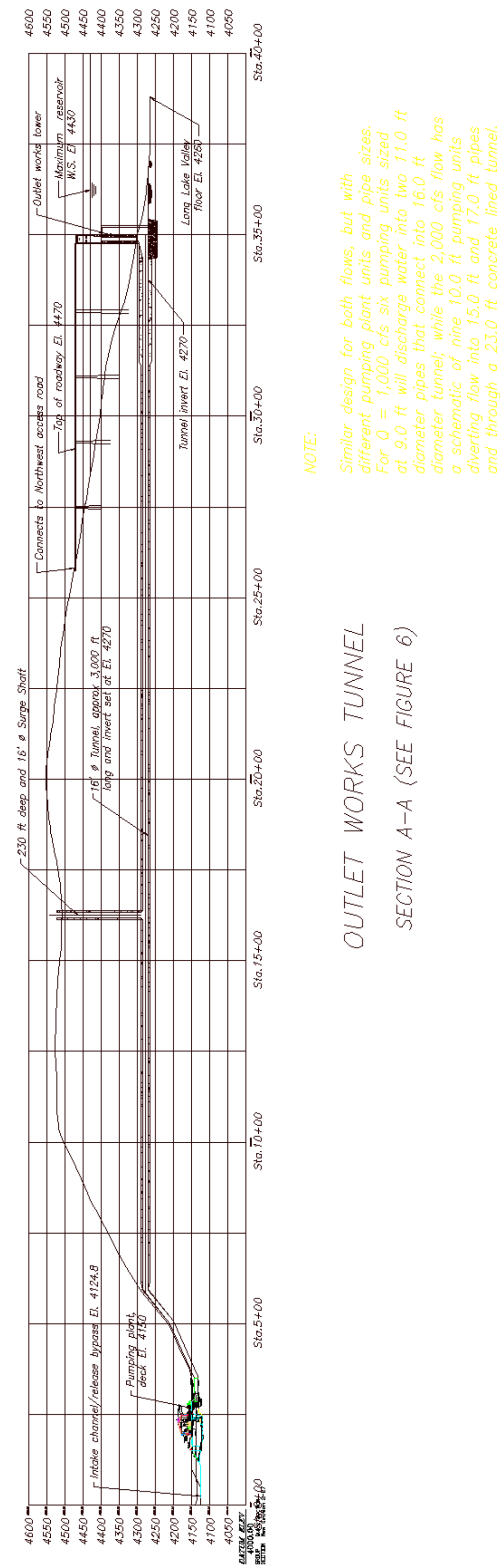

Figure 6.—Proposed Long Lake Valley Reservoir intake/outlet works and pumping plant.

Outlet Works Tower and Access Bridge

Refer to figures 4 and 6.

The proposed outlet works tower and access bridge follow the same design as the San Luis Dam Outlet Works. The 200-foot high outlet works tower, also called a trash rack structure, would sit on an 8-foot thick concrete base and serve as a discharge, inlet, and gate structure. The trash rack structure would consist of a rectangular semi-bell-mouth-shaped entrance that would transition from a rectangular cross section to a circular cross section, and then would connect to the tunnel. A single 24- by 30-foot bulkhead gate would be seated vertically in the entrance opening. Ten feet past the entrance opening would be an 18.25- by 24-foot roller-mounted gate. The roller-mounted gate would provide emergency closure of the outlet works tunnel, while the bulkhead gate would permit inspection, maintenance, and repair of the roller gate. The bulkhead gate would be lowered and raised by a 60-ton capacity gantry crane. The trash rack would be supported by columns and beams that would extend about 100 feet high and 26 feet away from the opening. Access to the tower would be provided by a 16-foot wide by 1,000-foot long bridge that would connect from the Northwest Access Road.

Access Roads

Refer to figures 4 and 5.

The Northwest Road would be 3 miles long and would provide access to the outlet works bridge and tower. The road would connect to the Caledonia Canal (O&M) road approximately 4,000 feet south of Highway 140. In the opposite direction and less than 6 miles long, the Southeast Road would connect from Balsam Drive (1 mile north of West Klamath) and provide access to the pumping plant. Both access roads would be paved, 25 feet wide, and follow pre-existing alignments. The construction of these roads may require roadway clearing. Additional land acquisition may be necessary since the current alignments are on privately owned land, and accesses to both ends of the valley are blocked by locked gates.

For feasibility-level studies, the geologic stability of the Northwest Road should be investigated and if found to be infeasible or to have geologic concerns, a road to the outlet surge shaft and tower bridge should be investigated, which would provide access along Wocus Ridge from the county road extension of Balsam Drive. (AR-1)

Reservoir Lining

Refer to figure 10 of the March 2006 reconnaissance design report.

Geologic investigations of the water-holding capability of Long Lake Valley indicate that it may only be warranted to line less than 20 percent of the total 2,700-acre lake area. The minimum areas requiring lining are shown in figure 10 of the reconnaissance design report and were identified by MP-230 (Geology

Branch). The type of reservoir lining used would be either soil or a geomembrane. MP-230 geologic investigations revealed that borrow sources of material with relatively low permeability can be obtained locally within the valley or near the conceptual plan site. In future evaluations, other suitable methods, such as shotcrete lining, should be explored.

A hydrogeology study is nearing completion to determine if and how much lining would be necessary given the existing data. The 20 percent lining figure mentioned above needs to be confirmed through iteratively more detailed studies of the LLV site. This information should be presented should the decision be made to proceed to the final feasibility-level studies and provided as design data input. (RL-1)

Electrical Power

Electrical power would be required to operate the pumping plant, new headworks, fish facility, and outlet works tower. Smaller power demands could also exist at the penstock/tunnel junction and at the surge shaft.

Through a discussion with Pacific Power Company, the source of electrical power was estimated to be in the vicinity of Klamath Falls but could be as distant as 8 miles from the proposed pumping plant location. Pacific Power advised that an allowance be made for a longer transmission line route that may be dictated by environmental considerations. Specific electrical transmission components besides transmission lines include modifications to the Klamath Falls substation, a new breaker station, a new meter station, and a substation/switchyard at the pumping plant. It is assumed that power to the canal intake, outlet works tunnel, surge tank, and trash rack tower would come from the pumping plant's substation.

As for the entire LLV conceptual plan configuration, the design for this feature, and hence its description, is one that is pending the outcome of the current Klamath Basin Restoration Agreement discussion and ratification process. One of the elements within the agreement calls for the delivery of power to Klamath Project water users at "project use" rates. A potential exists, through the Klamath Basin Restoration Agreement, that the Klamath Project could receive Bonneville Power Authority (BPA) power at a project use power rate. Such a scenario needs to be investigated in feasibility-level studies along with the facilities that would be necessary to transmit the power from BPA facilities at either Malin or Captain Jack switchyards near Malin, Oregon across the Klamath Project to the proposed LLV pumping plant. Investigative studies need to consider that the length of such transmission lines may fall under the jurisdiction of the Oregon Energy Facilities Siting Council. (EP-1)

Water Treatment Features

Water treatment features have been scoped at the subappraisal level, and construction and life-cycle costs have been developed. The facilities would consist of an in-lake reservoir water circulation system and, if required by the Oregon Department of Environmental Quality (ODEQ), a media filtration system on the outlet pipe for filtering release water to remove algae and suspended solids before release back into UKL. These features and costs are more fully discussed in a following section.

Other Costs

A more thorough determination of costs for LLV mitigation and other issues would be undertaken in the event that studies of the BCR for LLV conceptual plan features showed positive results.

Mitigation Features

Mitigation features (e.g., ecological, biological/habitats and species of concern, cultural, tribal assets, social, and economic) are not included in the discussion of the list of conceptual plan features, nor their related costs and benefits because developing these is beyond the scope of this appraisal study for the above reason.

Real Estate

Acquisition costs for real estate such as lands, easements, rights-of-way, and relocations are not included in the discussion of the list of conceptual plan features, nor are their related costs and benefits because they were not available at the time of the development of this appraisal study report for the above reason.

Estimated Costs for Preliminary Long Lake Valley Conceptual Plan

The construction cost estimate used for this final appraisal report is the cost estimate from the March 2006 *Reconnaissance Design and Construction Cost Estimate Report* updated to a July, 2008 price level:

Estimated Costs (July, 2008)	Pumping plant capacities (ft^3/s)	
	1,000	2,000
Field cost (billions)	$1.00	$1.20
Total construction cost (billions)	$1.25	$1.50

The following worksheets show the estimated construction costs for the major features.[4] Costs of land acquisition, operations, maintenance, relocations, etc. are not included in construction costs.

Attachments 4 and 5 in the reconnaissance design report provide explanations for the percentage factors applied to calculate the mobilization, unlisted items, contingencies, and noncontract costs.

[4] Note that these estimates are construction costs only and do not include environmental or other mitigation or permitting costs.

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:	PROJECT:
Long Lake Valley Canal - Tunnel & Power Optimization Study	**Upper Klamath Offstream Storage Study**
Alternative 1: Option B: 2,000 cfs - Pumping Only - *19,000 ft*	**At Long Lake Valley**
Earthen Lined Canal from Klamath Lake to Long Lake Valley	**WOID:** LLVED **ESTIMATE LEVEL:** Appraisal
with fully lined reservoir	**REGION:** MP **UNIT PRICE LEVEL:** Jul-08
Summary Sheet: Alt1-OptB-PO-2000cfs-Earthen Lined Canal Full Lined Reservoir	**FILE:** H:\D8170\EST\Spreadsheet\Zlomke\0-Work Files\MP\LLV\LLV 350K AF Appraisal\1A & 1B fully lined\[Alt1-OptB-PO-2000cfs-Earthen Lined Canal with full res liner.xls]Alt1-OptB EC

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	**Canal ID: A1-2K-EC-19K (4 sheets)**					$191,715,155.00
	2	**Tunnel ID: A1-2K-T (1 sheet)**					$32,519,400.00
	3	**UK Intake/Fish Screen Eq ID: A1345-2K-PO&PG-IntFS Eq (3 sheets)**					$13,897,640.00
	4	**UK Intake/Fish Screen Hyd Eq ID: A1-5-2K-All-IntFS HydEq (1 sheet)**					$4,806,750.00
	5	**Fish Screen Pipe ID: A1-5-All-FSPipe (1 sheet)**					$305,456.00
	6	**UK Intake/Fish Screen Structure ID: A134-2K-All-FS Struct (1 sheet)**					$23,070,028.00
	7	**UK Intake/Fish Screen Cofferdams ID: A124-All-Coff-Rev1 (1 sheet)**					$5,329,000.00
	8	**UK Plant CS ID: A134-2K-PO&P-T-CSPlt (3 sheets)**					$62,587,830.00
	9	**UK Plant Mech Eq ID: A1-5-2K-PO-MEqPlt (3 sheets)**					$13,957,000.00
	10	**UK Plant Hyd Eq ID: A1-5-2K-PO-Plt HydEq (1 sheet)**					$29,100,000.00
	11	**UK Plant Pipe ID: A1-5-2K-PO-Plt Pipe (2 sheets)**					$49,917,784.00
	12	**UK Plant Electric ID: A1-5-2K-PO-Eplt (2 sheets)**					$16,626,400.00
	13	**Switch Yard & T-Line ID: A1&3-2K-All-SY (1 sheet)**					$13,073,000.00
	14	**Plant Penstock ID: A1-2K-All-PltPen (1 sheet)**					$2,114,340.00
	15	**LLV Intake Tower CS ID: A1&3-2K-All-T CS (2 sheets)**					$15,756,200.00
	16	**LLV Intake Tower Mech Eq ID: A1-5-2K-PO&PG-T-MEq (2 sheets)**					$15,517,500.00
	17	**LLV Intake Structure Hydraulic Eq ID: A1-5-2K-All-T HydEq (1 sheet)**					$3,130,000.00
	18	**Non Plant Structures Electrical ID: A1&3-All-NonPlt Elec (1 sheet)**					$1,288,200.00
	19	**350 TAF Full Clay Liner (1 sheet)**					$294,490,000.00
		Subtotal 1					**$789,201,683.00**
		Mobilization %		5.0%			$39,000,000.00
		Subtotal 1 w/Mobilization					**$828,201,683.00**
		Design Contingencies %		15.0%			$121,798,317.00
		APS = Allow: (Procurement Strategies) %		none			
		CONTRACT COST					**$950,000,000.00**
		Construction Contingencies %		25.0%			$250,000,000.00
		FIELD COST					**$1,200,000,000.00**
		Non-Contract Cost %		25.0%			$300,000,000.00
		CONSTRUCTION COSTS					**$1,500,000,000.00**

Notes:

1. Escalation to Notice To Proceed (NTP) is not included.
2. Non-Contract Costs are included in this cost estimate to obtain a Construction Cost. The Non-Contract Costs shown are distributive only.
3. Project specific lands and rights, and contracts for relocation of property by others, are not included.
4. Construction Costs do not include land acquisition.

Reference documents RM D&S Cost Estimate (FAC 09-01) and RM D&S CCE and PCE (FAC 09-02).

QUANTITIES		PRICES	
BY —	CHECKED —	BY L. Zlomke	CHECKED Kyle Hughes 8-25-09
DATE PREPARED —	PEER REVIEW —	DATE PREPARED 8/25/2009	PEER REVIEW DCD 8/25/09

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: **Long Lake Valley Canal - Tunnel & Power Optimization Study** **Alternative 1: Option A: 1,000 cfs - Pumping Only** - ***19,000 ft Earthen Lined Canal from Klamath Lake to Long Lake Valley with fully lined reservoir*** **Summary Sheet:** **Alt1-OptA-PO-1000cfs-Earthen Lined Canal Full Lined Reservoir**	**PROJECT:** **Upper Klamath Offstream Storage Study** **At Long Lake Valley** **WOID:** LLVED **ESTIMATE LEVEL:** Appraisal **REGION:** MP **UNIT PRICE LEVEL:** Jul-08 **FILE:** H:\D8170\EST\Spreadsheet\Zlomke\0-Work Files\MP\LLV\LLV 350K AF Appraisal\1A & 1B fully lined\[Alt1-OptA-PO-1000cfs-Earthen Lined Canal with full res liner.xls]Alt1-OptA EC

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	1	**Canal ID: A1-1K-EC-19K (4 sheets)**					$168,138,400.00
	2	**Tunnel ID: A1-1K-T (1 sheet)**					$18,868,050.00
	3	**UK Intake/Fish Screen Eq ID: A1345-1K-PO&PG-IntFS Eq (3 sheets)**					$9,140,140.00
	4	**UK Intake/Fish Screen Hyd Eq ID: A1-5-1K-All-IntFS HydEq (1 sheet)**					$4,806,750.00
	5	**Fish Screen Pipe ID: A1-5-All-FSPipe (1 sheet)**					$305,456.00
	6	**UK Intake/Fish Screen Structure ID: A134-1K-All-FS Struct (1 sheet)**					$16,975,657.00
	7	**UK Intake/Fish Screen Cofferdams ID: A124-All-Coff-Rev1 (1 sheet)**					$5,329,000.00
	8	**UK Plant CS ID: A134-1K-PO&P-T-CSPlt (3 sheets)**					$54,568,925.00
	9	**UK Plant Mech Eq ID: A1-5-1K-PO-MEqPlt (3 sheets)**					$9,410,000.00
	10	**UK Plant Hyd Eq ID: A1-5-1K-PO-Plt HydEq (1 sheet)**					$12,600,000.00
	11	**UK Plant Pipe ID: A1-5-1K-PO-Plt Pipe (2 sheets)**					$25,035,656.00
	12	**UK Plant Electric ID: A1-5-1K-PO-Eplt (2 sheets)**					$11,496,400.00
	13	**Switch Yard & T-Line ID: A1&3-1K-All-SY (1 sheet)**					$8,753,000.00
	14	**Plant Penstock ID: A1-1K-All-PltPen (1 sheet)**					$1,191,000.00
	15	**LLV Intake Tower CS ID: A1&3-1K-All-T CS (2 sheets)**					$15,098,200.00
	16	**LLV Intake Tower Mech Eq ID: A1-5-1K-PO&PG-T-MEq (2 sheets)**					$7,758,750.00
	17	**LLV Intake Structure Hydraulic Eq ID: A1-5-1K-All-T HydEq (1 sheet)**					$2,030,000.00
	18	**Non Plant Structures Electrical ID: A1&3-All-NonPlt Elec (1 sheet)**					$1,288,200.00
	19	**350 TAF Full Clay Liner (1 sheet)**					$294,490,000.00
		Subtotal 1					**$667,283,584.00**
		Mobilization %		5.0%			$33,000,000.00
		Subtotal 1 w/Mobilization					**$700,283,584.00**
		Design Contingencies %		15.0%			$109,716,416.00
		APS = Allow: (Procurement Strategies) %		none			
		CONTRACT COST					**$810,000,000.00**
		Construction Contingencies %		25.0%			$190,000,000.00
		FIELD COST					**$1,000,000,000.00**
		Non-Contract Cost %		25.0%			$250,000,000.00
		CONSTRUCTION COSTS					**$1,250,000,000.00**
		Notes:					
		1. Escalation to Notice To Proceed (NTP) is not included.					
		2. Non-Contract Costs are included in this cost estimate to obtain a Construction Cost. The Non-Contract Costs shown are distributive only.					
		3. Project specific lands and rights, and contracts for relocation of property by others, are not included.					
		4. Construction Costs do not include land acquisition.					
		Reference documents RM D&S Cost Estimate (FAC 09-01) and RM D&S CCE and PCE (FAC 09-02).					

QUANTITIES		PRICES	
BY ---	CHECKED ---	BY L. Ziomke	CHECKED Kyle Hughes 8-25-2009
DATE PREPARED ---	PEER REVIEW ---	DATE PREPARED 8/25/2009	PEER REVIEW DED 8/25/09

Uncertainties of Conceptual Plan Features, Findings, and Recommendations

Given the limited design data and information on the existing conditions of each feature site, the cost estimates and design assumptions are subject to some uncertainties. Some issues that need further exploration and issues that would need to be addressed should the LLV planning process move to the higher level feasibility-level studies and investigations include:

- The location of the pumping plant—The same location as the 1970 proposal was assumed for planning purposes at this level. However, this site has not been determined as the optimal location and has been studied further within the tunnel/canal conveyance facilities optimization studies. (PP-1)

- Caledonia Canal and Wocus Drainage Canal—Data available on these features were minimal. Information on the canal existing conditions, capacity, operations, dimensions, and geologic conditions is needed to determine the most suitable design of this feature. The reconnaissance study did not examine if the present canal can handle the proposed pumping flow rates or if other improvements would be necessary. A specific inventory of potentially affected infrastructure also needs to be prepared. A subfeasibility-level optimization study has been undertaken to further determine alternative conveyance facility combination types and alignment configurations. This optimization study took into consideration any and all existing design data and would be the basis for the final feasibility-level design decisions and the subsequent conceptual plan configuration. (CCSFF-1)

- Highway 140 modifications—Depending on the location of the canal intake structure, other modifications/relocations of the Highway 140 bridge may be necessary. (CCSFF-2)

- The foundation conditions at all identified features (fish facilities, canal conveyance, pumping plant, tunnel, reservoir lining, etc.)—If adequate foundation materials are not present at relatively shallow depths, then the cost estimates for the fish facility, canal, and pumping plant may be low. The Oregon Department of Transportation was consulted, and they shared design data information on their recently completed Highway 140 at Caledonia/Wocus Bay bridge design. These data were in turn provided to TSC staff who worked on the optimization study for alternatives for the conveyance facility type and alignment. (CCSFF-1 and 2)

- Access roads—Other road alignments may be preferred to provide access to the pumping plant, tunnel, and outlet works tower. Information on the proposed roads was limited. The extent of improvements needed for construction and long term operation and maintenance were estimated based on verbal descriptions of the existing roads. (AR-1)

- Biological input on the proposed fish facilities—The intake structure (with fish facility) was patterned after the designs for A-Canal Fish Screen. However, the remote location of the Caledonia Canal inlet area may warrant a different arrangement of these facilities. The precise location and arrangement of the fish bypass facility would need much more refinement. (CCSFF-3)

- Dead storage elevation—Conceptual plan water storage elevation 4430 feet has been cited as 350,000 acre-feet of storage. This estimation is correct based on the area-capacity curve, which indicates this amount. However, this figure does not reflect the usable storage amount. Reclamation set the tunnel invert elevation (elevation 4270 feet) at 10 feet above the average valley bottom elevation. According to the area-capacity curve (dated 8-27-69) the amount of storage available between elevations 4270 and 4430 feet is approximately 340,000 acre-feet. In the 1970 study scenario most similar to this appraisal study, a tunnel invert of elevation 4271 feet was used. Also, the minimum water surface was identified at elevation 4296 feet. The amount of “usable” storage available between elevations 4296 and 4430 feet is approximately 305,000 acre-feet. Apparently, the cited 350,000 acre-feet of storage is a nominal figure. Care should be taken when indicating the actual usable capacity of the conceptual plan. (RES-1)

- Reservoir storage—A potential exists for Long Lake Valley to hold up to 500,000 acre-feet. This should be further explored in feasibility-level studies should the decision be made to proceed with further studies. (RES-2)

- Reservoir lining—Further hydrogeology studies need to be undertaken to improve upon the modeling efforts that were started under the appraisal-level investigations into the capability for the Long Lake Valley Reservoir to hold water. The hydrology modeling efforts should also determine, with greater certainty and accuracy, the location and types of lining needed. The lining feature of a conceptual plan as large in scale as LLV could be very expensive. (RL-1)

- Power generation—The opportunity for power generation should be further explored and refined within post-appraisal -level studies and investigations. Discussion with potential operating entities or partners, private and public, should be pursued. (PP-2)

- A potential exists, through the Klamath Basin Restoration Agreement, that the Klamath Project could receive BPA power at a project use power rate. Such a scenario needs to be investigated in feasibility-level studies along with the facilities that would be necessary to transmit the power from BPA facilities at either Malin or Captain Jack switchyards near Malin, Oregon across the Klamath Project to the proposed LLV pumping plant. Investigative studies need to consider that the length of such transmission lines may fall under the jurisdiction of the Oregon Energy Facilities Siting Council. (EP-1)

Summary

According to the design reconnaissance study with the price level updated to July 2008, an estimated \$1.25 billion is required to construct Long Lake Valley into a 350,000 acre-foot offstream storage reservoir with a 1,000-ft^3/s pumping plant capacity; and \$1.5 billion with a 2,000-ft^3/s pumping plant capacity. These two estimates represent the total construction costs, which consist of the field costs for all ten conceptual plan nonmitigation features and the noncontract costs. Even though the design reconnaissance study included some new reformulations—such as installation of a fish screen, elimination of a dam and dikes, construction of a pumping-only plant, and partial lining of the reservoir—further investigation would be recommended should the decision be made to proceed with further studies, especially to address the uncertainties associated with the conceptual plan features cost estimates and design assumptions.

Water Rights

KBAO has filed a Water Rights Application for surface water storage at Long Lake Valley with the Oregon Water Resources Department (OWRD). Preliminary discussions with OWRD have centered on storing water that ordinarily would be spilled from Upper Klamath Lake during winter and spring months.

An alternative reservoir capable of holding comparable volumes to LLV is the Whiteline Reservoir site, which has been identified in the early version of UKBOS IAIR as well. KBAO has begun preliminary studies to advance the LLV option to a feasibility-level study and has decided not to advance the Whiteline Reservoir option because preliminary construction cost estimates are approximately two times higher than those for LLV. The discussion of these two alternatives can be found in the IAIR. Nevertheless, the water rights application included the Whiteline alternative reservoir site so that if post-appraisal-level studies uncovered any problems that would not allow the Long Lake Valley Reservoir alternative site studies to proceed, studies could refocus and proceed on Whiteline with the foreknowledge that water rights were secure for it as well.

KBAO staff, working with TSC staff, have determined, through appraisal-level hydrologic model studies, that an average of 300,000 to 500,000 acre-feet of water could be available for storage in any given year. Reclamation is seeking OWRD concurrence with these appraisal-level hydrologic study results. The additional water storage available in the potential Long Lake Valley Reservoir would reduce the number of years in which there would be a shortage to the Klamath Project.

It is crucial to secure the water rights so Reclamation can proceed with the water storage project planning process. KBAO staff understand that other water rights filings may take place in the interim, which could reduce the amount of water available for the UKBOS alternatives. OWRD has concurred that all of the application materials, literature, maps, and other information meet requirements and is proceeding with the processing of the application for either of the two alternative reservoir sites at LLV or Whiteline in the amount of 350,000 to 500,000 acre-feet as of March 2009. Reclamation has requested an administrative hold on the processing of the application and will continue to do so until UKBOS studies conclude.

Hydrodynamics

A hydrodynamic model of Upper Klamath and Agency Lakes, Oregon, was used to explore appraisal-level effects of the operation of proposed off-stream storage in Long Lake Valley on transport of larval suckers through the Upper Klamath and Agency Lakes system during May and June when the larval fish swim up from spawning sites in the Williamson River and springs along the eastern shoreline. A range in hydrologic conditions was considered, including historically high and low outflows and inflows, lake elevations, and incorporation of pumps between Upper Klamath Lake and Long Lake Valley Reservoir. Two different wind forcing scenarios were considered: one dominated by moderate prevailing winds, and another dominated by a strong reversal of winds from the prevailing direction. Based on 24 model simulations that used all combinations of hydrology and wind forcing, as well as “with project” and “No-Action” scenarios, it was determined that, during the springtime period of interest, pumping rates between Upper Klamath Lake and Long Lake Valley would be low enough that the effects of conceptual plan operations on larval transport were most likely to be the result of alterations in management of the elevation in Upper Klamath Lake and the outflow at Link River and A Canal, rather than the direct result of pumping. The dominant effect was that an increase in lake elevation would result in more larvae in the Williamson River Delta and in Agency Lake, an effect that was enhanced under conditions of wind reversal. A decrease in lake elevation accompanied by an increase in the outflow at the Link River had the opposite effect on larval density and residence time. This appraisal-level hydrodynamic work focused on extreme operational scenarios, and therefore feasibility-level predictive modeling, if undertaken, should focus on more likely scenarios. (HD-1) The full hydrodynamic modeling report is available separately in Appendix A.

The scope of this study, for which the model was developed to accommodate post-appraisal-level model-supported studies, included a Long Lake Valley Reservoir storage capacity of 500,000 acre-feet, as well as two more potential withdrawal sites on the southern end of Upper Klamath Lake. However, the modeled reservoir storage capacity encompasses the appraisal-level 350,000-acre-foot capacity for Long Lake, and the model runs presented are only for a withdrawal/release point in Wocus Bay.

Seismotectonic Evaluation

In 2006, Reclamation undertook a study to provide screening-level ground motion parameters, in the form of a probabilistic seismic hazard analysis (PSHA), for use in feasibility studies designs and analyses for proposed offstream pump-storage facilities and/or structures located in and adjacent to Long Lake Valley near Klamath Falls, Oregon (figure 7). The results of this study were based on a review of existing data and limited analysis of vertical aerial photographs contained within the files of the Seismotectonics and Geophysics Group. No site visits were made, and no new geologic field studies were conducted as part of this analysis. The report on this study (Reclamation, 2007) is included in this appraisal report as appendix B.

Previous Reclamation seismic hazard studies in the Klamath Falls area include the deterministic study by Hawkins et al. (1989) for Fish Lake and Fourmile Lake Dams (northwest of Klamath Falls) as well as similar studies by Klinger et al. (1990, 1996) for Clear Lake and Gerber dams to the east (figure 7). Reconnaissance-level studies of several of the faults in the area were also conducted as part of seismic hazard studies for Clear Lake Dam (Anderson, 1999, unpublished data). Geomatrix (1995) conducted a State-wide seismic hazard study for the State of Oregon while Schapiro et al. (2002) did the first site-specific PSHA in the area for Gerber, Link River Diversion, Fish Lake, and Savage Rapids Diversion Dams as part of Comprehensive Facility Reviews for these Reclamation structures.

The latest study for the Long Lake Valley area built upon these earlier seismic hazard investigations and presented the results as hazard curves of peak horizontal acceleration (PHA) and 1-second spectral acceleration (1-s SA). For the purposes of this study, a “site” area was chosen in the general center of Long Lake Valley (figure 7).

The results of this screening-level analysis showed that for return periods greater than about 1,000 years, the faults of the Klamath graben—in particular, the nearby faults associated with the southwest margin of the graben—dominate the seismic hazard at Long Lake Valley. At shorter return periods, large events from the Cascadia plate interface dominate the hazard. For 1.0-s spectral response, the hazard is dominated by the Cascadia interface up to a return period of 30,000 years, and the southwest Klamath Lake fault beyond that. Surface fault rupture, as well as liquefaction and seismically induced landsliding are potential hazards to facilities constructed within and near the margins of both Long Lake Valley and Wocus Marsh. Options that include pumping of water into shallow aquifers as a water storage mechanism, or construction of a small reservoir appear to pose a negligible risk of inducing seismicity.

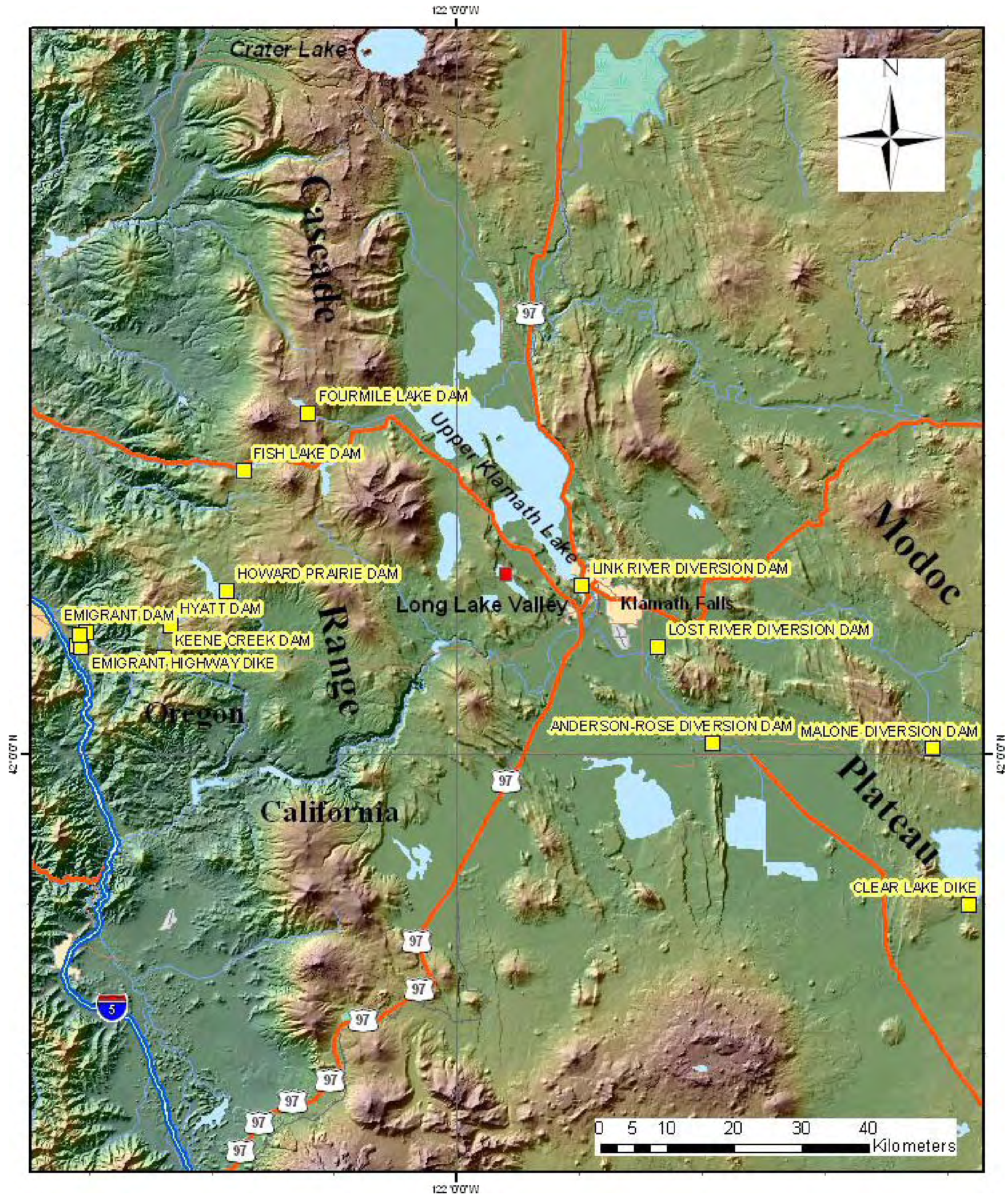

Figure 7.—Map showing the location of the Long Lake Valley site (red square) as well as other Reclamation facilities in southern Oregon and northern California.

The latest study was a screening-level analysis for a generic site in Long Lake Valley. As such, a simplified source model and "rock" site conditions were assumed. Depending upon the location and type of facility considered for construction, additional studies for feasibility-level or final designs should include a more detailed seismic source model and geologic field studies to better define slip rates and fault locations. Such investigations should refine the rather simplified seismic source model used for this analysis and better define the risks associated with potential surface fault rupture and other earthquake-related hazards.

This PSHA was computed assuming generic "rock" site conditions. As potential sites and associated structures become more specifically identified, the PSHA also should be recalculated using appropriate site correction factors. Finally, a M~6.0 earthquake sequence that occurred in 1993 (Braunmiller et al., 1995) is important in that it was near or directly below Long Lake Valley. Although detailed seismological analyses have been performed for the sequence, it is likely that additional analyses, including a simultaneous three-dimensional velocity model-hypocenter inversion and site response studies, would provide more accurate information regarding fault geometries, velocity structure, maximum depth of faulting, wave propagation, and site response characteristics than is currently available. Analyses of this type also are recommended for any further site development studies. (ST-1)

Biological Resources

This section describes biological resources in the conceptual plan area and potential issues concerning the conceptual plan plans that may be necessary to address during conceptual plan planning or that warrant further review as part of the NEPA compliance process. Biological resource issues are identified based on appraisal of existing conditions and information contained in the Long Lake Valley IAIR. The actual scope of NEPA biological resource investigations depends on the viable alternatives yet to be determined through appraisal and feasibility-level planning efforts.

Purpose and Scope

For appraisal purposes, the biological resource study area includes the proposed Long Lake Valley Reservoir site (closed basin); the corridor used for water conveyance and control structures; a quarry "borrow site" area for construction materials; external features such as access roads and power lines; and nonstructural attributes associated with reservoir operations. The proposed Long Lake Valley Reservoir site vicinity and related conceptual plan features are depicted in figure 8. Potential implications for the downstream Klamath River are not included in the current scope.

Conceptual Plan Area Description

The proposed reservoir site is located within a rural setting. Seasonal wetlands/grasslands occupy the valley floor, and forest covers the surrounding slopes and ridges.

The primary land-owner uses most of the valley bottom lands for seasonal cattle grazing. In the center of the valley, forage is enhanced with groundwater supplied through a small ditch irrigation system. Sprinklers irrigate a small portion of the southern valley floor for hay production.

The remainder of the valley bottom lands are naturally irrigated by snowmelt and direct precipitation, and most of the northern part of the valley is operated under a grazing lease from the BLM. Drainages that flow from the ridges into the valley are small seasonal streams. Some of these ephemeral streams have been modified (channelized and extended) to better serve the irrigation function and now divert water directly into the irrigation ditch system. Two small man-made ponds at the south end of the valley are used to store spring snowmelt water for farm uses.

Figure 8.—Long Lake Valley Reservoir site aerial rendition (adapted by Riedman and Fenton, 2008).

The corridor proposed for reservoir water conveyance systems runs along the base of the forested ridge that forms the east side of the reservoir basin and the western edge of the diked and drained farm area known as Wocus Marsh. The proposed corridor is 3 miles long and 300 feet wide. An existing 60-foot wide irrigation ditch with adjacent access road and levee runs along the southernmost two-thirds of the corridor length.

Conceptual plan plans include a potential borrow source area at Round Lake Hill that could be used to excavate materials for construction. This borrow area is undeveloped forest, open meadow, and rock outcroppings.

Regulatory Considerations

The proposed LLV offstream storage reservoir conceptual plan has regulatory implications concerning biological resources. Dredge and fill activities in regulated waters or wetlands could be subject to the provisions of Section 404 of the Clean Water Act (CWA), administered by the U.S. Army Corps of Engineers (USACE) and similar provisions of the Oregon Department of State Lands (DSL).

For example, construction within the proposed closed reservoir basin may not require a 404 permit because the seasonal wetlands in the valley basin were determined to be “isolated” waters that are not subject to Federal CWA jurisdiction (USACE, 2007). However, the proposed reservoir water conveyance systems could require delineation of existing wetlands and a Section 404 permit from the USACE and/or a Removal-Fill permit from DSL for construction.

Activities that could affect federally listed, threatened, or endangered species or their designated critical habitat are subject to the provisions of the Endangered Species Act. Other regulatory considerations may include the Klamath County Special Resource Overlays concerning large game and Bald Eagles. In addition, provisions of the Migratory Bird Treaty Act should be reviewed with respect to conceptual plan actions in subsequent planning stages. Detailed assessments of listed species and potential impacts on birds or wildlife should occur during subsequent NEPA and feasibility-level planning stages.

Existing Vegetation and Wildlife

Biological resources are linked to the vegetation communities and land uses in the conceptual plan area. Distinctive vegetation communities based on dominant plant species that are evident in the area are shown in figure 9.

The dominant communities are grouped into emergent wetlands, riparian and shoreline zones, canal/drain habitats, agricultural lands, forest/woodlands, and shrub lands. The occurrence and locations of these communities is influenced by prevalent land uses, topography, surface and groundwater hydrology, and other human disturbance or exposure factors.

Upland Communities and Habitats

Upland vegetation communities in the reservoir site area fall into two categories, agricultural lands and forested woodlands. Wetland communities including wet meadow, emergent marsh, and aquatic riparian zones are described separately.

Agricultural Lands

Agricultural land uses throughout the proposed conceptual plan vicinity include cultivated crops, irrigated pasture, and unimproved (unirrigated) pasture. Wocus Marsh is primarily agricultural lands that are intensively managed for cultivating hay and small grains including alfalfa, wheat, barley, and oats. Irrigated pastures

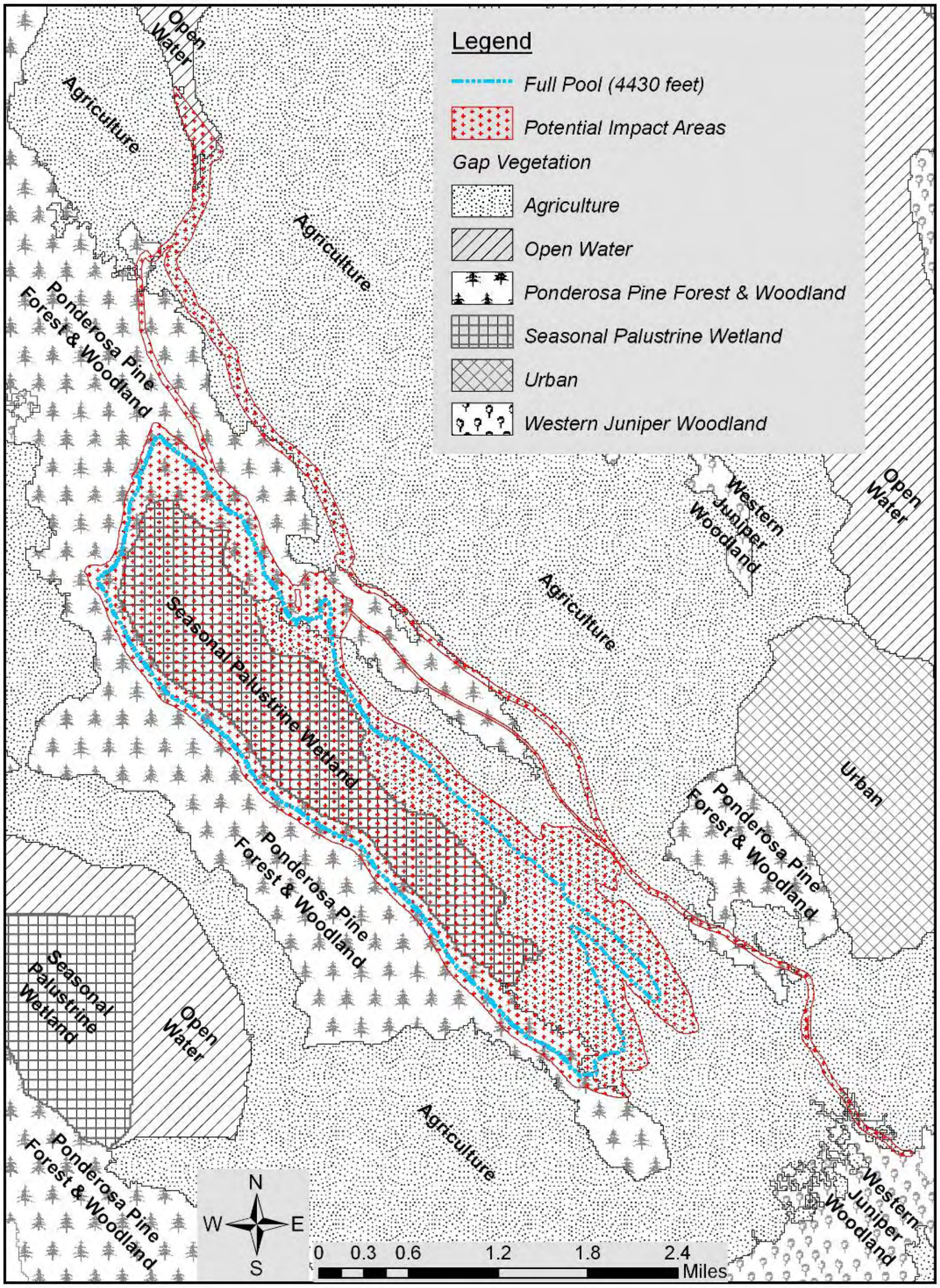

Figure 9.—Long Lake Valley area vegetation and land uses (adapted from Oregon, 1998).

are disked and planted with livestock forage or turf grasses such as intermediate wheatgrass (*Elytrigia intermedia*), Kentucky bluegrass (*Poa pratensis*), fescues (*Festuca* spp.), redtop (*Agrostis alba*), and foxtails (*Alopecurus* spp.). Dryland grasses and legumes dominate unirrigated pasture lands. Both irrigated and unimproved pastures in the conceptual plan area typically are used for seasonal cattle grazing and, less frequently, for horses and sheep.

The intensive management of cultivated croplands, including disking, crop rotation, harvest activities, grazing, and the use of chemicals, reduces the value of these habitats for wildlife; however, many common wildlife species have adapted to particular agricultural types and use them for foraging and nesting.

Irrigated pastures offer some species habitats similar to those of seasonal wetlands and nonirrigated pastures; however, if frequently harvested, the habitat quality for ground-nesting wildlife is reduced. Irrigated pastures also provide foraging and roosting for many shorebird and wading bird species including killdeer, long-billed curlews, sandhill cranes, and white-faced ibis.

Lightly grazed, nonirrigated pastures have value similar to native grasslands, providing forage and cover for seed-eating birds and small mammals. Larger mammals ranging from raccoons to deer are also commonly found using agricultural lands for foraging and travel corridors. Small mammals found in the area pasture habitats include voles, pocket gophers, and ground squirrels.

Alfalfa grown in irrigated pastures can provide high quality forage for rodents, and as a result, recently harvested croplands often provide high quality feeding areas for raptors including hawks, owls, and falcons that prey on rodents. Some waterfowl and ground-nesting birds such as pheasants, western meadowlark, and quail are also found in pasture areas if adequate residual vegetation remains after harvesting or grazing.

Seasonal grasslands located on the valley floor and the predominantly forested upland slopes around the reservoir site are depicted in figure 10.

Forested Woodlands

Ponderosa pine forest and woodlands typical of the eastern Cascade Mountains in central Oregon, are a major cover type in the mid to lower elevation zones along the proposed reservoir basin slopes and borrow area (figures 8 and 9).

Overstory trees are typically widely spaced and include ponderosa pine (*Pinus ponderosa*) and white fir (*Abies concolor*). The understory layer may include regeneration of the overstory species, as well as shrubs such as bitterbrush (*Purshia tridentata*), serviceberry (*Amelanchier alnifolia*), mountain mahogany (*Cercocarpus ledifolius*), and Greenleaf manzanita (*Arctostaphylos patula*).

Herbaceous common grasses may include Idaho fescue (*Festuca idahoensis*) and various wheatgrass, bluegrass, and brome species. Small linear stands of Aspen (*Populus tremuloides*) occur in isolated locations along the western edge of the valley floor within the Long Lake Valley Reservoir site and borrow area.

Figure 10.—Long Lake Valley looking north, along reservoir site bottom in May 2008.

Wetland and Riparian Communities and Habitats

Wetlands and riparian communities are present within the proposed reservoir site and the areas designated for water supply facilities. These areas can support a broad variety of wildlife and ecosystem food chain functions.

Wetland Habitat

Wetland habitats vary greatly and are generally distinguished by the amount and duration of water. Seasonal to permanently flooded emergent and aquatic bed wetlands (Cowardin, et al., 1979) are present throughout the Long Lake Valley bottom area. Flooding of major portions of the valley floor during the spring is evident in figure 11. An existing wetland pond located in the southern end of the valley is shown in figure 12.

A recent wetland delineation survey documents the presence and boundaries of existing wetlands within the proposed 350,000 acre-foot reservoir site area (TetraTech, 2007). A functional assessment of these delineated wetland areas was completed in 2009 to further differentiate specific wetland functions and values according to Oregon DSL criteria.

Riparian Areas

Within the reservoir site, riparian areas are limited to the few small tributary streams that flow from the local forest hills into the valley. Nevertheless, these areas could warrant further review because of the vital functions that transitional riparian zones serve for food, cover, and migration corridor habitats.

Figure 11.—Long Lake Valley looking south at the wet valley floor in May 2008.

Figure 12.—Long Lake Valley small wetland pond near the south end in May 2007.

Lake/Reservoir Shoreline Habitat

Other than the wetland pond fringes, shoreline habitat is not present in the reservoir valley site area. The existing Upper Klamath Lake shoreline habitat near the proposed conceptual plan diversion controls is relatively small in comparison to the entire lake shore perimeter. However, this area could require additional review when specific information is available regarding the design of these facilities.

Aquatic Communities and Habitats

Most of the reservoir site area and lands designated for water supply facilities are presently upland terrestrial areas. As a result, the existing aquatic communities and habitat within the conceptual plan area are generally limited to small localized areas near existing agricultural water systems.

Existing fish species within Upper Klamath Lake, including endangered Lost River and shortnose sucker species, are a particular concern. Factors such as the life cycle, distribution in the lake, and annual movement warrant further evaluation. Fish screen systems for the proposed reservoir water supply are an important identified need.

Canals and Drains

Unlined canals and drains provide wetland and aquatic habitats throughout the Klamath Basin including the general conceptual plan vicinity. The quality of habitat varies depending on the degree and frequency of maintenance, duration and seasonality of flows, water quality, types of adjacent habitats, and other factors.

The small irrigation system that operates seasonally on the LLV floor provides minimal aquatic habitat due to the small size of its ditches and the limited duration of its seasonal operation. Within the proposed intake/outlet canal corridor, the existing Wocus Drain is a substantial permanently watered canal that is not screened to prevent fish passage.

Lakes, Reservoirs, and Ponds

Only small wetland ponds are found in the reservoir site. All areas that could be inundated by the proposed reservoir waters are included in the functional wetland delineation and associated permitting requirements.

The quality of water withdrawn from Upper Klamath Lake and returned from the proposed reservoir is a potential concern since the quality and temperature could change during storage in the proposed reservoir. The nature and extent of any potential effects depends on design and operational details that remain to be determined through further conceptual plan planning stages. As a result, these processes and potential biological implications require more detailed investigation once information is available for specific design and operating alternatives.

In addition, possible implications of the proposed Long Lake Valley Reservoir operations on conditions within Upper Klamath Lake or the downstream Klamath River may warrant further review and investigation. For example, augmenting the annual storage in Upper Klamath Lake could alter water release patterns to the river. At this point, it is impossible to determine whether influences on hydrologic patterns and biota in the lake or river could be significant or subtle. Specific information and data on the reservoir operating scenarios are essential to accurate evaluation.

Special Status Species

Species that are identified as threatened or endangered (T&E) according to the provisions of the Endangered Species Act could require special attention during subsequent conceptual plan planning. A complete and approved list should be requested from the U.S. Fish and Wildlife Service as part of the ESA compliance process during any further project planning and feasibility-level investigations. An initial review and tentative list of potential T&E species is shown in table 1.

A federally listed T&E plant species, Applegate's milk-vetch (*Astragalus applegatei*), is found in Klamath County (http://www.fws.gov/klamathfallsfwo/es/species_list/Klamath County Species List.pdf). Other possible sensitive species are Peck's milk-vetch (*A. peckii*), Pumice grape-fern (*Botrychium pumicola*), and Gentner's fritillaria (*Fritillaria gentneri*). Of the four, only Applegate's milk-vetch is found in areas with conditions similar to the proposed reservoir facilities. No special status plant species were found during a recent survey on the BLM lands within the valley area. However, the reservoir site and associated facility lands would require more detailed evaluation as part of subsequent NEPA investigations and feasibility-level planning stages.

Summary of Potential Biological Issues

Biological resources in the vicinity of the proposed Long Lake Valley Reservoir conceptual plan are identified for use in further planning and assessments conducted to meet the provisions of NEPA. At the appraisal level, the intent is to identify biological resources and potential issues; however, this initial review does not replace or preclude NEPA or ESA compliance in any way. Potential biological resource issues identified for further review are summarized in table 2.

Table 1.—Tentative list of special status species in the proposed conceptual plan site area

Species	Federal status	State status	Suitable habitat in conceptual plan area?
Bald eagle	Formerly Threatened, still protected under Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act	Threatened	Nesting sites observed and possible foraging habitat in vicinity of canal and reservoir sites. Klamath Co. bald eagle State recreation area (SRA) nearby.
Northern spotted owl	Threatened	Threatened	None
Greater sandhill crane		Sensitive Vulnerable	Suitable foraging habitat available
Oregon spotted frog	Candidate	Species of Concern	Suitable habitat available
Lost River sucker	Endangered	Endangered	Possible migratory and rearing in vicinity of diversion structure and potential mitigation sites; larvae may be entrained in UKL water supply into Long Lake Valley Reservoir
Redband trout		Sensitive	Possible presence in vicinity of diversion structure and potential mitigation sites; larvae may be entrained into reservoir
Shortnose sucker	Endangered	Endangered	Possible migratory and rearing in vicinity of diversion structure and potential mitigation sites; larvae likely entrained in UKL water supply into Long Lake Valley Reservoir
Bull trout	Threatened	Threatened	None
Applegate's milk vetch	Endangered		Possible habitat in the reservoir basin (no individuals observed during limited survey effort)

Table 2.—Summary of potential biological resource issues and considerations that are identified for further review and assessment

Resource	Issue description
Upland resources	
Forest lands	Forest lands around the reservoir basin slopes that are inundated by the reservoir high water level could be permanently lost. Localized forest areas could also be permanently lost to construct the new access roads and water conveyance systems. Temporary haul roads, borrow source excavation areas, equipment yards, and other areas disturbed during construction should be restored to the original landscape, as much as practicable, by regrading, planting, and seeding as required. Flooding the basin may interrupt migratory corridors; agency personnel familiar with big game movements should be consulted to determine potential effects.
Large birds	Depending on design and location, placement of the conceptual plan electric transmission lines and towers could result in collision hazards for raptors, sandhill cranes, and other large birds. The nearby presence of nesting raptors may affect construction timing, and removal of nest trees may require mitigation; a nest survey should be considered.
Agricultural lands	Temporary or permanent effects to agricultural land and other uplands associated with the pumping plant, reservoir outlet works, and canal intake and conveyance facilities are expected to be minor.
Wetland and riparian	
Existing valley wetlands within reservoir site	Construction and operation of the proposed 2,700-acre reservoir would result in the permanent loss (inundation) of 1,331 acres of valley floor wetlands. The affected wetlands include 1,263 acres of seasonal and semi-permanently flooded emergent wetlands, 54 acres of shrub wetlands, and 14 acres of ephemeral drainages and farm ponds. The USACE (2007) determined these wetlands were isolated from Waters of the U.S. and thereby not subject to jurisdiction under the Clean Water Act, Section 404. No determination has been made by the Oregon DSL.
Proposed water conveyance systems	Construction of the proposed 3.6-mile inlet/outflow canal (immediately adjacent to the existing earth-lined 60-ft wide Wocus Drain) potentially could adversely affect up to 50 acres of emergent, aquatic bed, and lacustrine wetlands that have developed within and adjacent to the existing canal. Loss of these wetlands could be subject to regulation by both the USACE and DSL.
Proposed reservoir operations	At the full pool elevation 4430 feet, the proposed Long Lake Valley Reservoir has about 13.5 miles of shoreline. However, fluctuating water levels are expected to limit the quality of habitat. Common vegetation along a fluctuating reservoir's drawdown zone may be dominated by invasive annual forbs and grasses. Fluctuating shorelines tend to have low value for most wildlife species because generally no vegetation exists to provide forage and cover. Barren shorelines may attract use by small numbers of shorebirds (killdeer, stilts, avocets), wading birds (herons, egrets), dabbling ducks (mallards, wigeon, gadwall), and coots that feed on invertebrates, herbaceous vegetation, or seeds scattered along the shoreline.
Aquatic resources	
Reservoir waters	Construction of the fish screen facility and portions of the canal would result in temporary construction effects. Fish screen operations in Upper Klamath Lake could reduce fish losses of juvenile fish by entrainment, but larvae may still be entrained to Long Lake Valley Reservoir, so options for a fish screen in Long Lake Valley Reservoir to retain fish in the reservoir should be considered. Allocation of Long Lake Valley Reservoir water should include contingencies for releases to address fisheries concerns. Larval fish distribution in Upper Klamath Lake may be affected by Long Lake Valley Reservoir pumping operations. Investigations of how circulation patterns may change in Upper Klamath Lake are under way, and results should be considered in future planning stages. Construction and operation of the inlet/outflow canal could result in temporary and adverse effects to the historic operation of the existing Wocus Drain canal affecting a canal fishery. Construction and operation of the proposed Long Lake Valley Reservoir may provide a limited fishery, or provide suitable habitat for fish from Upper Klamath Lake, either of which may cause reservoir operators to conduct fish salvage operations during drawdown. However, the water quality, temperature conditions, and operational effects (filling and drawdown) require more detailed evaluation when accurate information is available regarding the proposed reservoir design and operations.
Special status species	
Tentative list above	A final approved list should be requested from the FWS and the Oregon Department of Fish and Wildlife (ODFW) and evaluated during subsequent NEPA and feasibility-level planning.

Long Lake Valley Wetland Delineation

Wetlands in Long Lake Valley and at the inflow canal corridor/intake/pumping plant could be inundated or disturbed as a result of the proposed action. In order to consider the potential effects and any potential mitigation that could be required, Reclamation delineated wetlands and other Waters of the U.S. in the action area. Appendix C gives the entire report on this effort (Reclamation, 2007).

As discussed previously in *Biological Resources—Regulatory Considerations*, under the Clean Water Act and possibly Oregon State Law, mitigation for impacts to wetlands will most likely be required for the construction of Long Lake Valley Reservoir. In a preliminary effort to determine possible sites for such mitigation, wetland delineations were conducted on ALR and Barnes Ranch, properties owned by Reclamation and the Fish and Wildlife Service, respectively. The delineations were performed in order to determine if they could be viable options for wetland mitigation sites (Reclamation, 2009; North State Resources, Inc., 2007). Although these properties might provide some potential as mitigation sites, additional properties and the feasibility of using these properties need to be further evaluated. Other sites in the Klamath Basin could provide a more viable option for mitigation than ALR and Barnes Ranch. Wetland mitigation can become a costly component of this conceptual plan due to the magnitude of impacts to existing wetlands; therefore, all mitigation sites and options need to be fully analyzed and issues further vetted.

Discussion

The conceptual plan area is shown in figures 13 (Long Lake Valley) and 14 (canal area). A total of 200 plots were sampled along 24 transects. Drainages and upland areas were also characterized. Six wetlands and nine other Waters of the U.S. (intermittent streams and canal deepwater habitat) were delineated.

According to the USACE *Wetland Delineation Manual* (1987) and subsequent implementation guidance, including the *Arid West Region Interim Regional Supplement* (USACE, 2006), positive indicators of three parameters (hydrophytic vegetation, hydrology, and hydric soils) must be present to make a wetland determination. The Arid West Regional Supplement was used to provide additional indicators for each of the parameters. However, because this site is a potential problem area due to grazing, volcanic soils, pronounced summer/fall drought, and hydrologic manipulation through irrigation and drainage ditches, indicators for one of the parameters, hydric soils, hydrology, or hydrophytic vegetation were missing in a few sample locations.

Figure 13.—Conceptual plan site aerial view for Long Lake Valley with conceptual plan boundary at elevation 4430 feet.

Figure 14.—Conceptual plan site aerial view for the inflow canal area showing 300 foot conceptual plan boundary.

Positive indicators for all three parameters were found at the vast majority of the 114 wetland sample plots. Hydric soil indicators were lacking at some sample sites within wetland 1 (figure 15), which occupies all but the southern end of the valley bottom. However, at these sample sites, the hydrophytic vegetation and hydrology indicators were very strong. The dominant species at both plots were greater than 50 percent FAC or wetter (typically FACW or wetter), and there were distinct surface soil cracks and/or drainage patterns.[5] The preponderance of evidence indicates that these communities are seasonally inundated, most likely in the spring following snow melt (April-May). The landowner indicated that during winter, the entire valley typically becomes inundated.

Approximately 1,381 acres are either wetlands or Waters of the U.S. Wetland 1 consists of five different wetland habitat classifications (Cowardin et al., 1979) including palustrine emergent semipermanently flooded diked/impounded (PEMFh), palustrine emergent seasonally flooded (PEMC), palustrine emergent seasonally flooded diked/impounded (PEMCh), palustrine emergent temporarily flooded (PEMA), and palustrine scrub/shrub temporarily flooded (PSSA), and totals 1,316 acres for the entire wetland. The hydrogeomorphic (HGM) classifications for these habitats are depressional closed permanent or nonpermanent (depending on the duration of inundation).

Wetland 2 (figure 15) consists of two different wetland habitat classifications (Cowardin et al., 1979) including palustrine aquatic bed semipermanently flooded diked/ impounded (PABFh) and palustrine emergent seasonally flooded diked/ impounded (PEMCh) and totals 4.60 acres. The HGM classifications for these habitats are depressional closed permanent or nonpermanent (depending on the duration of inundation).

Wetland 3 (figure 15) consists of two different wetland habitat classifications (Cowardin et al., 1979) including riverine intermittent streambed vegetated (R4SB7) and palustrine aquatic bed rooted vascular seasonally flooded (PAB3C) and totals 0.32 acres. The HGM classifications for these habitats are riverine flow-through and riverine impounding.

Wetland 4 (figure 15) has one wetland habitat classification (Cowardin et al., 1979) of palustrine emergent seasonally flooded (PEMC) and is 0.06 acres. The HGM classification is depressional closed nonpermanent.

Ephemeral drainage channels are classified as riverine intermittent streambed cobble-gravel (R4SB3) except for one riverine intermittent streambed vegetated (R4SB7) drainage. The ephemeral drainage channels in Long Lake Valley total 10.04 acres. The HGM classification is riverine flow-through.

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[5] FAC = occurs equally in wetlands and uplands
FACW = occurs more in wetlands than in uplands

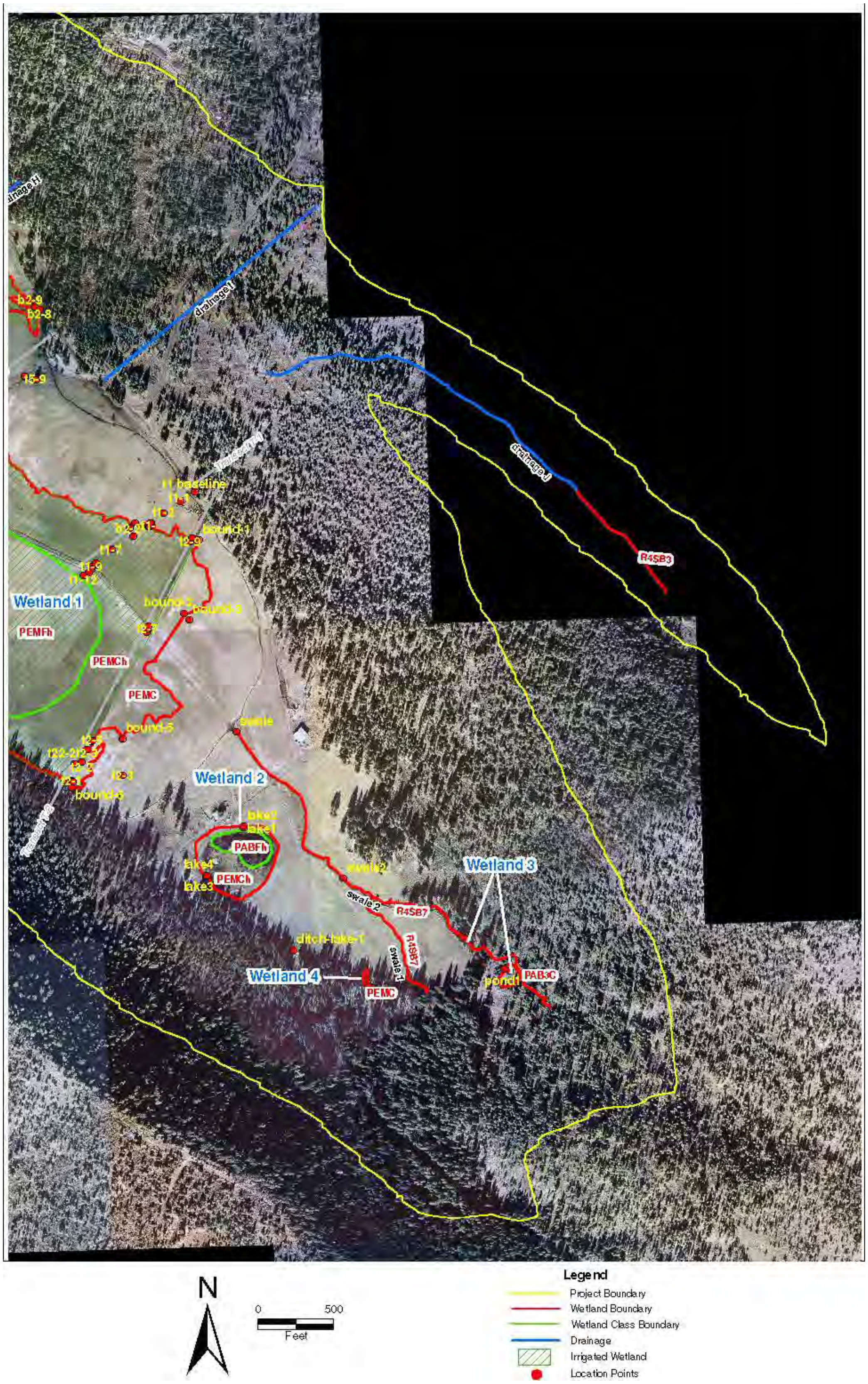


Figure 15.—The southern end of the Long Lake Valley study area.

The southern canal wetland has two wetland habitat classifications (Cowardin et al., 1979) of palustrine aquatic bed unknown submergent semipermanently flooded (PAB5F) with a fringe of palustrine emergent seasonally flooded (PEMC) that cannot be identified on aerial photos due to the wetland boundary line being as wide as the fringe (typically fringe is only 10 feet in width). The farmed or pastured fields are one habitat classification (Cowardin et al., 1979) of palustrine emergent saturated diked/impounded (PEMBh), and the north canal area that is essentially part of Upper Klamath Lake is lacustrine limnetic aquatic bed permanently flooded diked impounded (L1ABHh). The total acreage of wetlands is 51 acres.

The quality of wetland 1 is moderate to high in that the plant communities are very diverse and provide significant nesting habitat for a variety of waterfowl and migratory birds, but the whole site has been subject to significant disturbance such as grazing, leveling, and irrigation and drainage. The canal area has been significantly disturbed from its historic wetland state and is now entirely manipulated by the irrigation system. It is of relatively low quality with very few native species present.

Numerous bird species were observed in Long Lake Valley including yellow-headed blackbird, red-winged blackbird, black tern, greater sandhill crane, western meadowlark, American goldfinch, bald eagle, red-tailed hawk, and unidentified songbirds. An unidentified small rail was also observed, potentially a yellow rail. At the Wocus Marsh canal area, waterfowl including western grebe, wigeon, Canada geese, and pelicans were observed.

The upland areas up to elevation 4430 feet are also quite diverse. *Pinus ponderosa/Purshia tridentata* woodland dominates the west-facing slopes whereas Douglas fir, grand fir, and incense cedar forest dominate the east-facing slopes. No endangered, threatened, or otherwise rare plant species were encountered, but over 60 species were identified in the uplands. The landowner indicated that the uplands are only subjected to light and infrequent grazing, thus maintaining a largely native species dominated ecosystem.

Conclusions

In conclusion, six wetlands and nine other Waters of the U.S., totaling 1,381.43 acres, are present on the conceptual plan site. Vegetation communities within the wetlands include: *Scirpus acutus* marsh (PEMFh and PEMF), *Eleocharis/Juncus* marsh (PEMFh and PEMF), *Typha* marsh (PEMFh and PEMF), and *Alopecurus* seasonal wetlands (PEMC), *Artemisia cana* seasonal wetland (PSSA), and farmed/grazed pasture wetlands (PEMBh).

Table 3.—Summary of Long Lake Valley wetland characteristics

Wetland/water ID	Cowardin et al. (1979) classification	HGM classification	Acreage	Preliminary jurisdictional determination*
Long Lake Valley				
Wetland 1	Pemfh	Depressional closed permanent	230	Isolated
	PEMC	Depressional closed nonpermanent	780	Isolated
	Pemch	Depressional closed nonpermanent	100	Isolated
	PEMA	Depressional closed nonpermanent	152	Isolated
	PSSA	Depressional closed nonpermanent	54	Isolated
Wetland 2	Pabfh	Depressional closed permanent	1.4	Isolated
	Pemch	Depressional closed nonpermanent	3.2	Isolated
Wetland 3	R4SB7	Riverine flow-through	0.4	Isolated
	PAB3C	Riverine impounding	0.32	Isolated
Wetland 4	PEMC	Depressional closed nonpermanent	0.06	Isolated
Wocus Marsh/Canal				
Canal	PAB5F	Lacustrine fringe valley	14.5	Jurisdictional
	PEMC	Lacustrine fringe valley	4.8	Jurisdictional
Fields	Pembh	Lacustrine fringe valley	11.7	Jurisdictional
Northern Canal/Lake	L1abhh	Lacustrine fringe valley	20	Jurisdictional

* Long Lake Valley is not connected to any other water bodies; all runoff flows into the valley as a "sink." The USACE has preliminarily determined that this valley is isolated (Pers. Comm. Benny Dean, U.S. Army Corps of Engineers, July 2007).

A wetland functional assessment was conducted in 2009. Functions that both sites likely perform include bird and mammal habitat, amphibian habitat, storage of runoff from adjacent slopes, groundwater recharge, and filtration of runoff from adjacent slopes.

Long Lake Valley is a sink that collects runoff from the adjacent hillslopes, but there is no outlet. This potentially isolated wetland still provides a significant area of habitat for waterfowl, songbirds, raptors, small mammals, and amphibians.

The Wocus Marsh canal area is highly modified for agricultural purposes including grazing and farming, and the majority of the delineated area consists of drainage and irrigation canals (Wocus Drainage Canal) and lateral irrigation ditches. However, this area was a former marshland connected to Upper Klamath Lake. This area still provides habitat for waterfowl, and is primarily dominated by nonnative species.

Cultural Resources

The purpose of this section is to provide a broad prehistoric, ethnographic, and historic overview for Long Lake Valley and address potential future cultural resource requirements should the conceptual plan progress to a feasibility-level study. This overview includes a synthesis of the existing literature for cultural resources and information received from Federal, State, and local agencies, Indian tribes, and other interested persons to determine what cultural resources may be present at Long Lake Valley.

A search of records at the Oregon State Historic Preservation Office, requested on August 20, 2004, identified no archeological sites or inventories performed within Long Lake Valley, on the valley floor and around its rim. Reclamation contacted the current land owners, Jim and Carol Creswell, who identified the remains of historic structures, but no archaeological sites. Reclamation sent letters to the Klamath Tribes on May 24, 2005 and March 27, 2007 requesting information regarding any possible properties of religious and cultural significance within Long Lake Valley pursuant to the regulations at 36 CFR 800.4(a)(4). To date, the Klamath Tribes have provided no information.

While there is little cultural resource information available for Long Lake Valley and its vicinity, the archaeological, ethnographic, and historic resources documented throughout the Upper Klamath Basin provides a relevant backdrop for predicting what resources may be found in Long Lake Valley. A number of archeological investigations have been completed for the Upper Klamath Basin. Early archaeological investigations were conducted in the region by anthropologist Leslie Spier (1930) around Upper Klamath and Agency Lakes, along the Sprague River by Cressman (1956), and in Lava Beds National Monument by Squire and Grosscup (1954) and Swartz (1964). Later work was conducted at Lower Klamath Lake by McGuire (1985) and Sampson (1985). Mack (1979; 1983) also conducted a substantial amount of archeological research along the Klamath River. Other cultural resource overviews have also been completed for lands managed by the Bureau of Land Management adjacent to Upper Klamath Lake (Follansbee and Pollack 1978) and the United States Forest Service (Thompson et al., 1979). More recently, many prehistoric and ethnographic inventories conducted within the Upper Klamath Basin have been compiled in comprehensive studies produced by Bailey (2005), PacifiCorp (2003; 2004), and Reclamation (West and Welch, 2003).

These projects, among others, have revealed an apparently continuous occupation within the Upper Klamath Basin from prior to 7,000 years ago to present. The widest variety and greatest number of sites have been documented along marshes, lakeshores, and river courses. The majority of intensive surveys have occurred around the wetland, lake, and river margins, resulting in a greater frequency of sites as opposed to areas more distant from large water sources; therefore, more than 35 archaeological sites have been identified around the shores of Upper Klamath and Agency Lakes (Thompson, et al. 1979). There are also many sites that are located away from the large bodies of water. Site types range from lithic scatters to house pits to campsites to vision quest sites.

The Klamath and Modoc people occupied the Klamath Basin from approximately 6,500 years ago to European contact (Cressman, 1956; Sampson, 1985; Stern, 1998). They spoke dialects of a single language, one of the Plateau Penutian family (Stern, 1998). The major divisions related to the winter settlements, which constituted semi-autonomous political entities rather than reflecting subcultural differences. The Klamath groups generally occupied the areas around Klamath Marsh, Upper Klamath Lake, and the Williamson and Sprague Rivers. Modoc groups generally occupied Lower Klamath Lake, the Klamath River, and Tule Lake areas. Klamath/Modoc villages were located along the shores of lakes and streams. Many of these villages were occupied year round, and fishing continued through the winter months. Approximately 36 ethnographic village sites have been documented close to the shorelines of Upper Klamath and Agency Lakes (Spier, 1930; Theodoratus et al., 1990). Most of the archaeological record can be linked to Klamath and Modoc people who historically inhabited the area (Cressman, 1956; Sampson, 1985; Stern, 1998). No ethnographic study has included Long Lake Valley.

Euro-American settlement in the Klamath Basin was slow due to its isolation, lack of transportation routes, and conflicts with Klamath and Modoc people. Up to about the 1850s, many fur traders and explorers traveled through the area, but few Euro-Americans established permanent residence. By 1900, however, sustained settlement, ranching, and agricultural development within the Klamath watershed had occurred (Bartoy, 1995). Roads had been built (Southern Emigrant Road/Applegate Trail [1846] and Southern Oregon Wagon Road [1873]), towns were established, such as Klamath Falls (1867), and a number of private irrigation canals had been constructed to supplement the limited water supply (Bartoy, 1995; Blake et al. 2000; City of Klamath Falls, 1986; Hills et al., 1996; Historical Research Associates and Amphion, 1996; Hopkins, 1977; Klamath County Historical Society, 1984).

At the turn of the 20th century, private interests were irrigating approximately 13,000 acres in the Klamath Basin. Following passage of the Reclamation Act in 1902, the Federal Government investigated the potential for a large-scale irrigation project in the Klamath Basin. On May 15, 1905, the Klamath Project was authorized. Construction began in 1906 with the building of the main "A" Canal on Upper Klamath Lake, which is one of the two primary sources of project water. Subsequent construction included Clear Lake Dam (completed in 1910), Lost River Diversion Dam (completed in 1912), and Anderson-Rose Diversion Dam (completed in 1921, formerly Lower Lost River Diversion Dam)

(Reclamation, 1961). The distribution structures associated with the dams were built incrementally over the course of decades.

In addition to agriculture, the timber industry was a driving force in shaping the growth and economy of the area. Railroad building within the Klamath Basin is inescapably tied to timber. The ability to extract the abundant timber resources and transport them to market was the leading incentive for development of the railroad system in the basin (Fagan, 1994). Towns and settlements emerged around the logging companies, which provided loggers and businessmen with multiple services, including schools, stores, and post offices. The railroad that entered Klamath Basin was completed in 1909 and involved a partnership between the Weed Lumber Company and Southern Pacific Railroad. In 1920, Weyerhaeuser Timber Company established a major presence in Klamath Falls, acquiring the timber interests of several local companies (Bailey 2005; Bartoy, 1995; Hessig, 1978; Harder 2003; Hills et al., 1996; Lewis, 1987; Siskiyou County Sesquicentennial Committee, 2003).

A number of surveys for historic resources have been conducted in Klamath County, some of which bracket the east and west boundaries of Upper Klamath and Agency Lakes (Thompson et al., 1979). Structures at these sites are mostly remnants of ranching/farming operations, and most sites are recorded on private lands. The majority of historic resources that have been identified are located in Klamath Falls, settled in the 1860s and originally called Linkville. In 1986, an inventory was conducted of buildings and structures in the oldest districts of the community, and over 400 properties were documented. In 1990, a survey was undertaken of historic resources on private lands in the unincorporated portions of rural Klamath County (Tonsfedlt, 1990). In the Upper Klamath Lake vicinity, 17 resources were identified. These included primarily residences, schools, and commercial buildings. Included in the survey area were the communities at Fort Klamath, Klamath Agency, Pelican Bay, Algoma, and Modoc Point. Although some studies of historic resources in the county have been conducted on public lands, comprehensive surveys of the lands around Upper Klamath and Agency Lakes have not been undertaken (Tonsfedlt, 1986, 1990; Fagan, 1994). No specific inventories exist for Long Lake Valley.

There is one ranch at the south end of the valley that is owned by Jim and Carol Creswell, who bought the property in 1969 and built their current house in 1971. According to the Creswells, the previous owners bought the ranch in about 1917 and raised cattle and did some logging. There was apparently a logging camp at the north end of the valley, the remains of which may or may not be visible. There are also the remains of some old logging cabins near the ranch house that have rotted in place to where they are only piles of wood covered by vegetation. Apparently, the ranch has always been used for livestock and in one case, for rodeo horses (Creswell, 2007).

At this early stage of planning, it cannot be determined what effects the conceptual plan would have on cultural resources. The activities involved with the proposed off-stream storage conceptual plan have the potential to affect historic properties (36 CFR Part 800.3(a)). Reclamation would comply with the National Historic Preservation Act (NHPA) of 1966, as amended, which is the primary Federal legislation that outlines the Federal Government's responsibility for preserving historic properties (16 USC 470 et seq.). Compliance with Section 106, outlined at 36 CFR Part 800, requires a series of steps, in consultation with Klamath Tribes and the Oregon State Historic Preservation Office, to identify interested parties, determine the area of potential effects (APE), conduct cultural resource inventories, determine if historic properties are present within the APE, assess effects on any identified historic properties, and resolve any adverse affects. (CR-1)

Recreation Resources

Developing the Long Lake Valley Reservoir as an off-stream storage reservoir could offer some outdoor recreation opportunities. The lake would lie northwest to southeast and would be about 5 miles long, with a width ranging from ¾ to 1 mile (8). Steep hillsides would ring the lake in a configuration similar to a bathtub. The only option for close vehicle access to the water would be at the southeast end of the lake, which would have a gently sloping gradient. At this end, a saddle area sheltered from the nearby highways and the city of Klamath Falls could provide a quiet outdoor environment.

Roads and Access

The only practical location for developed recreation at Long Lake Valley Reservoir is served by existing county roads and is only a short drive from Klamath Falls. Therefore, no access roads would need to be constructed for recreation. A well maintained, all-weather, gravel road provides access to the southeast end of the proposed Long Lake Valley Reservoir and is adjacent to the saddle area, which is the logical site for recreation facilities. A short spur into a parking lot could be constructed, which would provide direct access to the proposed Saddle Recreation Area. The existing county road continues past this area into the valley and provides access to private property (figure 16).

Figure 16.—Proposed Saddle Recreation Area looking northeast from the county road near a potential entrance to the parking lot.

Development and Partnership

Developing and funding recreation at the proposed Long Lake Valley Reservoir is envisioned to be on a partnership basis. Partnering with an agency that could successfully manage and maintain the proposed facilities would be required to enable recreation to be a viable part of this conceptual plan. Reclamation may provide the development and construction funding and possibly fund some ongoing operations and maintenance. However, another agency would be needed to provide the continuing operations and maintenance functions, including providing for the necessary law enforcement functions by an appropriate agency or agencies.

Reclamation has a history of cooperatively providing for recreation at many of the reservoirs it develops and operates. Reclamation has successfully partnered to help provide recreation at the national level (e.g., Hoover Dam and Lake Mead National Recreation Area with the National Park Service), at the State level (e.g., B.F. Sisk Dam and San Luis State Recreation Area with the California State Parks Department), and at the local level (e.g., California and San Justo Reservoir with the San Benito County). In many cases, recreation facilities can be funded and developed as other parts of the conceptual plan progress and thus can be prepared for management by the managing agency when the reservoir is filled and operational.

Klamath County is a likely candidate for Reclamation to partner with to provide recreation at Long Lake Valley Reservoir. As the County has previous experience and current recreation capabilities. Klamath County currently manages and maintains several recreation sites on Upper Klamath Lake that were developed cooperatively by Klamath County, Oregon State Marine Board, and the U.S. Fish and Wildlife Service (figure 17). Several of these sites are similar in form and function to the proposed recreation area at Long Lake Valley Reservoir. Klamath County has the expertise to perform many of these functions and, with some additional Federal funding, may be able to successfully undertake the operations, maintenance, and law enforcement responsibilities.

Other Federal agencies within the area also have the required capabilities and expertise to manage a recreation site like the one proposed for Long Lake Valley Reservoir. The U.S. Forest Service, FWS, and BLM all have offices and staff in Klamath County. These agencies manage lands and recreational facilities in Klamath County.

Funding

Funding availability for planning, designing, and constructing any recreational facilities and any continuing source of funding for management and maintenance would be a factor in the final determination of any development of Long Lake Valley Reservoir for recreation. The funding source and amounts would also play a role in successfully attracting a partner to assume the operations and maintenance responsibility for the recreational resources (figure 18).

Figure 17.—Petric Park—typical county facilities near Agency Lake/Wood River Marsh.

Figure 18.—Petric Park near Agency Lake/Wood River Marsh.

The Saddle Site

The area available for a recreational development is partially wooded with an open middle parcel between two ridges (identified as the parking area in figure 19). The area is currently used as a grazing allotment. As discussed previously, a gravel county road traverses the edge of the steeper western ridge bordering the location. The area slopes gradually toward the northwest in the

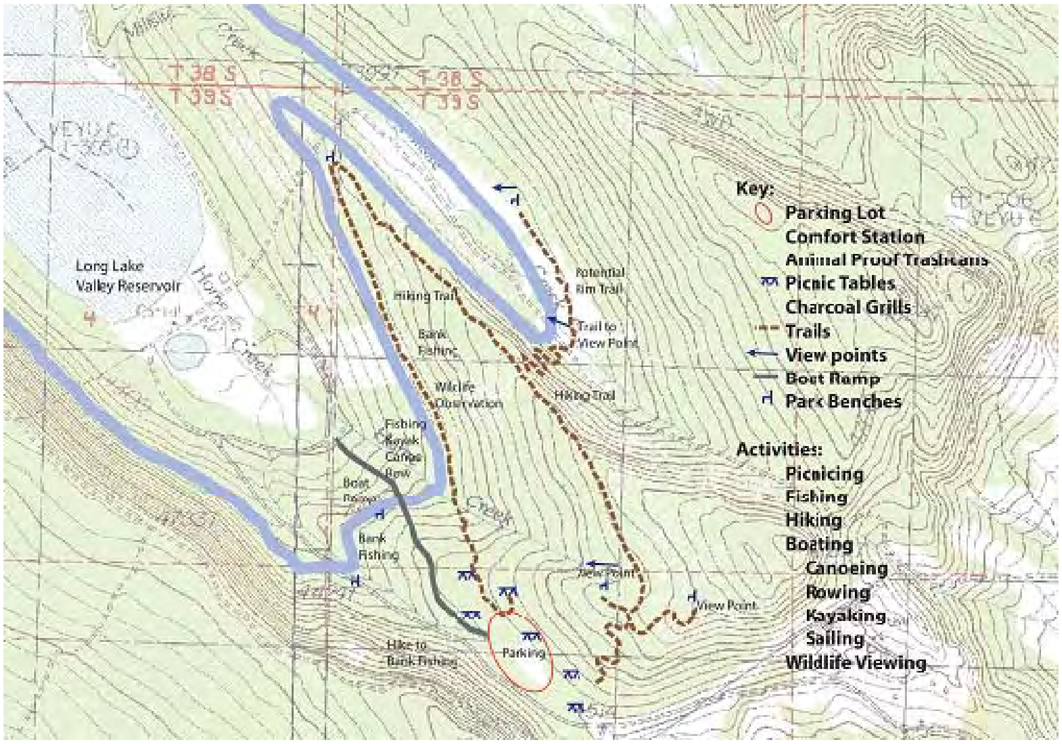


Figure 19.—Saddle Recreation Area—preliminary concept plan.

direction of the southeast edge of the reservoir (figure 20). This recreation site would not be far from the water when the reservoir is full; however, as the lake level is drawn down, even by a few feet, the distance to the water would increase rapidly.

The proposed Long Lake Valley Reservoir offers the potential for recreation close to the city of Klamath Falls. The site is most suitable for day-use, nonmotorized types of recreation because of its size, topography, and the primary purpose of the reservoir—to provide water storage.

To fulfill its primary purposes, the reservoir would be subject to withdrawals that could change its depth from 150 feet to a relatively low elevation at the bottom of the withdrawal outlet over the course of a water year or even a shorter time period. The surface area would also change correspondingly. A few feet change in water elevation would expose a large area of mud flat at the southeastern edge of the reservoir, making motor boating hazardous and requiring an excessively long boat ramp to provide access. While recently exposed mud flats may facilitate bird watching, they would not necessarily be conducive to hiking or carrying a boat to the receding water.

The site presents an opportunity to provide access to water recreation through a low level of development while being sensitive to the natural setting. Careful development can conserve the site's relatively quiet and natural environment.

Figure 20.—Potential Saddle Recreation Area looking northwest from the proposed parking lot.

Site development could be managed to conserve as many of the existing trees as possible to provide visual screening, shade, noise abatement, etc. Natural materials could be used to blend with the area (large rocks and timbers to delineate the parking lot and walkways, a natural crushed rock parking lot instead of asphalt, etc.)

The primary recreational attractions that might be offered at Long Lake Valley Reservoir are day use, nonmotorized boating, fishing, picnicking, hiking, wildlife observation, and nature interpretation. Some interpretive nature trails to nearby scenic high points that offer views of Long Lake Valley Reservoir could be developed. figure 21 shows an example of a small BLM site that offers hiking, biking, and nonmotorized water access.

When at or near full pool, the reservoir would offer a lengthy stretch of flat water for canoeing, kayaking, rowing (sculling), and sailing (if wind conditions are right). The boating season would depend upon access to the water (the length of the boat ramp) and water conditions throughout the year. Restricting the reservoir to nonmotorized boating would preserve a more natural ambience type boating and fishing experience and reduce recreational conflicts between competing recreationists. This action would help to reduce law enforcement problems.

The activities above require a recommended level of development to help provide a safe and healthful environment for the visitor and to protect the resource base:

- A parking lot

- Comfort station (perhaps self composting)

Figure 21.—BLM Wood River Wetland—driveway, sign, parking area, comfort station, trail, and canoe/kayak access.

- Picnic tables
- Charcoal grills
- Animal-proof trash receptacles
- Shade structures—potentially taking advantage of available trees
- Boat launch ramp (length to be determined)
- Trails
- Park benches at view points or bank fishing locations
- Scenic view points
- Interpretive sites and signs

Other possible services include a potable water source and a fish cleaning station. This type of recreation site would require a minimum level of services:

- Regular trash pickup
- Seasonal and as necessary maintenance of picnic tables, grills, hiking trails, parking lot, etc.

- Regular law enforcement patrols
- Fish and game law enforcement

Water Recreation Opportunity Spectrum

Although the proposed Long Lake Valley Reservoir site is currently in an undeveloped area, the corporation that owns the land surrounding the valley may develop the surrounding ridges. If these lands are developed with expensive housing units, and Long Lake Valley Reservoir becomes a reality, the generalized recreational setting would most likely be classified as rural developed (Hass, 2004). The housing would be visible from the water and as the water level dropped, the "high water mark" would be visible to boaters and visitors from the shore.

With ridge development (such as housing developments), a rural type recreation experience would be expected at the proposed recreation site because of the location and level of development. As hikers move down one of the trails or boaters travel northwest along the reservoir, the experience would graduate to a more rural natural recreation experience as the sights and sounds of human activity become more distant. The houses along the ridges would be visible; however, they may be distant enough to be unobtrusive, allowing the natural environment to dominate the scene.

Preliminary Concept Plan

Figure 19 presents a preliminary concept plan for the Saddle Recreation Area showing the recommended level of development listed above. A staging area near the reservoir shoreline and the boat ramp where vehicles with trailers could be maneuvered to launch and retrieve boats and a parking lot where vehicles with trailers could be parked while visitors are boating is not shown on figure 19. Also, the number and location of picnic sites and tables, view points, trails, etc. represent a preliminary concept of potential plans for the recreation area. As shown on this diagram, the boat ramp is about a half mile from the edge of the reservoir's high water line to near the bottom of the reservoir. This represents at least 100 feet of elevation change. However, it may not be practical to allow boating on the reservoir through this great a range of elevation change.

Visitor Use

The amount of visitor use cannot be reliably predicted at this time. If recreational facilities are built at Long Lake Valley Reservoir, the public would likely make use of them. If the facilities are well maintained and patrolled by law enforcement officials the public would, most likely, continue to use the area.

Boaters would likely use the facility as long as there was sufficient water in the reservoir to provide an attractive recreational experience. The expectation would be that visitation would be positively correlated with the reservoir's elevation—the higher the elevation, the higher the visitor use.

Some Challenges to Recreation

The first challenge to recreation at Long Lake Valley Reservoir is: Should recreation be provided here at all? Recreation is a secondary priority at Long Lake Valley Reservoir, and draw downs would affect the reservoir's elevation considerably. Recreation would always be a secondary priority to water storage and potential power generation.

Lake surface elevation variations is another challenge. The water depth could vary from 150 feet to just a few feet at the outlet level during the water year or from year to year. The reservoir could have stagnant water for most of the year unless there is a provision for providing some flow. As a result, there may be low water quality in the reservoir. Recreation may not always be available at the reservoir because of water quantity (e.g., low or no water) or water quality (e.g., bad odor, unsightly algae scum) issues as well as fishing resource issues. Interrupted recreation service or poor quality of service due to low water conditions and/or decaying vegetation and odor problems may at times result in some poor public relations for Reclamation and the recreation managing agency.

Developing even the proposed relatively low level of features represents financial commitments, and taking on the future operation and maintenance responsibility without an accompanying source of funding would be a concern to Klamath County or any other partner. Other concerns affecting the provision of recreation at this reservoir are the viability of a sport fishery and the periodic closures of the lake due to low water or other adverse conditions.

The view shed would change as the water is drawn down (figure 22). The clear-cut slopes would come into view and the sight would not be aesthetically appealing. This and the other challenges are all topics for interpretation at the proposed recreation area. The various aspects of operating Long Lake Valley Reservoir (e.g., draining the reservoir and the reasons why) would need to be explained to the public and potential visitors to the recreation site.

Why Not Motorized Recreation?

An intensive, high level of development on either the recreation site or the reservoir would be inappropriate and unwarranted. The highly variable water level and the concentration of recreational activity at one site at the southeastern

Figure 22.—Long Lake Valley from the southeast end looking northwest.

part of the reservoir are only two of the several reasons to avoid intensive development.

It is not likely that motorized recreation would be practical at Long Lake Valley Reservoir. If motorized recreation opportunities were introduced, the opportunity for relative quiet and solitude would be lost and not likely recoverable. The boat ramp would be very long and wide, and tree stumps left behind (figure 23) would make for hazardous motorized boating. Providing motorized boating recreation opportunities at low water elevations could make for difficult navigation with trailers for retrieval of boats. Thus, it may not be practical or reasonable to provide for motorized boating at this reservoir given the fluctuations in the lake's elevation. Furthermore, the area available at Long Lake Valley Reservoir for development as a recreation site is not necessarily large enough to accommodate motorized recreation (RV camping, motor boating) and nonmotorized recreation while providing a natural type recreational experience at the same time. Moreover, Upper Klamath Lake, the largest lake in Oregon, is nearby and offers opportunities for motorized boating activities of all types and at ten locations with boat ramps.

Motor-boating introduces another level of management concerns. Law enforcement becomes more complicated. A water patrol capability would be necessary to comply with U.S. Coast Guard safety regulations. Additionally, boating while under the influence (especially on holidays) is a safety risk and law enforcement concern.

A campground to accommodate recreational vehicles would require an even greater level of development, encompassing more space, maintenance, and facilities and services (water, electricity, campground host, fee collection, etc.).

Figure 23.—Proposed Saddle Recreation Area looking southeast.

These factors make it inadvisable to provide motorized recreational opportunities or more intensive development.

Impacts to Long Lake Valley Reservoir

Other than developing the facilities and the facilities' footprint, the impacts to Long Lake Valley Reservoir from recreation for nonmotorized boating and day use would likely be minor to moderate. Most of the human impacts would be confined to the parking lot, picnic sites, comfort station, trash receptacles, trails, benches, and boat ramp. Regular maintenance and law enforcement patrols can mitigate most trash and depreciative behavior and vandalism problems.

If a fishery is established, there could be some ecological impacts should fish escape into Upper Klamath Lake. Lake scum and fish die-offs could be a problem as Long Lake Valley Reservoir is drained completely during dry years to provide irrigation water.

Summary

If Long Lake Valley Reservoir is developed for water storage and perhaps hydropower purposes, there is potential to develop the saddle area at the southeastern end of the reservoir for recreation. Vehicle access would be available from a county maintained gravel road. Private land would have to be acquired. Funding, operation and maintenance obstacles would have to be overcome. Hydropower operations, water levels, fish die-offs, and other factors could affect recreation opportunities and experiences. However, these problems may be overcome and recreation might be a beneficial use of Long Lake Valley Reservoir. (REC-1)

Hydrology

Modeling Software

Modeling has been conducted using the Water Resources Integrated Modeling System (WRIMS)—general purpose river and reservoir planning and operations modeling software developed and maintained by the California Department of Water Resources Modeling Support Branch. WRIMS was first used for Klamath Project planning modeling in 2004 and by 2006, had replaced the old, spreadsheet-based Klamath Project Operation Simulation Model (KPSIM) as the analytical tool of choice to address increasingly complex water management scenarios and strategies in the basin.

WRIMS uses a mixed integer linear programming solver to route water through a network. Policies and priorities for water routing are implemented through user-defined weights applied to flow arcs and storage nodes in the network. System variables and the constraints on them are specified with a scripting language called the "water resources engineering simulation language" (wresl). Wresl code is developed in simple text files. Time series input data and model results are stored in files compatible with the USACE's Hydrologic Engineering Center Data Storage System (HEC-DSS). Relational data (lookup tables) are stored in text files.

Hydrology Data

The current representation of the Klamath Project uses a 46-year period of hydrology, encompassing water years 1961 through 2006. A full set of data is available from the United States Geologic Survey (USGS) for key streamflow gauges for this period, which includes a dry period of record as well as some of the wettest years recorded for in the Upper Klamath Basin. Hydrologic input to the model includes historical records for net inflow to Upper Klamath Lake, Lost River Diversion Canal spills to the Klamath River, local gains between Link River and Keno Dam, runoff from agricultural lands above Lower Klamath Lake, gains between USGS gauges at Keno and Iron Gate Dams, and returns from Klamath Straits Drain.

Each water year is divided into 17 timesteps—full months August through February and half-months March through July. This temporal scale is necessary to represent some operational requirements for UKL elevation and Iron Gate Dam downstream on the Klamath River.

System Description and Model Network

Figure 24 shows the schematic diagram of the model used in the appraisal analysis. Headwaters inflows are represented for Upper Klamath Lake, Gerber Reservoir, and Clear Lake. Local gains and other inflows are represented by Lake Ewauna gain, Lost River Diversion Channel Spill, Area A2 Winter Runoff, Klamath Straits Drain inflows, and Keno-to-Iron-Gate gain. Diversions to project demands are represented at A Canal, Lost River Diversion Channel, North Canal, and Ady Canal. Long Lake Valley Reservoir is represented as an offstream storage facility, connected to the system via Upper Klamath Lake. With a monthly/bimonthly timestep, the net balance of flow between Long Lake Valley Reservoir and Upper Klamath Lake is either inflow or release.

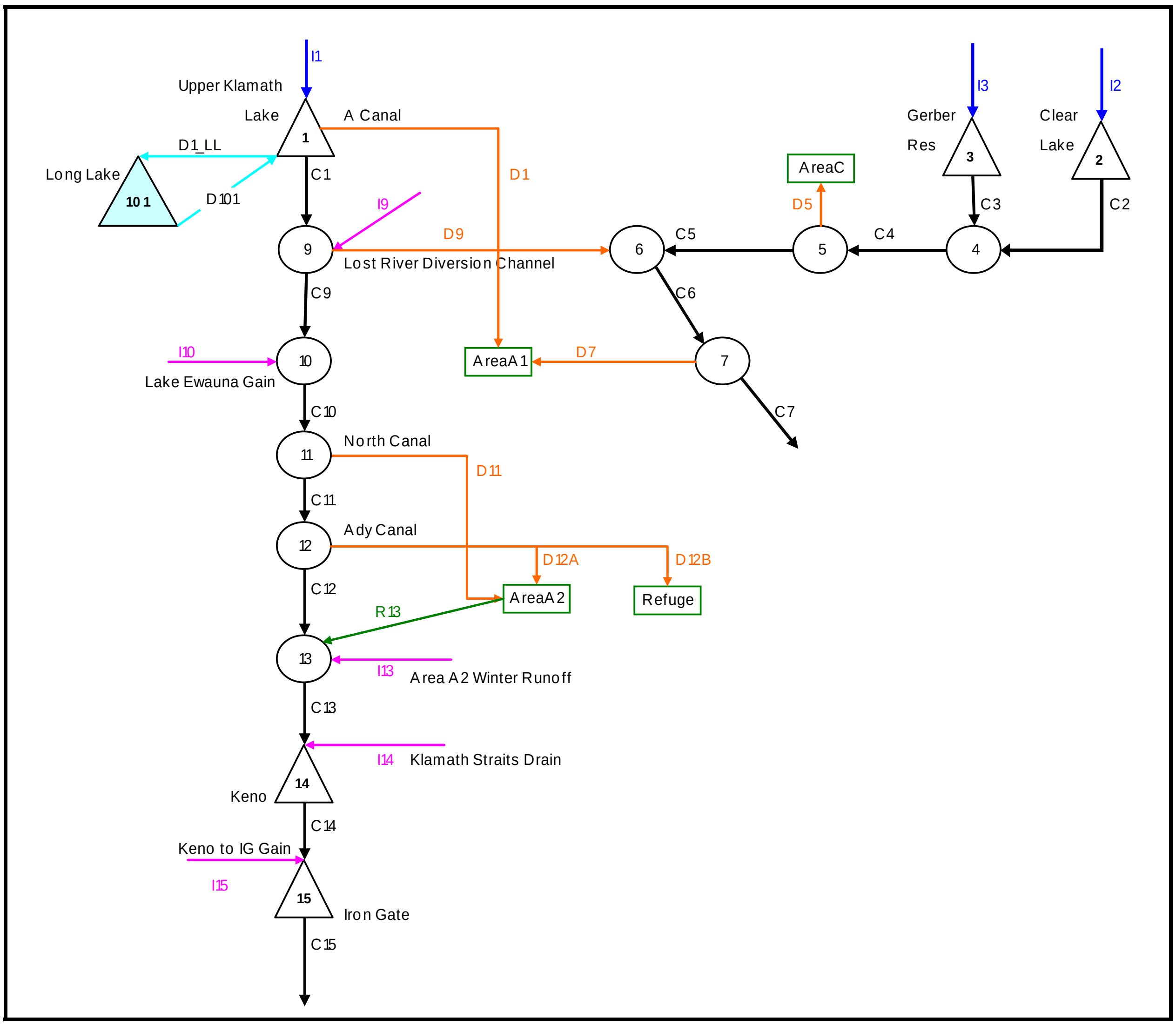


Figure 24.—Schematic network of the Klamath Project planning model.

Although it is included in the model, the Lost River portion of the system is not germane to the outcome of the model runs in this study. Lost River inflow and operations for Gerber Reservoir, Clear Lake, and Area C delivery are completely separate and have no hydrologic impact on Klamath River operations in the model.

Alternatives Operations Criteria

The model was run for three alternative scenarios—a No-Action scenario and two with-project scenarios. The No-Action scenario is the March 2008 Proposed Action for Klamath Project operations included in Reclamation's Biological Assessment. The with-project alternatives are consistent with the proposed action assumptions, but also include Long Lake Valley Reservoir and use the additional stored water in meeting conceptual plan operating goals and enhanced Iron Gate flow augmentation. The with-project alternatives differ only in the conveyance capacity assumed between Long Lake Valley Reservoir and Upper Klamath Lake.

	Long Lake Valley Reservoir storage capacity (TAF)	Canal capacity (ft^3/s)
Proposed Action	0	0
LL350 1K	350	1,000
LL350 2K	350	2,000

Input data and operating rules for both scenarios are consistent with the criteria for the Klamath Project 2008 Proposed Action, and these are described below. If operational requirements are altered as a result of new biological opinions, new modeling inputs would result in potential changes in model outputs.

- Priorities for water use are to:

  1. meet or exceed the minimum Iron Gate Dam flows
  2. meet or exceed the minimum Upper Klamath Lake elevations
  3. sustain water diversions to meet contractual agreements between Reclamation and water users
  4. meet the Upper Klamath Lake

  Remaining water supply is split between flow in the Klamath River at Iron Gate Dam and storage in Upper Klamath Lake according to an interactive management process to be described later.

- Base flows at Iron Gate Dam and base water surface elevations for Upper Klamath Lake are shown in table 4.

Table 4.—Base flow and lake elevation criteria

	Klamath River	Upper Klamath Lake	
Month	Proposed min. flows below Iron Gate Dam	Proposed min. elevation (ft)	Proposed lake refill targets (ft)
October	1300		4139.1
November	1300		4139.9
December	1300		4140.8
January	1300		4141.7
February	1300	4141.5	4142.5
March	1450	4142.2	4143.0
April	1500	4142.2	
May	1500	4141.6	
June	1400	4140.5	
July	1000	4139.3	
August	1000	4138.1	
September	1000	4137.5	4138.0

- Klamath Project demand for irrigation and refuge water users is based on a precipitation index that defines annual demand and its monthly distribution. A1 deliveries include diversion from UKL to the A Canal, and diversion from Lake Ewauna to the Lost River Diversion Channel. A2 deliveries include diversions from the Klamath River to irrigation uses through North and Ady Canals. Refuge deliveries as modeled are the Ady Canal deliveries to the Lower Klamath Lake National Wildlife Refuge. Tule Lake National Wildlife Refuge, D-pump operations, and distribution of Lost River water are not explicitly represented in the model. Annual demands based on the precipitation conditions are shown in table 5.

- Expanded storage capacity in Upper Klamath Lake includes Agency Lake/Barnes and the Tulana Farms/Goose Bay areas. Evaporation and changes to consumptive use for these new storage areas are represented specifically in the model.

- Flood control rules are adjusted from the original Pacific Power and Light levels to reflect the same amount of available storage space given the modified storage capacity.

Table 5.—Conceptual plan demand

Feb-Mar precipitation index (in)	A1 demand Apr-Mar (TAF)	Refuge demand Apr-Mar (TAF)	Oct-Jan precipitation index (in)	A2 demand Apr-Mar (TAF)
0.00-1.999	340	30	0.00-3.99	105
2.00-2.749	310	25	4.00-6.99	95
2.75-3.299	300	20	7.00-9.99	90
>=3.30	275	15	>=10.00	80

- Interactive management of "surplus water." Surplus water is identified water supply that is above and beyond that required to meet the base criteria for conceptual plan operations. The IM process provides a method for sharing that surplus between additional flow at Iron Gate and higher carryover storage in UKL. Augmentation of spring and summer flows at Iron Gate Dam above base levels is based on the computed surplus water supply likely to occur by the end of September. The surplus water supply is calculated in April as:

$$\text{Surplus water supply} = A + B - C - D + E - F$$

where,
A = the end-of-March storage in Upper Klamath Lake
B = Upper Klamath Lake inflow, April through September (perfect foresight)
C = September target carryover storage
D = Iron Gate minimum flow requirement, April through September
E = Link River to Iron Gate Dam gain, April through September (perfect foresight)
F = agricultural and National Wildlife Refuge demand, April through September

A portion of the surplus water is allocated to increasing Iron Gate Dam flows above the minimum levels. This portion is based on a seasonal water supply factor, which evolves as water supply conditions change through the year. This factor is calculated in each time period April through September as:

$$\text{Seasonal water supply factor} = G + H - I$$

where,
G = the end-of-previous time period storage in Upper Klamath Lake
H = the Upper Klamath Lake inflow, "now" through September, (perfect foresight)
I = September target carryover storage

The percentage of the April through September surplus water supply allocated to flow augmentation, interpolated relative to this continually updated seasonal water supply, is shown in table 6. Note that there is not an explicit allocation of the surplus to UKL. Whatever portion of the surplus were not specifically targeted for Iron Gate flow augmentation would remain in storage in UKL, and is considered de facto "lake level augmentation."

Table 6.—Percentage of surplus water supply allocated to Iron Gate flow augmentation

Semimonthly or monthly period*	If seasonal supply factor in TAF were:	If seasonal supply factor in TAF were:	If seasonal supply factor in TAF were:	If seasonal supply factor in TAF were:
May 1-15	0-790	790-920	920-1181	above 1,181
May 16-31	0-728	728-850	850-1069	above 1,069
June 1-15	0-661	661-775	775-949	above 949
June 15-30	0-579	579-687	687-853	above 853
July 1-15	0-501	501-604	604-756	above 756
July 16-31	0-434	434-530	530-685	above 685
August	0-363	363-458	458-609	above 609
September	0-256	256-349	349-498	above 498
Percent of surplus water supply to augment the Iron Gate discharge flow would be:	20%	20-36%	36-35%	35%

* In modeling, there was no flow augmentation above Iron Gate Dam minimum flows in April. However, flows in excess of minimums did occur during spill events. Spills have historically occurred in April.

Monthly distribution of the bulk seasonal flow augmentation is shown in table 7. This is also a function of the seasonal supply factor.

Table 7.—Distribution of Iron Gate Dam flow augmentation

Semimonthly or monthly period	Seasonal supply factor in TAF	Dist. of IG flow aug.	Seasonal supply factor in TAF	Dist. of IG flow aug.	Seasonal supply factor in TAF	Dist. of IG flow aug.	Seasonal supply factor in TAF	Dist. of IG flow aug.
May 1-15	0-790	0.33	790-920	0.26	920-1,181	0.15	above 1,181	0.15
May 16-31	0-728	0.33	728-850	0.25	850-1,069	0.15	above 1,069	0.15
June 1-15	0-661	0.1	661-775	0.135	775-949	0.22	above 949	0.20
June 15-30	0-579	0.1	579-687	0.135	687-853	0.22	above 853	0.20
July 1-15	0-501	0.03	501-604	0.055	604-756	0.065	above 756	0.075
July 16-31	0-434	0.03	434-530	0.055	530-685	0.065	above 685	0.075
August	0-363	0.03	363-458	0.035	458-609	0.04	above 609	0.05
September	0-256	0.05	256-349	0.075	349-498	0.09	above 498	0.1

Finally, water that is not specifically targeted for flow at Iron Gate Dam remains in Upper Klamath Lake, and is considered de facto “lake level augmentation.”

- With-project Long Lake Valley Reservoir operations criteria:
  - Maximum storage—350 TAF
  - Minimum storage—30 TAF
  - Conservation pool—320 TAF
  - Canal capacity—2,000 or 1,000 ft^3/s
  - Diversions to Long Lake Valley Reservoir—limited to spill from Upper Klamath Lake that would otherwise have occurred in the absence of Long Lake Valley Reservoir
  - Releases from Long Lake Valley Reservoir—encouraged to meet shortages to other system constraints—UKL minimum elevation, Iron Gate Flow, or delivery targets—that would have occurred in the absence of Long Lake Valley Reservoir. Discouraged otherwise.
  - Use of Long Lake Valley Reservoir storage to further enhance Iron Gate flow was implemented as follows:
    - 50 TAF/yr in the drier 60% of years when flow augmentation is scheduled
    - Distributed 60%/40% in April/May in the drier of these years and 40%/40%/20% April/May/June otherwise
    - Triggered only if end-of-March storage in Long Lake Valley Reservoir was at least 150 TAF
    - Triggered in April and May if flow would otherwise have been below 3,000 ft^3/s

Consideration of Climate Change

It is anticipated that future trends in hydroclimatology in the Klamath River basin may include reduced inflows, changes to timing of spring runoff, changes to the form, timing, and spatial distribution of precipitation, and increased consumptive use of water by irrigated agriculture. Klamath Project responses to these trends may include changes in irrigation practices, crop selection, and conjunctive use of surface water and groundwater.

The implications of these responses to hydroclimatology trends could also affect the role of Long Lake Valley Reservoir storage in conceptual plan operations. Long Lake Valley Reservoir storage might be called on to alleviate higher or more frequent project delivery shortages, and adjusted goals for timing and magnitude of flows at Iron Gate Dam could present new possibilities for flexibility in the use of Long Lake Valley Reservoir capacity to exchange high winter spills for spring and summer flows.

Feasibility-level studies for Long Lake Valley Reservoir could include the simulation of offstream storage benefits given a range of scenarios for climate change in the basin. Climate change scenarios would be input to rainfall/runoff scenarios for watershed hydrology, providing altered inflow data sets that would drive the operations model used for this appraisal-level study.

Modeling Results

The results of the with-project alternatives identify the potential to divert winter and spring spill to offstream storage in Long Lake Valley Reservoir and to use this stored water for reduction of project delivery shortages seen in the No-Action alternative and to further enhance spring and summer flows at Iron Gate Dam by saving high spill events in winter months.

Figure 25 shows the impact of Long Lake Valley Reservoir storage on project delivery shortages. Occurrence of shortages to project delivery decreases from 16 years to 8 or 9 years with the use of Long Lake Valley Reservoir storage. If only considering shortages over 5 percent of the total annual demand, Long Lake Valley Reservoir reduces the number of years in which this occurs from 10 to 5. In years such as 1977, 1981, 1991, and 2001, which are not preceded by dry years and where shortages under current operations criteria would range from 10 to 40 percent, full Long Lake Valley Reservoir storage reserves would have the ability to make up all project shortages. In the 2001-2004 period of dry and below-average years, Long Lake Valley Reservoir storage is also able to meet project demands that would have been shorted with just Upper Klamath Lake storage reserves. Actual annual deliveries from Long Lake Valley Reservoir to address project shortage range from 13 to 160 TAF in 8 of the 46 years in the study period. Long Lake Valley Reservoir also releases water for supplemental

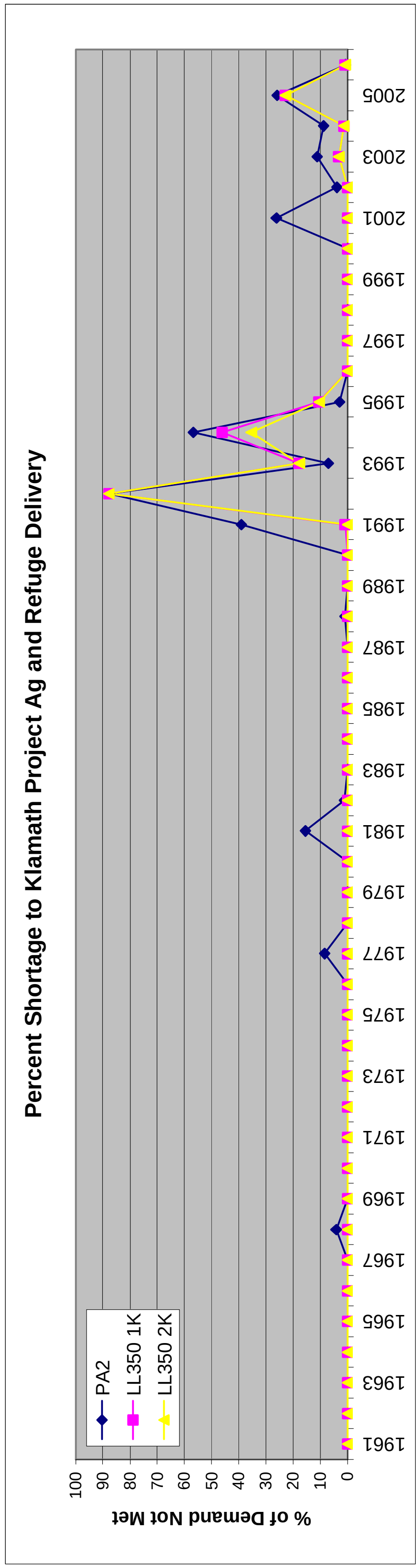


Figure 25.—Klamath Project shortages.

augmentation of Iron Gate flow and, in the driest years also maintains, Upper Klamath Lake minimum elevations.

While Long Lake Valley Reservoir storage can offset a large delivery shortage in 1 year or provide enhanced flows and address a series of smaller shortages over multiple years, the size of the conservation pool limits its ability to address severe Klamath Project delivery shortages over a multiyear dry period. Figure 26 (top) shows Long Lake Valley Reservoir storage results for the two with-project alternatives over the 46 years of simulation. For isolated drier years like 1981, Long Lake Valley Reservoir can meet project shortage and also contribute to augmenting flow at Iron Gate Dam, and then is able to refill given the high inflows during the winter and spring of the following water year.

The multiyear dry period of 1991 to 1995, however, presents a more difficult challenge to project operations. At the end of water year 1990, Long Lake Valley Reservoir is drawn down due to releases made to augment Iron Gate flows in previous years. Dry conditions in the winter of 1991 do not allow the lake to refill, and continued dry conditions through the irrigation season lead to the release of 160 TAF from Long Lake Valley Reservoir to fully alleviate project shortages. The following extremely dry year of 1992 allows for no refill, so relief of shortage in 1992 is negligible because remaining storage reserves are used to maintain minimum elevation in Upper Klamath Lake. While a more nuanced operational strategy might ration Long Lake Valley Reservoir resources differently, it is nevertheless the case that the limited additional storage cannot sustain normal project deliveries in two consecutive very dry years.

No shortages occur to Iron Gate flows in the No-Action scenario, so there is no need to use Long Lake Valley Reservoir storage to meet this criteria. Enhancement of flows at Iron Gate Dam above the Proposed Action criteria is under consideration as a potential use for Long Lake Valley Reservoir storage in years when full project deliveries are being made. The flow enhancement strategy detailed in the Operations Criteria produces results as shown in the plots of figure 27. Higher flows are evident in 30 percent of Aprils, 50 percent of Mays, and 40 percent of Junes, with flows increasing by 168 ft^3/s to 500 ft^3/s over No-Action levels.

Figures 28 and 29 display time series of Klamath Project deliveries and flows at Iron Gate for the 46-year period of study. In all figures, the thick blue lines represent the results of the No-Action study, while the narrow pink lines are the with-project results. Demands are also shown on the delivery plots. When with-project Iron Gate flows are lower than No-Action flows, spill is being stored in Long Lake Valley Reservoir. Similarly, if with-project flows are higher than No-Action flows, a specific release is being made from Long Lake Valley Reservoir for flow augmentation.

Other Considerations for Any Potential Feasibility-Level Studies

The potential to include power generation operations that move water back and forth between Upper Klamath Lake and Long Lake Valley Reservoir or potentially release water directly to the Klamath River is being studied as part of this appraisal-level report. Specific strategies for these operations should be added to the overall representation of Long Lake Valley Reservoir in any potential future modeling if feasibility-level studies were to proceed. A reservoir with 500-TAF capability should also be investigated through modeling to see if there are different benefits to be gained or different years of shortages that can be mitigated.

Logic that carefully considers water supply forecasts and anticipated delivery shortages should be developed to determine how best to allocate Long Lake Valley Reservoir resources. Stochastic methods should be used to construct alternative hydrology traces to test potential strategies. (HYD-1)

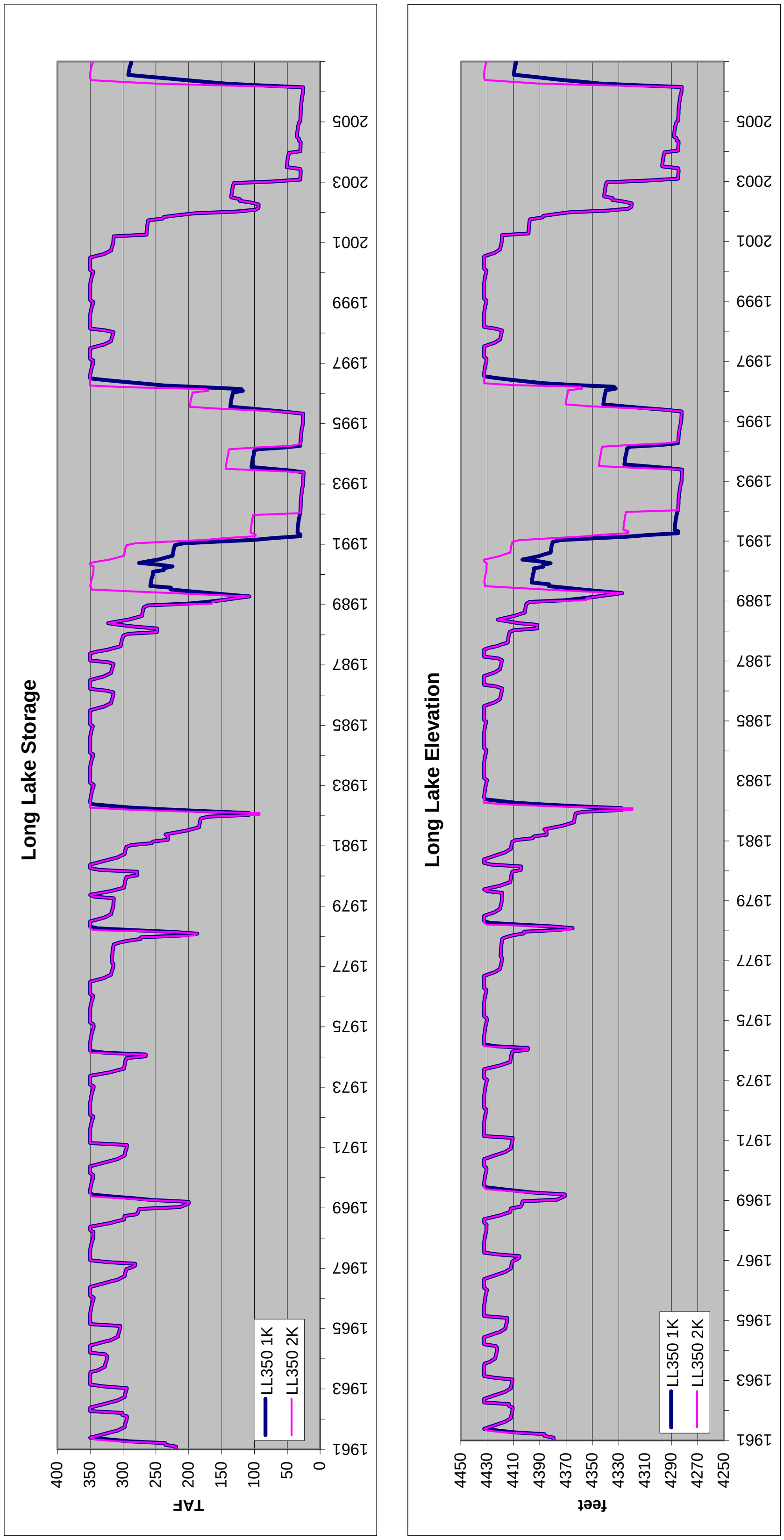


Figure 26.—Long Lake Valley Reservoir storage, inflow, and release for the with-project alternative.

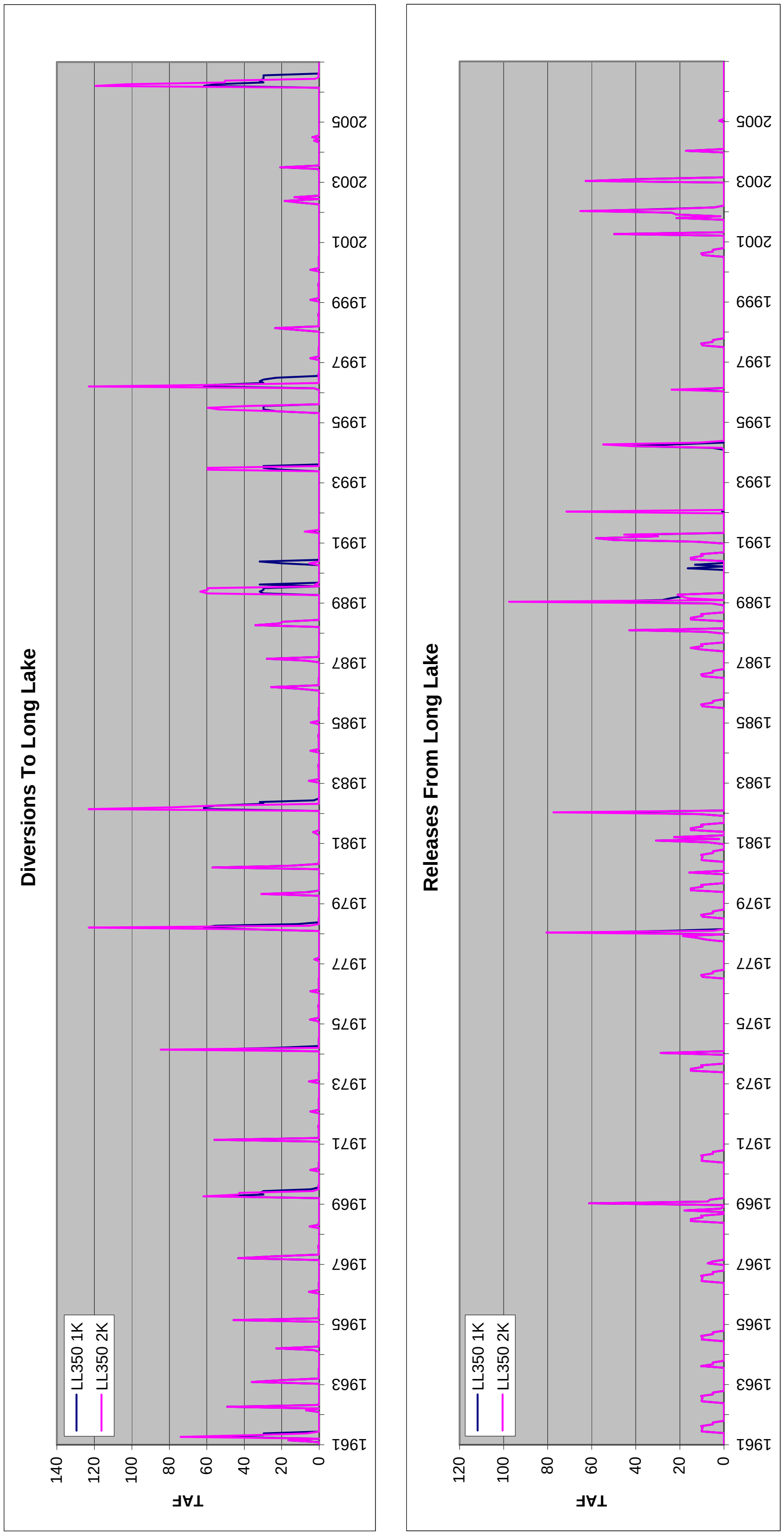


Figure 26 (continued).—Long Lake Valley Reservoir storage, inflow, and release for the with-project alternative.

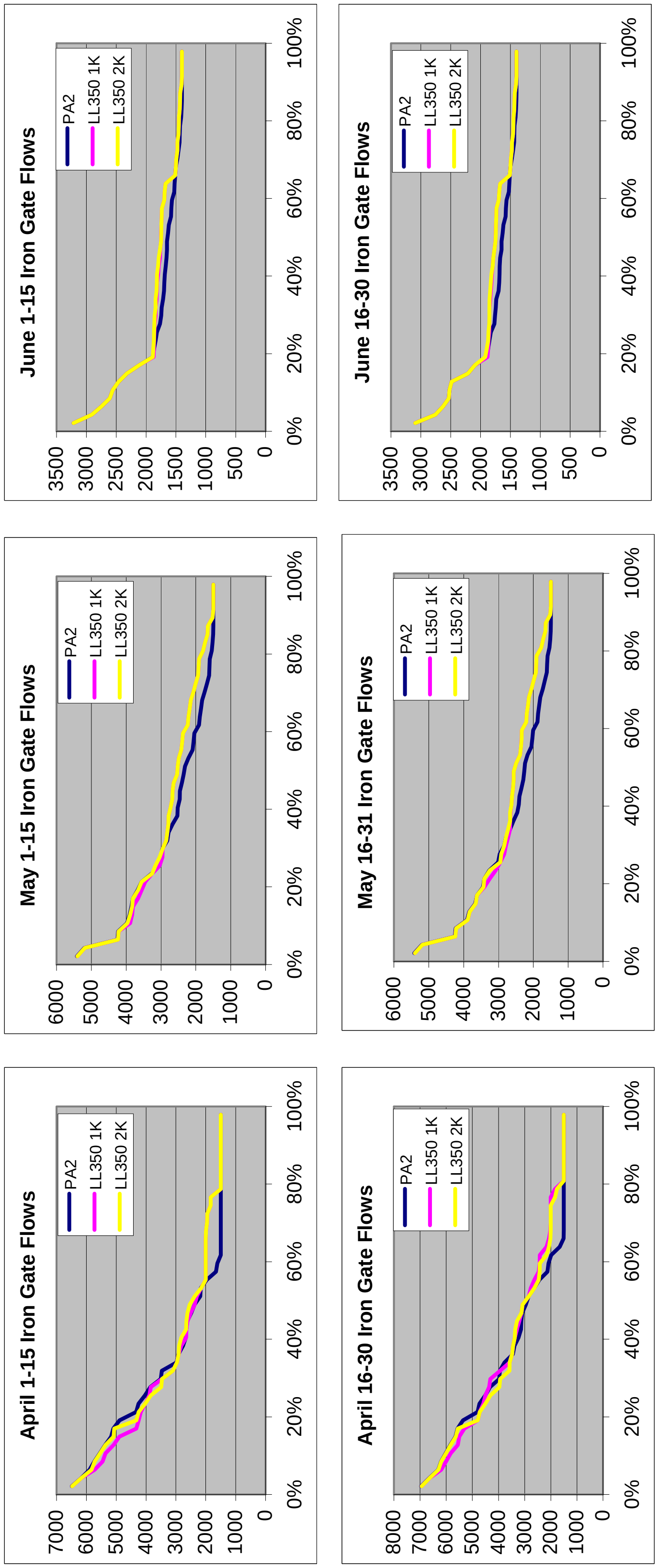


Figure 27.—Exceedence plots for Iron Gate Flows in April, May, and June.

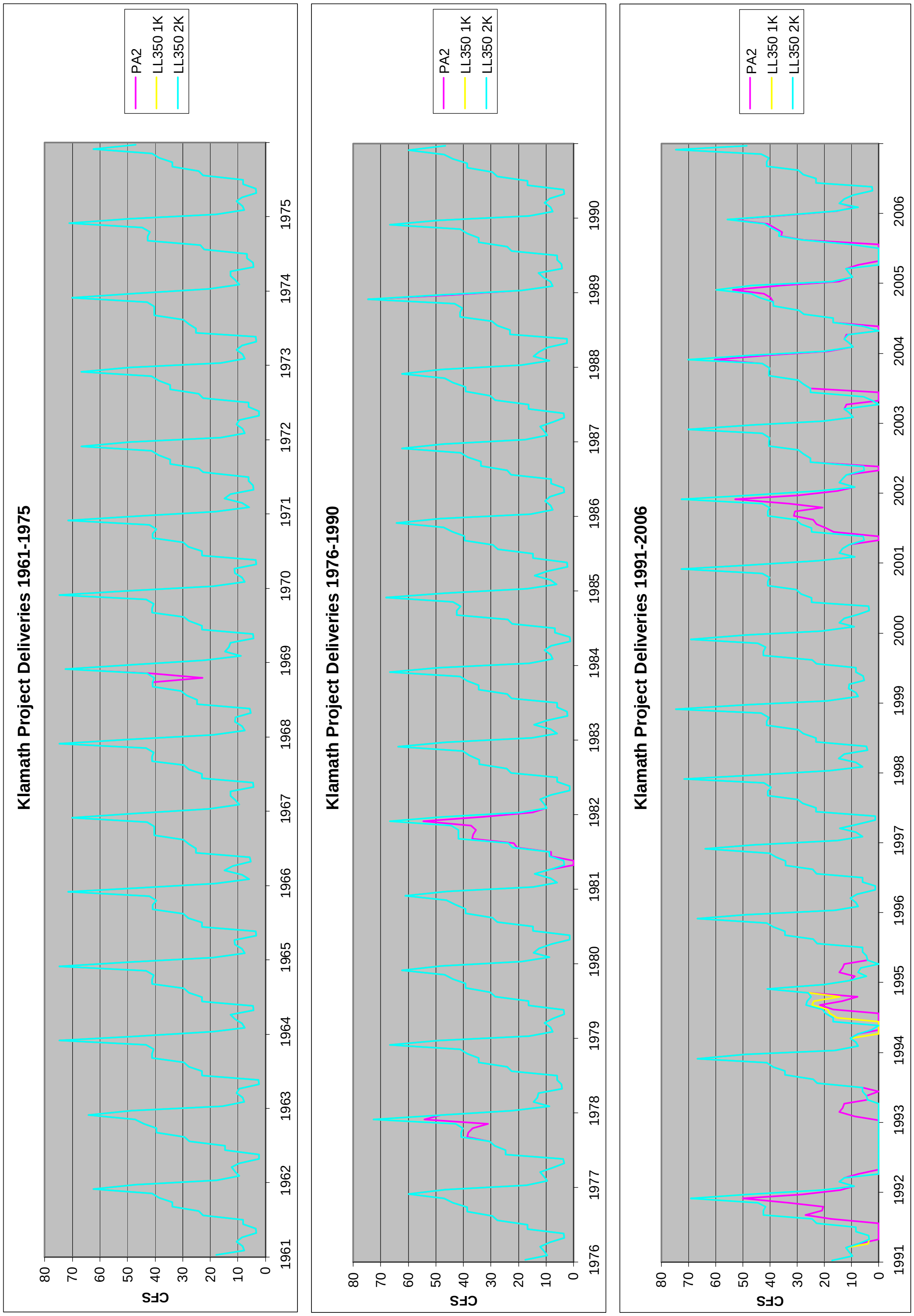


Figure 28.—Long Lake Valley Reservoir effect on Klamath Project deliveries.

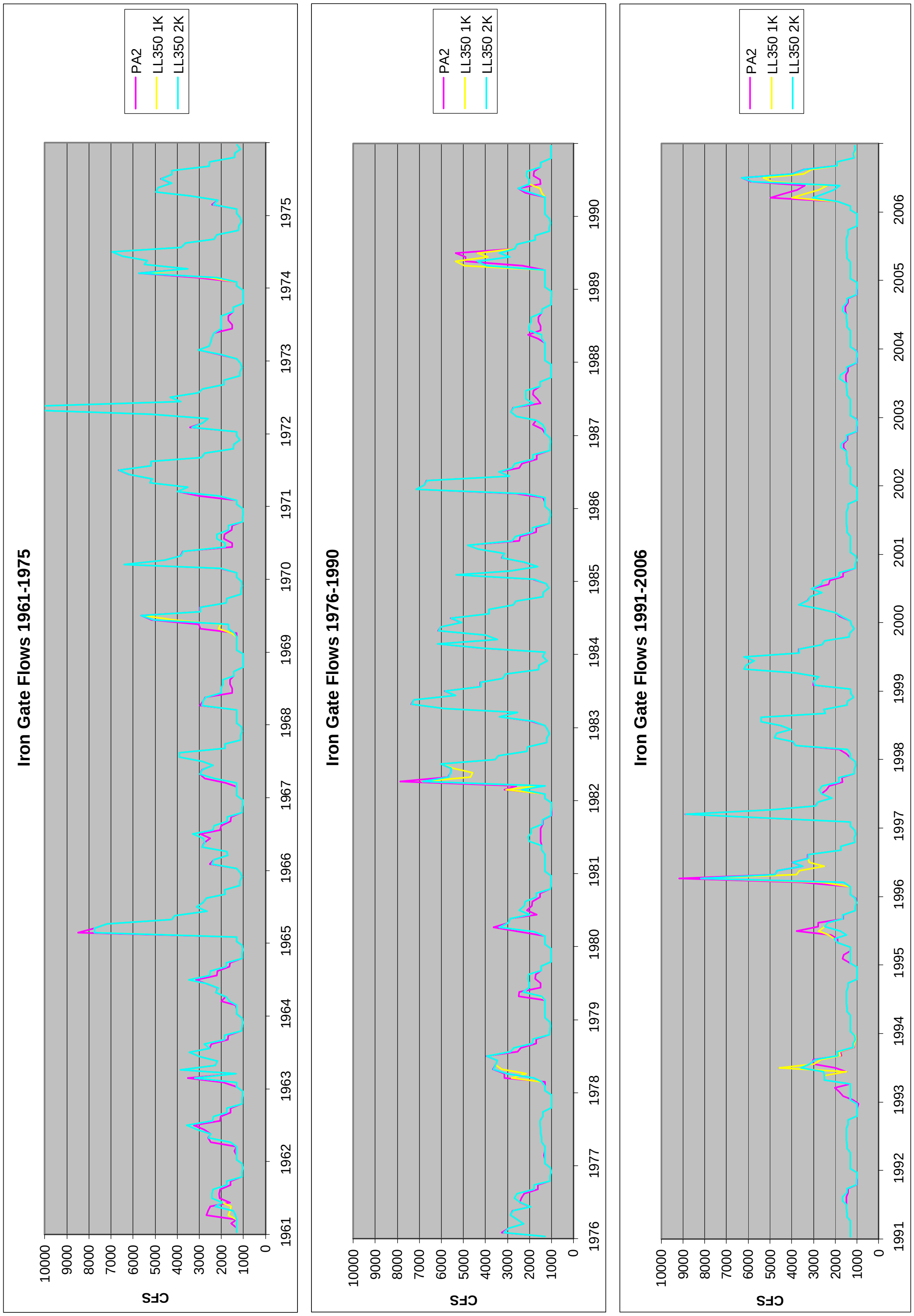


Figure 29.—Long Lake Valley Reservoir effect on flows at Iron Gate Dam.

Operational Simulations and Water Quality Assessment

To assess potential in-reservoir and release water quality from Long Lake Valley Reservoir, a CE-QUAL-W2 hydrodynamic and water quality computer model was developed. Appendix D gives the full report written for this assessment. Numerous simulations were performed to explore potential reservoir water quality dynamics under differing operational criteria. Filling from Upper Klamath Lake was assumed to occur from January through mid-April, and releases were assumed from June through September. Inflow location was always at the north end of the reservoir near Wocus Bay for all simulations described in this assessment; however, outflow was assumed to occur from two principal locations: discharge back to Wocus Bay and discharge to the Klamath River downstream of Link River Dam. For discharges to the Klamath River, two locations were considered: Miller Island and Link River Dam.

Pumped storage operations were also examined. Pumped reservoir storage operations were simulated for selected alternatives to determine the potential effects of such operations on water quality.

A total of 42 Long Lake Valley Reservoir simulations, including sensitivity simulations, were completed. To assess potential water quality conditions on downstream Klamath River reaches, a previously developed CE-QUAL-W2 model of Lake Ewauna/Keno Reservoir was employed. Output from three Long Lake Valley Reservoir model simulations were used as input to the Klamath River model. Conditions below Keno Dam were not assessed in this study. The studies defined and presented in this section are appraisal or pilot-level studies, intended to identify any severe (e.g., fatal flaw) water quality issues, and provide direction and insight as to what possible issues of concern warrant additional study.

Long Lake Valley Reservoir simulations considered a range of storage conditions (i.e., low, medium, and high), as well as static and dynamic fill and drawdown conditions. For purposes of this model, data were only available for low, medium, and high storage values of approximately 65, 170, and 320 TAF, respectively. For the majority of simulations, Long Lake Valley Reservoir initial storage was set low, filled to a approximately half capacity, and then drawn down to approximately the initial elevation by the end of the year. Depending on maximum desired storage volume, fill rates ranged from zero (static storage with no input or output) to 1,000 ft^3/s (for transition from low to high storage). Outlet configuration studies included a single low level outlet and multiple outlets allowing selective withdrawal of reservoir waters (selective level outlet works, [SLOW]).

Conclusion/Summary

The results from these simulations provided an exploration of operations resulting in reservoir water quality differences between simulations of different combinations of conditions. Additionally, the impact of Long Lake Valley Reservoir releases on water quality in the Klamath River was assessed. Below are bullet point summaries of key findings for Long Lake Valley Reservoir conditions and Klamath River conditions.

Long Lake Valley Reservoir

- Long Lake Valley Reservoir would be of sufficient size and depth that the reservoir would experience strong seasonal thermal stratification. At low storage (i.e, less than approximately 10 meters of depth, the reservoir may not stratify seasonally). This seasonal stratification of Long Lake Valley Reservoir is a critical element of reservoir water quality.

- Generally, higher storage volumes resulted in cooler in-reservoir water temperatures, and epilimnion depth was relatively small compared to when active drawdown and filling operations are imposed. The full reservoir conditions retained cooler water and had lower concentrations of algal growth as compared to the simulations with lower starting storage volumes.

- After the onset of algae growth near the surface, there is a transition to higher algal concentrations in deeper water due to near-surface nutrient depletion. Even with the epilimnion mixing (e.g., by wind), during the summer, there seems to be insufficient energy to increase the nutrient levels sufficiently to allow algae to grow in near-surface waters.

- Long Lake Valley Reservoir and the Wocus Bay arm of UKL are fundamentally different in their geometry, hydrology, and nutrient loading. Therefore, differences in water quality between the two water bodies is expected, and the relative differences between source and receiving waters may be important considerations during operational planning.

- Bottom withdrawal as a sole operational strategy limits management options for the quality of release water. Limitations include inefficient use of cold water storage, subsaturation dissolved oxygen conditions, and larger carryover volumes to ensure cold water supplies are not exhausted. A prudent approach to water quality management would make use of a SLOW and/or fill elevations, which would provide the most flexibility for long term water quality management of in-reservoir and discharge waters. Depending on the time of year when filling and when waters are withdrawn (including short term pumped storage), selective placement or withdrawal of water from the reservoir could help manage water quality in the reservoir and in releases (e.g., by maintaining stratification, epilimnetic volumes).

- SLOW logic used in these simulations was a simple representation for modeling purposes, blending water based on water surface elevation and outlet elevations spaced at 10-meter intervals. Simulated strong stratification of Long Lake Valley Reservoir suggests that more closely spaced outlets, at vertical intervals of approximately 5 meters may be required over the anticipated operational range to control release temperature and water quality. Managing Long Lake Valley Reservoir for release water quality would be a challenging task likely requiring near real time monitoring to capture temporal and spatial distribution of water quality constituent(s) of interest.

- Pumped storage both mixes the reservoir at times when it would otherwise be in a relatively stable state, and also potentially imports nutrient-laden water from UKL during the primary production growth season. Because pumped storage utilized a low level inlet, the mixing energy increases temperatures slightly in the hypolimnion, but seemed to have little or no impact on the timing of reservoir turnover. At low lake levels, pumped storage operations can have a greater impact on water quality in Long Lake Valley Reservoir, particularly near the inlet, due to both importation of lower quality water and hydraulic mixing associated with the jet and buoyant effect from warm inputs in the cool hypolimnion. An isolated recirculation facility in reclaimed Wocus Marsh could be used exclusively for recirculated pumped storage water. This would include placing water back in a small storage facility so the same water would be used for pumped storage operations. Such a facility could overcome regulatory criteria regarding receiving water discharge limitations or could minimize the input of organic matter and nutrients from UKL. This facility could be explored in a future study.

- Conducting pumped storage operations during times of winter/spring filling and summer/fall releases could be beneficial. This could be accomplished if there were excess capacity in the system after meeting the respective fill and release requirements. This could be explored further in a future study.

- One possibly important but not evaluated consideration is the sensitivity to initial conditions. While the start of the simulation used conditions that may be found in UKL, the differences in Long Lake Valley Reservoir dynamics resulted in different water quality than when simulation started. Future studies may include multiyear simulations to look at potential longer term conditions. A second consideration is that initial filling may disturb sediments with unknown nutrient load. This could have unknown impacts during the initial fill and initial water quality conditions. Soil sampling for nutrient content prior to construction may help identify possible impacts on water quality.

- Generally, the Long Lake Valley Reservoir longitudinal water quality variations during simulations were relatively small, the exception being during pumped storage in early fall. Withdrawal location more noticeably impacted reservoir release quality when a pumped storage schedule was active (versus a nonpumped storage schedule). The water quality differences are most noticeable in fall when a SLOW located a the southern end of the reservoir discharges higher water quality and lower temperatures as compared to the northern end near the inlet. These discharge differences are due to the water quality differences between the source and receiving waters. A SLOW with pumped storage applied near the inlet (i.e., Wocus Marsh) is noticeably affected by the inflows from pumped storage as compared to a release point at the downstream end of the reservoir (i.e., releases for Miller Island).

- Generally, if the Long Lake Valley Reservoir storage remains low all year (i.e., static), at approximately 64.9 TAF, the water quality from summer onward is diminished in all respects as compared to when filling and drawdown operations occur. Although water quality conditions are largely similar at the onset of stratification for both static low storage and fill and drawdown operations, the larger hypolimnion from fill and drawdown operations moderates water quality conditions. These relative conditions occurred regardless of whether pumped storage was implemented in either scenario.

- For the static, low storage condition, pumped storage operations resulted in an overall reduction in water quality in Long Lake Valley Reservoir due to increased loading from UKL, internal loading, and mixing of anoxic water in the deeper waters. Stratification is not as pronounced and the hypolimnion volume is smaller when pumped storage operations are in effect during static low storage conditions.

Klamath River

- Discharge at Miller Island is sufficiently far upstream that any water quality benefits are modest by the time release waters reach Keno Dam. Temperatures warm relatively quickly in the downstream direction, dissolved oxygen (DO) conditions respond strongly to reservoir conditions as well as exchanges with the atmosphere, and nutrient conditions, although locally different, are generally similar to baseline conditions at Keno Dam.

- Discharges at Link River Dam are sufficiently far upstream that water quality benefits are minimal by the time water reaches Keno Dam for reasons similar to those stated in the previous point.

- Local water quality benefits occur at both locations for temperature, and with lesser influence for DO and nutrients. For example, local thermal refugia could be created and managed via Long Lake Valley Reservoir discharge. However, in a run-of-the-river reservoir such as Keno Reservoir, failure to maintain appropriate temperatures for even a day or two could expose aquatic organisms to rapidly rising temperatures.

- The three previous points suggest that current physical, chemical, and biological processes in Keno Reservoir during summer months overwhelm any improved water quality inputs.

- Inputs at Miller Island may affect downstream water quality conditions through dilution, but may also adversely affect upstream water quality conditions through reduced releases from Link River Dam and increased transit time between Link River and Miller Island. Exploration of reverse flows due to Lost River diversion channel withdrawals were not examined here. In terms of temperature control and direct water quality benefits, there are clear challenges: temperature control and water quality benefits are minimal in the Klamath River below Keno Dam via releases from the Long Lake Valley Reservoir under assumed operations. One of the principal challenges is maintaining a persistent condition (without interruption) to retain an improved water quality in reaches downstream of Link Dam.

- If a release location were included at Keno Dam, similar limitations to the previous bullet point would be of concern (e.g., impairment in Keno Reservoir), with a few caveats. First, if conveyance were in a tunnel/pipeline from Long Lake Valley Reservoir to Keno Dam, heating would probably be minimal. However, tunnel/pipeline conveyance would preclude reaeration, so any low dissolved oxygen conditions and associated water quality would be conveyed to Keno. If in-reservoir treatment options were employed to ameliorate water quality, a final condition would still be diluted at the discharge point due to flow requirements at Link River. For example, to meet current Biological Opinion flows of 1,000 ft^3/s during summer periods at Iron Gate Dam, a total release at Keno would have to be approximately 700 ft^3/s (with an estimated 300 ft^3/s of net accretion between Keno Dam and Iron Gate Dam). Thus, Long Lake Valley Reservoir releases of up to approximately 300 ft^3/s to 400 ft^3/s would be necessary to augment Link Dam releases and accommodate operations within the Keno Reservoir reach. This dilution would considerably reduce the thermal benefit. Further, Long Lake Valley Reservoir flows would not be continuously available either within a year or from year to year. If listed species relied on these intermittent thermal "refugia," Reclamation may be required to maintain such features in the river, placing the economics and benefit of the Long Lake Valley Reservoir outlet tunnel/pipeline release point alternative in question.

Recommendations

This study also identifies areas for future work should additional studies be initiated. These include, but are not limited to:

- Convert the CE-QUAL-W2 model to more recent versions (v3.5 or v3.6) and test against existing simulation results. In addition, explore additional algae species representation and parameter selection, first order sediment processes, and other appropriate water quality modeling variables/processes that will be implemented in the CE-QUAL-W2 model. (WQ-1)

- Recently, additional geometric data has been acquired for Long Lake Valley Reservoir. This data should be used to update model geometry (and test). Also specify more detailed geometric representations of inlet and outlet works. If these elements require flow and water quality modeling to refine predesign consideration, identify a range of potential conditions. If treatment facilities are envisioned (e.g., discharge aeration, pretreatment aeration, in-reservoir oxygenation/aeration), identify location, capacity, and other pertinent features. (WQ-2)

- A wider range of operational information would better constrain the analysis. Define more comprehensive hydrology, inflows, outflows, and storage rules for Long Lake Valley. Operational elements may include fill rates, minimum pool volumes, reservoir storage rules, carryover storage targets, selective input and withdrawal, pumped storage schemes, and outlet tower design and operations. These elements may require water quality modeling to refine operations. (WQ-3)

- Evaluate local conditions at the Wocus Drain discharge point or terminus configuration. Specifically, explore potential local water quality impacts due to discharge to UKL from Long Lake Valley Reservoir and examine potential configurations, if applicable, that would minimize or ameliorate impacts. (WQ-4)

- Water quality boundary conditions could be improved through additional monitoring. Monitoring water quality in the Wocus Bay and Wocus Marsh region, including drains to the local area, would provide additional insight into potential water quality conditions of water imported to Long Lake Valley Reservoir. Parameters should include temperature, dissolved oxygen, pH, specific conductance, nutrients, organic matter, algae, and chlorophyll a and other necessary parameters to compliment model input. (WQ-5)

- Confirm any Long Lake Valley Reservoir water quality release benefits for a discharge point at Keno Dam to the Klamath River downstream of Keno Dam. (WQ-6)

- Additional, site-specific meteorological data can be collected in Long Lake Valley to assess local conditions. These conditions could be compared to long term meteorological stations in the vicinity (e.g., AgriMet KFLO). (WQ-7)

Water Treatment

Water impounded within Long Lake Valley Reservoir may require treatment prior to discharge into Upper Klamath Lake. A range of water treatment options were evaluated in a Preliminary Assessment titled *Preliminary Design and Cost Estimate for Water Treatment, Upper Klamath Basin Offstream Storage Study at Long Lake Valley* (Reclamation, 2008). Among these preliminary treatment options, one was selected to carry forward to the appraisal level: “In-lake aeration, algae removal, and phosphorus removal.” The term “in-lake” refers to treatment that is performed while the water is stored within Long Lake Valley Reservoir, as opposed to treatment by conveying the water to a land-based water treatment plant.

Water Quality and Treatment Objectives

The source of influent water to Long Lake Valley Reservoir would be UKL. The Preliminary Assessment determined expected average and potential maximum values for constituents of concern within Long Lake Valley Reservoir. These values were based upon an evaluation of water quality data from UKL. Treatment and discharge goals for the constituents of concern were based upon the primary goal of maintaining the water quality within Long Lake Valley Reservoir at approximately the same level as the influent quality from UKL, prior to discharge back into UKL.

An evaluation of the potential reservoir water quality, potential regulatory and permitting requirements, and associated treatment goals was not included within the scope of this appraisal study. The appraisal-level designs and cost estimates for in-lake water treatment options are based upon the water quality values and treatment goals as developed in the Preliminary Assessment, as shown below in table 8.

With the exception of dissolved oxygen, the expected maximum values for the constituents of concern in table 8 would occur near the surface of Long Lake Valley Reservoir as a result of seasonal algae blooms (similar to observations at UKL). Therefore, the principal strategy for avoiding water quality degradation is to control or eliminate algae blooms within Long Lake Valley Reservoir. The water treatment options evaluated here are focused on preventing or limiting the occurrence of algae blooms to meet the water quality goals shown in table 8.

Given the historical prevalence of algae blooms in UKL, it is expected that UKL water that is conveyed to and temporarily stored in Long Lake Valley Reservoir may eventually produce conditions that are favorable to the development of algae blooms. There are, however, several inherent differences between UKL and the proposed reservoir that will likely affect the frequency and extent of algae blooms:

Table 8.—Expected reservoir water quality and treatment goals*

Parameter	Average influent values	Maximum in-lake values	Treatment/ discharge goal
pH	9.0	10.6	9.0
Total phosphorus (mg/L)	0.2	1.0	0.5
Ammonia (mg/L)	0.4	7.6	< 0.4
TSS (mg/L)	10	100	30
Temperature (°F)	61	79	61
Dissolved oxygen (mg/L)	8.6	18.6	≥ 5.0

* Adapted from the Preliminary Assessment (Reclamation, 2008)

- Long Lake Valley Reservoir topography—Long Lake Valley Reservoir would be much deeper and have a much smaller surface-to-volume ratio than UKL. The greater depth will produce a different thermocline and temperature stratification, which is a primary factor in the dynamics of productivity, nutrient availability, dissolved oxygen, and water transport. The more stratified and smaller surface-to-volume ratio of Long Lake Valley Reservoir should result in a lower phosphorus release from sediment sources as compared to UKL where sediment sources are at least as great as inflow sources.

- Internal phosphorus loading—Algae productivity in UKL is heavily influenced by accumulated sediments that release phosphorus back into the water. These internal phosphorus loadings would not initially be present in Long Lake Valley Reservoir. Sediments will accumulate over time at the bottom of Long Lake Valley Reservoir; however, the dynamics of the phosphorus cycle of deposition and release will be different than in UKL as a consequence of Long Lake Valley Reservoir topography and management.

- Long Lake Valley Reservoir management—In contrast to UKL, Long Lake Valley Reservoir would be constructed and operated to permit complete control and management of inflows, outflows, and storage volume. Additionally, Long Lake Valley Reservoir's intake tower would have the ability to selectively withdraw water through several gates across a range of elevations. These hydraulic operating parameters will likely have a significant impact on the water quality for the constituents of concern within Long Lake Valley Reservoir. To the extent practicable, water quality discharge goals should be addressed through hydraulic management techniques. If additional in-lake treatment steps are required, they should be integrated within Long Lake Valley Reservoir's hydraulic management framework.

The reservoir's site-specific physical characteristics, limnology, and hydraulic operations will affect both water quality and the efficacy of in-lake treatment. Modeling and analyses of these parameters was not performed as part of this appraisal-level study, but should be performed if feasibility-level studies were to proceed.

Water Circulation and Aeration

The Preliminary Assessment evaluated two types of technologies used for circulation and aeration of impounded water bodies: mechanical circulators (both grid powered and solar powered) and line diffusers. The evaluation determined that line diffusers should be eliminated from further consideration due to technical challenges and high cost. Additionally, it was recommended that either solar or grid powered circulators be carried forward to future studies to address water quality goals.

The primary difference between these circulators is the power source. Solar powered units derive 100 percent of their operating energy from the sun as opposed to grid powered units that require a physical connection above water to the on-shore electrical grid. Assuming that a nearby electrical grid power source would be available, distribution of this power to a network of circulators across Long Lake Valley Reservoir would entail the construction of a cable-supporting infrastructure that would likely be impractical and very expensive. For this reason, the solar powered circulators were selected as the focus in the appraisal study. If it is determined that grid power would be available at Long Lake Valley Reservoir and that construction of an in-lake cable-supporting infrastructure were a viable option, then grid powered circulators can be incorporated into the post-appraisal-level planning estimates.

A commercial water circulator technology used widely across the United States is the patented SolarBee long distance circulator, which is manufactured and distributed by SolarBee, Inc., a subsidiary of Medora Environmental, Inc., of Dickenson, North Dakota. Substantial technical documentation and reports are available at SolarBee's corporate website: www.solarbee.com.

The SolarBee unit floats on the water surface while it draws water up a vertical intake hose and spreads it across the surface in a near-laminar long distance radial flow pattern. Solar panels are mounted on the top of the unit to provide power for a motor to spin an axial flow impeller, which creates the upward flow of water through the intake hose. The length of the intake is adjustable and can be set between 3 and 100 feet to permit a specific depth of water to be treated. The recommended SolarBee unit for Long Lake Valley Reservoir is Model SB10000HW v18, which has a flow capacity of 10,000 gal/min, provides a mixing zone across 35 acres of water surface, and is constructed to withstand high waves. A sketch of the recommended SolarBee unit is shown in figure 30.

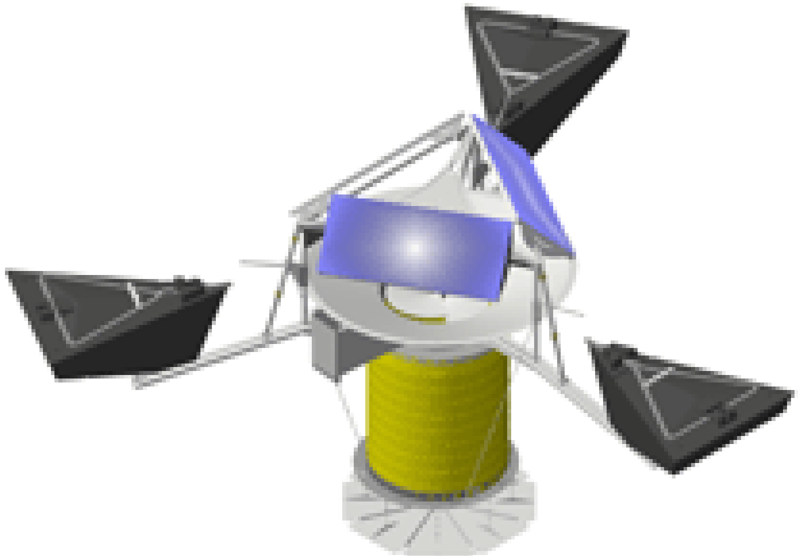


Figure 30.—SolarBee Circulator Model SB10000HW v18.

There are two primary methods of operating the SolarBee circulator machines: hypolimnetic oxygenation and epilimnetic mixing. The primary mode of operation for the proposed circulators at Long Lake Valley Reservoir would be epilimnetic mixing for control of harmful algal blooms (HABs). Under this scenario, the SolarBee intake hose is set to a shallow depth to circulate waters where the algae grow. The effect is to physically disturb the favored habitat (i.e., calm surface waters) of bloom forming blue-green algae. The intake hose would be set at or above the thermocline; water from this depth is brought up and spread radially from the machine. Surface waters then move downward and back toward the machine at the depth of the intake hose. A sketch of the epilimnetic mixing operation is shown in figure 31.

The hypolimnetic oxygenation mode of SolarBee operation could potentially be used in the vicinity of the intake tower if water is to be withdrawn at depths below the thermocline where the dissolved oxygen concentrations may otherwise be less than the water quality discharge goal of 5 mg/L. For this method of deployment, the SolarBee intake hose is set deep, below the thermocline, in order to bring oxygen-poor water to the surface for natural reoxygenation. More oxygen-rich water is transported downward to the depth of the SolarBee intake hose through displacement. The depth of the SolarBee draft tubes can be adjusted to optimize the pattern of circulation and achieve the desired dissolved oxygen levels in the vicinity of the gate openings of the intake structure. A sketch depicting this mode of operation is shown in figure 32.

The appraisal cost estimates for SolarBee operation include purchase and installation of circulators at a spacing of 35 acres per machine; this would provide

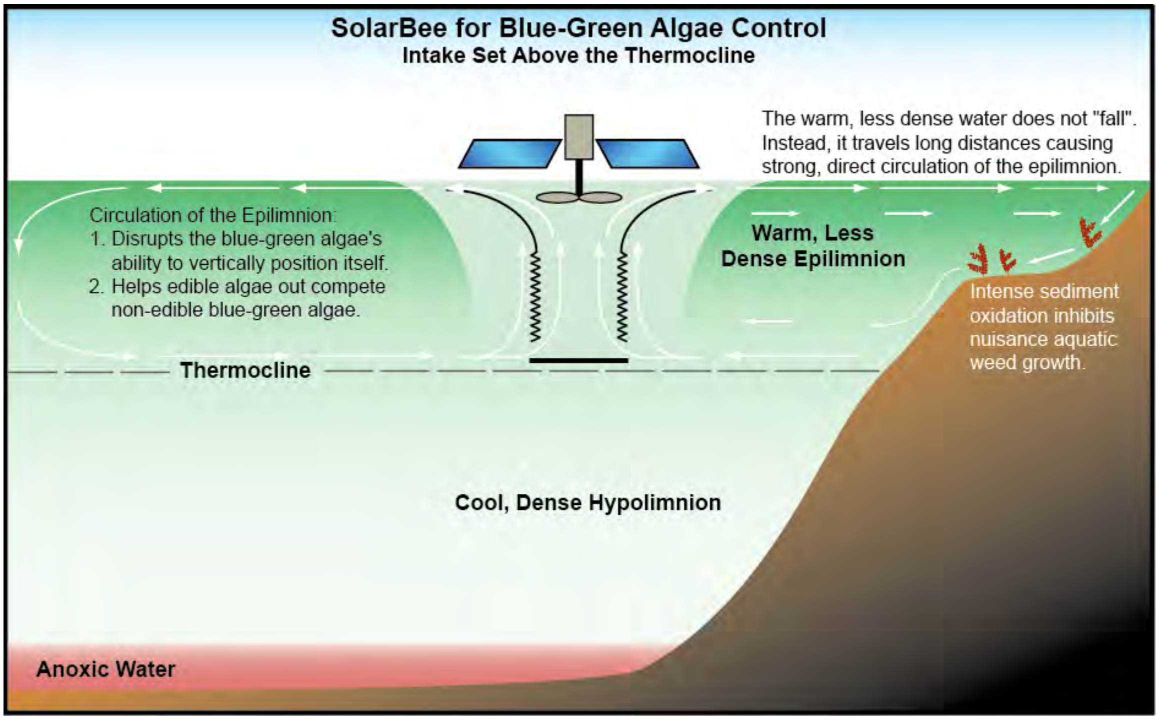


Figure 31.—SolarBee circulation pattern for epilimnetic control of HABs.

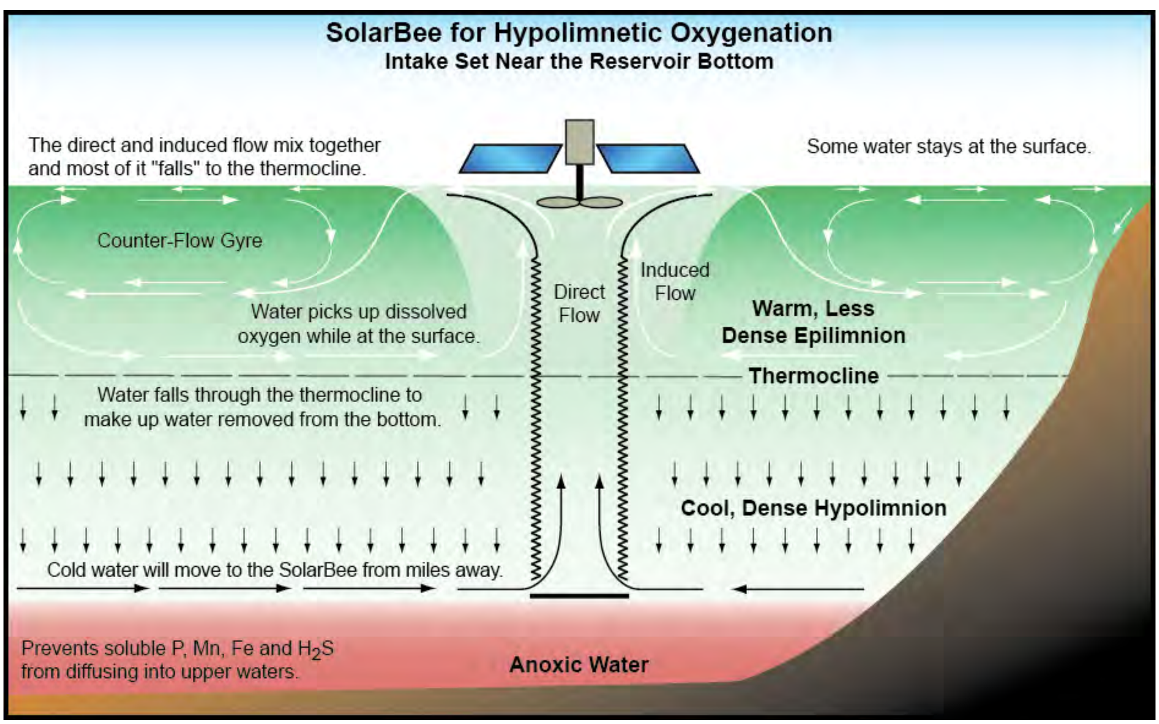


Figure 32.—SolarBee circulation pattern for hypolimnetic oxygenation.

a maximum of 77 circulators deployed across 2,680 acres of surface area when Long Lake Valley Reservoir is filled with 350,000 acre-feet of water. Operation, maintenance, and life cycle cost estimates provided by the vendor assume two full-time technicians using a watercraft and a 25-year replacement interval for the circulators.

SolarBee circulators are successfully used at hundreds of ponds, lakes, and reservoirs across the United States to eliminate or control algae blooms and their associated water quality problems. Given their proven track record for successful lake management of water quality parameters, it is possible or likely that additional treatment measures would not be required at the proposed reservoir. A pilot test of SolarBee units at an existing nearby lake or reservoir could provide useful performance data as part of post-appriasal-level studies.

Chemical Treatment for In-Lake Phosphorus Removal and Inactivation

Strategic operation of the SolarBee circulators may be adequate to eliminate or control potential algae blooms in Long Lake Valley Reservoir, which would be the source of seasonally high levels of phosphorus, pH, and suspended solids near the reservoir surface. Additionally, strategic operation of the intake tower gates to selectively withdraw water at depths that possess the desired water quality could potentially avoid the impaired water quality conditions associated with algae blooms near the surface. If additional measures were required to meet the water quality discharge targets, in-lake chemical treatment for phosphorus inactivation may be effective in achieving the water quality discharge goals.

Phosphorus inactivation is an in-lake technique to remove phosphorus from the water column through precipitation and subsequently retard its release from sediments. The first step of in-lake treatment consists of distributing a chemical coagulant across the surface using a fleet of barges or work boats. The coagulant is dispersed and mixed near the surface by the prop wash of the boat motor. Once dispersed, the coagulant reacts with dissolved constituents such as phosphorus and alkalinity to produce solid flocs. The flocs gradually increase in size through mixing and adsorption of other flocs and suspended solids. When the weight of the individual flocs exceeds the buoyant force of the water, they settle to the bottom of the reservoir and continue to sorb and retain phosphorus.

Chemical Selection and Dose

Two predominant coagulant chemicals are commonly used to precipitate, flocculate, and settle water contaminants in water and wastewater treatment: aluminum and iron salts. The selection of a particular chemical depends upon site-specific factors that require laboratory and field tests to evaluate performance and dosing requirements. Ultimately, the selection may depend upon the redox value that develops in the bottom sediment, which affects the level of phosphorus retention. These tests were not performed as part of this study and, therefore, ferric chloride was arbitrarily selected for development of appraisal designs and cost estimates for in-lake treatments. The chemical equation associated with the reaction of ferric chloride with phosphate is:

$$FeCl_3 + PO_4^{3-} \rightarrow FePO_4\downarrow + 3Cl^- \qquad \text{Equation 1}$$

Stoichiometry indicates that one mole of iron is required to react with each mole of phosphorus. In practice, however, ferric chloride also reacts with alkalinity and other constituents and typically requires a dose of two to three times the stoichiometric Fe:P dose (Denham, 2007). The reaction of ferric chloride with carbonate alkalinity of the water can be shown as:

$$FeCl_3 + 3HCO_3^- \rightarrow Fe(OH)_3 + 3CO_2 + 3Cl^- \qquad \text{Equation 2}$$

The chemical dosing estimate is based upon removing 0.5 mg/L of phosphorus, which is the difference between the reported maximum concentration (1 mg/L) and the treatment goal (0.5 mg/L), as shown in table 8. This is likely a conservative estimate given that the bulk of the phosphorus measurements reported in table 8 are insoluble species (i.e., already precipitated) and would not be substantially removed via the reaction of equation 1. Although some $FePO_4$ may precipitate, it is expected that the primary means of phosphorus removal from the water column and retention in sediments would occur through sorption to flocs formed by $Fe(OH)_3$ (equation 2) and other alkalinity, which forms part of an oxidized microzone over the sediment surface, providing high retention of phosphorus (Cooke et al., 2005).

The kinetics of ferric chloride coagulation occur rapidly (minutes) whereas floc formation and settling occurs more slowly (hours). The chemical dose estimate, therefore, assumes that the coagulant is consumed within a 10-foot layer of water near the reservoir surface that is subject to the direct mixing action of the boat motor's prop wash. This layer also coincides with the photic zone where the higher concentrations of phosphorus and other suspended solids would reside during algae production. Additional phosphorus removal may occur within the water column below this layer through adsorption to flocs as they settle to the bottom.

In summary, chemical quantities and cost estimates assume application of liquid ferric chloride coagulant at a dose that is three times the stoichiometric amount required by equation 1 to react with 0.5 mg/L of phosphorus, and treatment of the top 10 feet of reservoir water volume. The quantity of 38 percent ferric chloride solution needed for a single application on the reservoir surface at this level of treatment would be approximately 134,000 gallons. It is estimated that precipitation and settling of ferric flocs would produce an insignificant amount of sludge (~0.002 inches per application) at the bottom of the reservoir.

Chemical Storage

Liquid ferric chloride solution is a corrosive, dark brown oily appearing solution having a unit weight of about 11.2 lb/gal at 38 percent strength. The chemical solution can be safely stored in fiberglass-reinforced plastic (FRP) tanks and would remain liquid throughout the year at the ambient temperatures near the reservoir. It is uncertain, however, whether and how much chemical storage would actually be required. Depending on the distance, method of shipment, and other logistics, it may be possible to directly offload the chemical to the watercraft when needed.

Appraisal cost estimates assume installation of six double walled, FRP storage tanks, 12 feet in diameter by 30 feet in length, which would provide sufficient total capacity (134,000 gal.) for the amount of ferric chloride required to treat the entire surface of the reservoir. The tanks would be supported by a reinforced concrete foundation. The need and capacity for chemical storage should be further evaluated during post-appraisal-level studies.

Chemical Application

Liquid ferric chloride would be applied to the reservoir surface using a fleet of work boats or barges. The chemical would be pumped or flow by gravity from the on-shore storage tanks to a holding tank on the boat. On-board chemical metering pumps would measure and control the amount of chemical that is discharged over the side where it would be mixed and dispersed by the prop wash.

Appraisal cost estimates assume that a fleet of four boats (each having a 1,000-gal. chemical holding tank) would be able to distribute the chemical over the entire reservoir surface (2,680 acres) within 2 weeks.

Effectiveness and Longevity of Chemical Treatment

Iron and aluminum coagulants are used successfully at water and wastewater treatment plants throughout the world for contaminant removal and clarification. During the past several decades, these chemicals have also been employed as a lake management tool for phosphorus inactivation with varying degrees of success. Their use has primarily been focused on water bodies that have significant internal phosphorus loadings because chemical precipitation binds the phosphorus and retards its future release, thereby disrupting the internal loading at its source. In contrast, the proposed reservoir would be newly created and presumably would not have significant internal phosphorus loading (at least initially); the primary source of phosphorus would be the discharge of water conveyed from UKL.

As noted previously, it is unknown whether chemical precipitation treatments would be required to meet water quality discharge goals. If implemented, the effectiveness and longevity of in-lake chemical treatment are uncertain. Traditional applications that target phosphorus inactivation to control internal loadings typically last 2 or more years. The appraisal cost estimates for the proposed reservoir operation assume that the introduction of poor water quality from UKL might occur seasonally twice per year and, therefore, up to two separate chemical treatments per year would be required to remove phosphorus and suspended solids within the photic zone. Additionally, these treatments would likely reduce the pH and improve other water quality parameters associated with seasonal algae blooms.

Modeling of the reservoir water quality as part of any potential feasibility-level study may reduce the uncertainty of the potential effectiveness of in-lake treatments and enable evaluation of other chemical application options. For example, chemical coagulant could potentially target inflow spikes of phosphorus and suspended solids when and where it enters the reservoir, or the SolarBee circulators could potentially be used for injection, mixing, and distribution of chemical coagulant.

Commercial Algae Harvesting

Another method to remove phosphorus particles and other suspended solids near the reservoir surface is commercial algae harvesting using barges and transporter boats. Traveling conveyor screens along the side of the barge remove the algae from the water and lift it to the barge deck. Transporter boats carry the collected algae to shore where it is transported by trucks to a local facility for processing and packaging into health products that are distributed nationwide.

Commercial algae harvesting has been practiced in Upper Klamath Lake for more than 10 years. Given the uncertainty regarding the future types and amounts of potential algae production at the proposed reservoir, it is unknown whether algae harvesting would be a viable commercial enterprise. If implemented, it is expected that algae harvesting would be a private enterprise without significant associated costs to the Federal Government.

Recommendations

The proposed conveyance and storage of UKL water within LLV would likely produce seasonal adverse impacts to the impounded water quality. A range of reservoir management and treatment options is available to control and reduce these impacts in order to meet water quality goals when the water is subsequently discharged to downstream users. This appraisal study provides designs and cost estimates for mechanical circulation equipment and chemical treatment of the reservoir surface to meet the water quality goals as presented in the Preliminary Assessment. If further study is to be undertaken on the LLV alternative, it is recommended that the following investigations and analyses be performed:

- Permitting and discharge requirements—Federal and State regulations should be evaluated to determine and document any permitting and water quality requirements related to the operation and discharge of water from the proposed reservoir. This evaluation should include potential regulatory issues related to in-lake chemical treatment (effects on fish and wildlife), sludge accumulation, and reservoir lining. (WT-1)

- Water quality modeling—A limnology model of the proposed reservoir should be developed to predict water quality as a function of inflows, outflows, storage volume, and treatment options. (WT-2)

- SolarBee pilot testing—Field pilot testing of multiple SolarBee units should be conducted over a 12-month period to collect performance data. Suitable testing locations should have water quality that is similar to UKL's, have significant temperature stratification due to depth of water, and be geographically close enough to have ambient conditions comparable to those at LLV. (WT-3)

- Laboratory bench tests for chemical precipitation—Laboratory bench tests using UKL water should be conducted to evaluate the best chemical coagulant (ferric chloride or alum), the optimum dosage, mixing requirements, characteristics of floc formation and settling, and sludge production. (WT-4)

- Alternative treatment and water quality management options—Additional strategies not included in the appraisal study may be appropriate for feasibility consideration such as: water treatment along the conveyance between UKL and LLV to address discrete spikes in poor water quality, source control measures for inflows to UKL, and management techniques of flow and storage to mitigate potential water quality degradation. (WT-5)

Benefit-Cost Analysis

This section describes the results of the preliminary National Economic Development benefit cost analysis (BCA) developed for the proposed appraisal-level alternatives.

The *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, otherwise referred to as the P&Gs (U.S. Water Resources Council, 1983), represent the main set of guidelines for Federal water management agency economic analyses. The P&Gs describe the NED account that helps to facilitate the evaluation of the economic effects of proposed alternative plans. The NED account focuses on the economic benefits to the entire nation.

As a Federal agency, Reclamation must analyze the NED effects so as not to favor one area of the country over another. Economic justification is determined for each alternative solely by the benefit-cost analysis and must be demonstrated on the basis of NED benefits exceeding NED costs.

The NED BCA compares the present value of a proposed project's benefits to the present value of its costs. If benefits exceed costs, the project is considered economically justified. Because both benefits and costs can change at various points throughout the study period, it is important to convert them to a common point in time. For this analysis, the costs and benefits were measured as of the start of the benefits period (which is equivalent to the end of the construction period). The study period or period of analysis for the benefits period was assumed to be 50 years. The interest rate used to convert costs and benefits to a common year was Reclamation's fiscal year 2009 planning rate of 4.625 percent.

Preliminary Economic Assessment

Table 9 summarizes the preliminary conceptual plan costs, preliminary benefits, and preliminary benefit cost ratios. The preliminary benefit cost ratio for the 1,000-ft^3/s option equals 0.03. For the 2,000-ft^3/s option, the preliminary benefit cost ratio equals 0.02. It should be noted that the benefit cost ratios are incomplete because several benefit categories were not calculated due to insufficient data.

However, a more thorough determination of costs for LLV mitigation and other issues would be undertaken in the event that studies of the BCR for LLV conceptual plan features showed positive results.

Table 9.—Preliminary project cost summary for 350,000 acre-foot life cycle costs based on a July 2008 price level and assuming no water treatment

		Option A 1,000-ft^3/s pump only		Option B 2,000-ft^3/s pump only	
		Estimated costs ($)	Present worth ($)	Estimated costs ($)	Present worth ($)
Initial capital costs					
Construction costs Rev1, July 2008			1,250,000,000		1,500,000,000
Subtotal 1			1,250,000,000		1,500,000,000
Periodic costs	PW factor				
Year 5	0.79767	115,000	91,732	115,000	91,732
Year 10	0.63628	165,000	104,986	165,000	104,986
Year 15	0.50754	1,300,000	659,802	1,350,000	685,179
Year 20	0.40485	185,000	74,897	190,000	76,922
Year 25	0.32293	54,000,000	17,438,220	70,000,000	22,605,100
Year 30	0.25759	2,900,000	747,011	2,900,000	747,011
Year 35	0.20547	16,500,000	3,390,255	34,000,000	6,985,980
Year 40	0.16390	18,500,000	3,032,150	41,000,000	6,719,900
Year 45	0.13074	1,300,000	169,962	1,350,000	176,499
Subtotal 2			25,709,016		38,193,309
Annual costs	PWA factor				
Maintenance	19.36679	2,800,000	54,227,012	3,200,000	61,973,728
Operations costs	19.36679	2,900,000	56,163,691	3,200,000	61,973,728
Other annual O&M misc costs (nonmajor equipment)	19.36679	600,000	11,620,074	730,000	14,137,757
Other costs (evaporated water)	19.36679	93,816	1,816,915	128,918	2,496,728
Other costs (water seepage)	19.36679	310,325	6,009,999	372,390	7,211,999
Subtotal 3			129,837,691		147,793,940
Total present worth costs = subtotals 1 + 2 + 3			1,405,546,707		1,685,987,249
Total present worth costs rounded			1,400,000,000		1,700,000,000
Assumptions: • Inflation rate multiplier = 1.04625 • 50-year analysis period • FY2009 planning interest rate 4.625% per year for 50 years • PW factor = P/F = (1+i) - n = Single payment present worth (P/F, 4.625%, 50) • PWA factor = P/A = ((1+i)n - 1)/(i*((1+i)n) = Uniform series present worth factor (P/A, 4.625%, 50)					
Preliminary interest during construction costs			135,865,095		156,582,726
Preliminary total project costs = Subtotal 1 + 2 + 3 + IDC			1,541,411,801		1,842,569,975
Preliminary total project costs = Subtotal 1+2+3+IDC rounded			1,540,000,000		1,840,000,000
Long Lake Valley appraisal design—No Action			63,000,000		63,000,000
Preliminary Project costs less No-Action costs			1,397,000,000		1,697,000,000

Preliminary Project Benefit Summary

	Annual benefit ($)	Present worth ($)	Annual benefit ($)	Present worth ($)
A. Agriculture	797,730	39,886,493	833,356	41,667,818
B. Recreation	Insufficient data		Insufficient data	
C. Fisheries	See qualitative analysis on p. 113		See qualitative analysis on p. 113	
Preliminary total project benefits = A + B + C	797,730	39,886,493	833,356	41,667,818
Preliminary total project benefits = A + B + C rounded	800,000	39,890,000	830,000	41,670,000
Preliminary benefit cost ratio		**0.03**		**0.02**

Preliminary Estimated Costs

The cost analysis is performed on a life-cycle cost basis for each alternative is broken down into three subsections: (1) upfront construction costs (including noncontract costs), (2) interest during construction (IDC), and (3) annual operations, maintenance, and replacement (OMR) costs. The IDC calculation represents the cost of Federal borrowing during the construction period.

Preliminary Estimated Benefits

This section discuses potential economic benefit estimates for agriculture, recreation, and fisheries. Appraisal-level benefits are calculated for agriculture and hydropower. These analyses follow the criteria for measuring NED benefits defined in the P&Gs. Recreation and fisheries benefits are discussed qualitatively as data was not available to estimate these benefit categories.

Agricultural Benefits

Evaluation Method

The agricultural benefits analysis follows the criteria for measuring NED agricultural benefits defined in the P&Gs. The P&Gs are the Federal guidelines by which Reclamation determines NED benefits of Federal actions or project implementation. A P&G analysis of NED agricultural benefits is a "with and without" project comparison that identifies the change in net farm income related to a change in crop acreage while maintaining the same cropping pattern.

The model used in the hydrologic analysis of proposed operations of the offstream storage conceptual plan includes a representation of deliveries to Klamath Project water users, with demands based on precipitation conditions. The model uses a 46-year period of historical input hydrology (1961-2006) to drive operations of the Klamath River system to manage elevations in Upper Klamath Lake, flows at Iron Gate Dam, and delivery to meet agricultural and refuge demands in accordance with current and assumed future operational criteria. Delivery results for both the No-Action and with-project scenarios were processed to develop information on annual deliveries for each year of the model run. The average of these annual values was used in the determination of agricultural benefits.

The agricultural benefits are based on (1) the average annual water supply, (2) the cropping pattern both with and without off-stream storage, and (3) the benefit unit value per acre for each crop. The Klamath Basin Hydro-Economics Model (KB_HEM) measures the cropping pattern for the alternatives, including the No-Action alternative, based on the annual average water supply. The benefit unit values, estimated using a farm budget methodology, were applied to the cropping patterns, incremental to the No-Action alternative, to estimate the NED agricultural benefits for both with- and without-project alternatives. The KB_HEM and the benefit unit values are discussed below.

Klamath Basin Hydro-Economics Model

The KB_HEM is a positive mathematical programming model that simulates agricultural production. The modeling framework allows the model to respond in a manner consistent with agricultural behaviors. The model first replicates the agricultural producers' maximized profit subject to physical (e.g., water supply) and economic (e.g., prices and production costs) constraints. The KB_HEM utilized in this study attempts to capture farmers' decisions on a regional level. As economic constraints and/or physical constraints change, the model estimates the optimal mix of crops that maximize profit.

Agricultural Benefit Unit Values

After the KB_HEM model calculates acreages by crop for each alternative, benefit unit values are applied to estimate NED agricultural benefits for the alternatives. The benefit unit values follow the criteria for measuring NED agricultural benefits defined in the P&Gs. A P&G analysis of NED agricultural benefits identifies the change in net farm income related to a change in crop acreage while maintaining the same cropping pattern. Net farm income is estimated using a farm budget methodology. These values were derived by a previous study conducted by the Bureau of Reclamation.

Findings

The present value of the 50-year stream of agricultural benefits equals $39.9 million (the annual equivalent is equal to $800,000) and $41.8 million (the annual equivalent is equal to $830,000) for alternatives 1A and 1B, respectively.

Recreation Benefits

As stated in *Recreation Resources* (p. 67), visitor use cannot be predicted at this time; therefore, recreation benefits cannot be quantified for the appraisal-level study. Visitor use estimates influence recreation benefits, and Long Lake Valley Reservoir operations will greatly affect visitor use. Recreational benefits may be very minor due to the potential impacts of reservoir drawdowns. (ECON _REC-1)

Fisheries Benefits

Long Lake Valley Reservoir operations may also benefit fisheries resources, both reservoir and river fisheries. Fisheries benefit analyses typically focus on use values. Use values refer to values individuals obtain by using the resource. In the case of fisheries, use values accrue to individuals who use/consume the fish (e.g., commercial, sport, or tribal fishermen). Use values are based on the quantity of fish actually harvested or caught. It should be noted that tribal fishermen may harvest fish for a variety of reasons—commercial resale, subsistence, and ceremonial purposes. Tribal ceremonial harvest is typically not included in a benefit analysis since attempting to economically value ceremonial harvest would be akin to valuing tribal spiritual beliefs.

Another category of fisheries benefits that may also be considered are nonuse values. Nonuse values reflect values individuals hold for a resource even if they will never actually use it (e.g., threatened and endangered species). Since the Lost River and shortnose suckers in UKL and coho salmon in the Klamath River are federally listed species, and Long Lake Valley Reservoir operations may affect them, nonuse values may be applicable to this study. However, nonuse values can be very difficult to estimate, requiring the application of complex survey approaches, with the results often proving to be highly contentious.

Implementation of LLV would change Klamath River flow, which, in turn, would affect the production and harvest of coho and Chinook salmon.

Reclamation contracted with Cramer Fish Sciences to develop a coho salmon life-cycle model (Klamath Coho Integrated Modeling Framework, version 1.3, dated March 2008). The model is capable of quantifying how natural coho salmon production would change in response to changes in water management by the Klamath Project. The coho salmon life-cycle model projects out to only year 12 for the 3-year-old fish (4 cycles). There is no model to estimate impacts on Chinook salmon.

The Klamath coho life-cycle model integrates a series of quantitative relationships that determine life-stage survival and abundance based on current coho population structure and the influence of certain environmental variables such as flow and temperature. The model divides the Lower Klamath Basin into reaches to provide sufficient spatial resolution to capture the different flow and thermal regimes experienced by fish in different portions of the project area.

LLV options would primarily affect salmon production within the main stem of the Klamath River. Limited coho salmon production occurs within the main stem of the Klamath River. Thus, the alternatives would have a very limited impact (adverse or beneficial) on coho salmon production. Utilizing the coho salmon life-cycle model's default parameters, the average increase in production in year 10 is 13 fish (with a range of 12 to 14 fish). Although the model results indicate a slight increase, the level of precision is not within the model's capability. To estimate salmon production annually for the 50-year life of the project would be more problematic and would be unwise. However, it is likely that the operation of Long Lake Valley Reservoir could benefit coho salmon production, although insignificantly.

Unlike coho salmon, a substantial level of chinook salmon production occurs within the main stem of the Klamath River. There is no completed model to estimate the impacts on Chinook salmon. Reviewing the results of the coho salmon life-cycle model and our understanding of the relationships between where coho and Chinook salmon spawn (main stem versus tributaries), the alternatives would most likely benefit Chinook salmon production more than coho salmon production. Because estimating production depends on a number of incalculable factors, it is not possible to determine the benefits of the alternatives on Chinook salmon populations at this time.

Summary

The benefit-cost analyses that are included result in low BCRs ranging from 0.01:1 to 0.04:1, The BCRs were computed without estimated costs for mitigation, land acquisition, reservoir lining and water quality. Periodic costs included operations and maintenance costs, which included energy for pumping, except for the No-Action alternative.

A more thorough determination of costs for LLV mitigation and other issues would be undertaken in the event that studies of the BCR for LLV conceptual plan features showed positive results.

Real Estate

This section is related to the acquisition of lands or interests in lands for the proposed Long Lake Valley Off-Stream Storage conceptual plan. The acquisition would consist of approximately 4,370 acres of land or interests in lands affecting 61 parcels owned by 14 separate landowners as shown on the boundary map in figure 33. The proposed area consists largely of agricultural and timber lands.

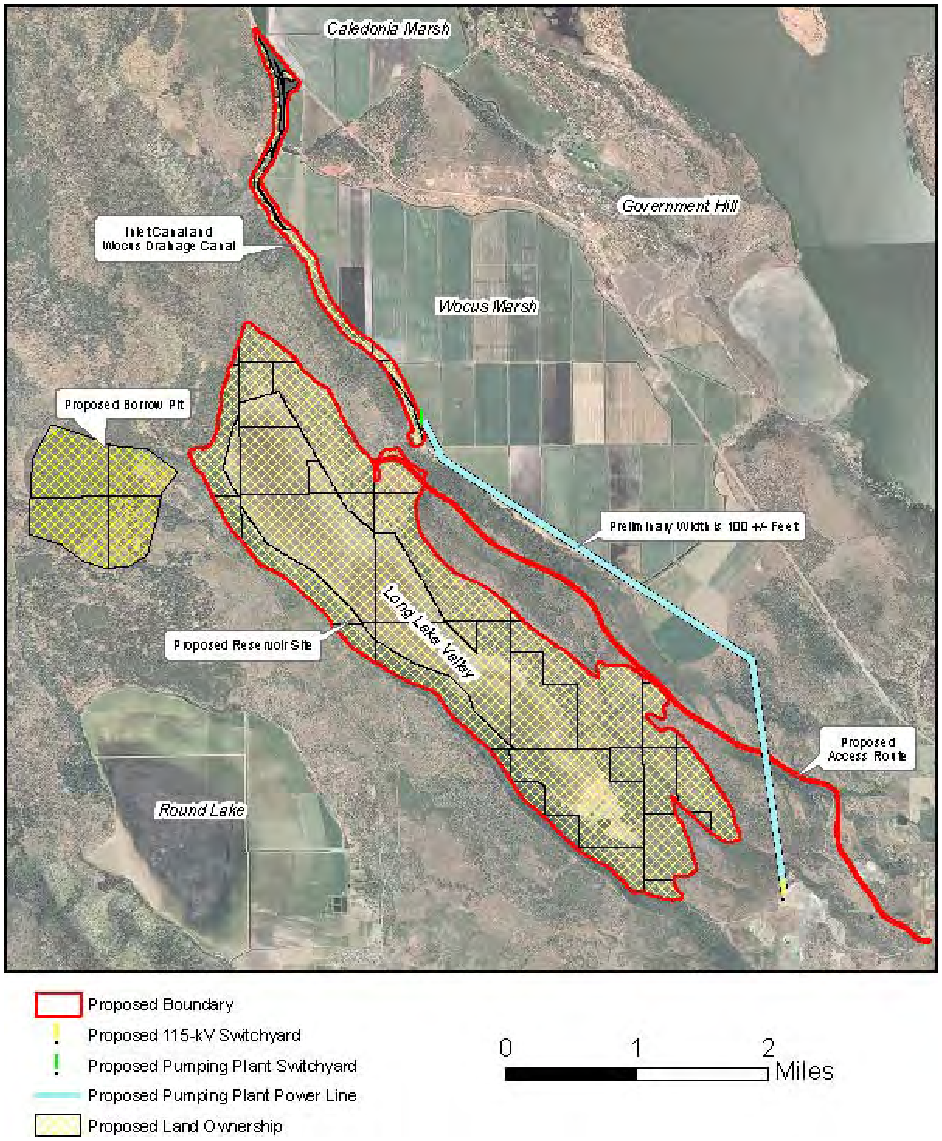


Figure 33.—Long Lake Valley boundary map.

Below are topics of discussion that relate to the acquisition of the lands or interests in lands for the proposed LLV Off-Stream Storage conceptual plan:

- Land acquisition plan—During the acquisition planning and programming stage, there needs to be a comprehensive Land Acquisition Plan. Once the plan were drafted it would go through periodic reviews and revisions. Upon completion, it would need to be approved by the Regional Director or designee (Regional Realty Officer). (REAL-1)

- Relocation assistance planning—During preconstruction planning and prior to initiation of negotiations for the acquisition of any real property, a determination must be made whether the acquisition would result in the displacement of persons from their dwellings, businesses, or farm operations. Prior to the commencement of acquisition activities (including development of property descriptions, title examinations, appraisal, and negotiations) that would cause such displacement, a relocation plan would be developed that complies with 49 CFR Part 24, Subpart C Section 24.205, pursuant to the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. This topic refers to all acquisition methods. Depending on the acquisition method, relocation assistance could be part of a negotiated sale or in condemnation proceedings. (REAL-2)

- Landowner relations—It is imperative that within 6 months of Congress authorizing and funding the project, a reasonable effort be made to advise owners/occupants in the conceptual plan area on the scope of the conceptual plan and the probable time when the lands or interests in lands or water rights would be acquired (this can be established through public meetings, personal contacts, etc.). Pamphlets and brochures that contain information on the lands or interests in lands and water rights acquisition methods and procedures should be distributed to owners and occupants of the lands in the vicinity of the proposed acquisition area. (REAL-3)

- Determination of program needs—A 9-month minimum lead time (this may not be sufficient time in which to accomplish the real estate program due to the size and significance) is required to allow sufficient time to develop a realistic schedule for land and water rights acquisition and to comply with requirements for acquisition and relocation assistance planning to ensure availability of sufficient replacement housing. (REAL-4)

- NEPA and other environmental laws compliance—NEPA compliance would include, but not be limited to, preparation of an Environmental Assessment (EA)/Finding of no Significant Impact (FONSI) or EIS/ROD, and completion of hazmat surveys/evaluations. In addition, other environmental laws, such as the National Historic Preservation Act and Endangered Species Act, require certain compliance measures. There must be confirmation of environmental law compliance before any construction activities may begin on the land or interests acquired. (REAL-5)

- Guide acquisition lines—Designation of interests in real property planned to be acquired may be established through the use of “guide acquisition lines,” “guide contour lines,” or “take lines.” These are lines established through Reclamation’s planning process that delineate the various lands and/or land estates to be acquired at different elevations both upstream (pool, etc.) and downstream (flood, etc.). (The term “guide acquisition line” is sometimes used in reference to safety of dams criteria.) Any maps or plans distributed should be labeled “Preliminary—Subject to Revision” when appropriate. For more detail, refer to the Reclamation Manual, LND 06-01(3)(K), p. 12. (REAL-6)

- Joint policy for reservoir conceptual plan lands—Reservoir conceptual plan land acquisition policy for the Department of the Interior and the Army is published in 43 CFR Part 8, which cites policy for subjects including, but not limited to:

    - Acquisition of the lands with adequate interest in lands necessary for the realization of optimum values for all purposes, including additional land areas for present and future outdoor recreational and fish and wildlife potentials.

    - Lands necessary for reservoir construction and operation (i.e., for permanent structures), lands below the maximum flowage line, and lands needed to provide for public access to the maximum flowage line.

    - Additional lands for correlative purposes (i.e., lands needed to meet present and future requirements for fish and wildlife as determined pursuant to the Fish and Wildlife Coordination Act), and lands needed to meet present and future public requirements for outdoor recreation, as may be authorized by Congress.

    - Easements in lieu of fee title (i.e., for lands lying above the storage pool, lands in remote portions of the conceptual plan area, and lands determined to be of no substantial value for protection or enhancement of fish and wildlife resources, or for public outdoor recreation). In some cases, it is to the financial advantage of the Federal Government to take easements in lieu of fee title.

    - Buildings for human occupancy as well as other structures that would interfere with the operation of the conceptual plan for any conceptual plan purposes are prohibited on reservoir conceptual plan lands. (REAL-7)

- Estates to be acquired—Reclamation would acquire estates in real property that are consistent with the joint policy and specific program requirements. In addition, Reclamation would provide that its water and land areas would, to the extent appropriate:

    - Be available to the public
    - Provide appropriate public access
    - Enhance recreation
    - Promote fish and wildlife habitats
    - Provide fishing access, if so desired
    - Facilitate and encourage optimum use and utilization of all lands acquired

  Reclamation typically desires the least amount of interest that allows management, operation, and maintenance of its facilities. Nothing is inherently better about having fee land compared to having an easement that gives Reclamation all the rights it needs. Lands or interests in lands that are acquired by the United States usually remain within the ownership of the United States even if management and operation and maintenance activities are transferred to an appropriate agency in the future. (REAL-8)

- Acquisition of fish and wildlife properties—Under the authority of the Fish and Wildlife Coordination Act, Reclamation is required to consult with the Fish and Wildlife Service during the planning of new conceptual plans so that wildlife resources receive equal consideration with other conceptual plan objectives. By statutory provision, the consideration of fish and wildlife values and the mitigation for any damage to those values must proceed concurrent with or before construction. Reports and recommendations from the Service and the head of the State wildlife resource agency may be provided to Reclamation detailing: (1) impacts to wildlife resources, (2) means to mitigate or compensate adverse impacts, and (3) enhancement measures. At this point during the planning process, acquisitions of fish and wildlife properties are not anticipated. (REAL-9)

- Flood hazard evaluations—In compliance with Executive Order 11988, requests to the Regional Director for approval to acquire or exchange lands or rights-of-way must be accompanied by a statement on flood hazards, including justification for anticipated construction of facilities and proposed land use within the floodplain. *(This requirement does not apply if such information, in accordance with Executive Order 11988, was included in the project feasibility report.)* (REAL-10)

- Land designation and/or legal descriptions—Consideration of the various estates to be acquired should lead to designation of the lands and/or land interests required for Reclamation purposes and preparation of legal descriptions and tracts maps including, but not limited to:

    - Land surveys, by a registered land surveyor for the delineation of all lands and land interests required for a project, should be expedited so that boundaries of land under Reclamation's jurisdiction can be obvious to Reclamation's management and to the public. The property boundaries should be monumented while construction funding is still available.

    - Early designation of sufficient lands (including mitigation of lands, habitat improvement areas, and recreational areas) for all authorized and planned conceptual plan purposes is essential in order to avoid additional land-purchase negotiations with the same owners.

    - Accurate descriptions of lands and interests of lands to be acquired would be prepared, checked, and certified together with an endorsement to that effect. A survey plat or tract map of the acquisition should also be prepared under the same standards as the description. (REAL-11)

- Ownership and title determinations—Title evidence must be obtained prior to acquisition of lands or interests in land or interests in water rights. Title evidence must conform to the 1992 Revised Department of Justice Title Standards, which include *Standards for the Preparation of Title Evidence in Land Acquisitions by the United States*, 1970; and *a Procedural Guide for the Acquisition of Real Property by Government Agencies*, 1972. Only approved abstracters and title companies may furnish title evidence. All title evidence must be submitted with the acquisition documents on each transaction for preliminary title opinions preparation by the Solicitors Office. Title evidence can consist of title insurance, abstracts of title, Torrens Certificates, or Memorandum of Ownership and Encumbrance. Evidence of title of property proposed to be acquired would be furnished by the Government at its expense, except where otherwise authorized by law or provided by contract (e.g., 40 U.S.C. 255, as amended). Prior to acquisition of lands or interests in lands or interests in water rights, both a Preliminary Title Opinion and Final Title Opinion must be submitted for approval for acquisition by the Solicitor. (REAL-12)

- Hazardous materials environmental site surveys—To comply with the Department of the Interior's Departmental Manual, two levels of hazardous materials environmental site surveys are specified for Reclamation (Phase I Site Survey and a Phase II Site Survey). Depending on the outcome of

Phase I, a Phase II may need to be completed prior to acquisition. (REAL-133)

- Encumbrance of funds—The appropriate Reclamation finance office must be given notice of the appraised value to encumber the necessary funds. (REAL-14)

- Land owned by BLM—The United States owns two parcels, managed by BLM. These parcels consist of 45.79 acres and 354.52 acres, for a total of 400.31 acres. An acquisition by transfer from BLM to Reclamation would need to take place with these parcels. No specific form exists at present for acquisition by transfer. However, whenever a Federal agency transfers jurisdiction of real property to another Federal agency, the transfer document typically includes signatures from both the agency releasing the property and the agency receiving the property that document the transfer of management responsibility, adjustment in real property inventory records, and adjustment in financial records (six signatures total). Provisions of the Federal Property and Administrative Services Act of 1949, as amended, among other directives and standards typically govern transfers. Other specialized legislation may be enacted to provide authority for transfer of Federal lands. (REAL-15)

- Appurtenant water rights acquisition—The term "water rights acquisition" as used in this section, means acquisition of existing privately owned water rights, as opposed to obtaining new water rights, or a new water right authorization. Water rights acquisitions will use appraisal methods to determine fair market value and title abstracts to determine ownerships. Water rights would be acquired and used for beneficial use as soon as feasible to avoid forfeiture or abandonment of the rights under State law. Acquisition of permanent appurtenant water rights (water rights that have been applied to property for a beneficial use, and are thus pertinent to land), would be consistent with the Uniform Relocation Assistance and Land Acquisition Policies Act, as amended; with implementing regulations (49 CFR Part 24); and with Department of Justice publications. (REAL-16)

- Issuance of easements for utilities/transmission lines—There would be existing utilities/transmission lines crossing the land or interests in lands to be acquired. Once the lands or interests in lands were acquired, Reclamation would need to give PacifiCorp, or the appropriate power entity, an easement right-of-way for the transmission lines from the poles to the plants for operation and maintenance of the lines. Reclamation has recognized a potential location for a power line corridor, which can be seen on the detailed boundary map in figure 33. Other utility corridors may be utilized in the future, but have not been identified at this time. (REAL-17)

- Timber not needed for construction purposes—Once the proposed reservoir were authorized for construction and Reclamation had acquired the land and timber, then the merchantable timber may be sold if it were not required for construction purposes. This entails an intricate and time-consuming process that would need to be inserted into the construction time frame and depends on which type of ownership scenario the timbered land falls under. For example:

  - Pursuant to Reclamation Manual LND 08-02.8.A, the process would depend on whether the timber were within the boundaries of a national forest. If it were within the boundaries of a national forest, then Reclamation would need to submit a request to the Forest Service to make an appraisal and suggestions for the disposal of the timber. Then at the discretion of the Regional Director, a sale may be conducted either by Reclamation or the Forest Service.

  - If the timber were not within the boundaries of a national forest, and were withdrawn from public domain, then BLM would dispose of the merchantable timber in accordance with the provisions of 586 Departmental Manual 1.

  - Since the proposed reservoir is not within the boundaries of a national forest and Reclamation would most likely acquire the land and timber in fee title, then, Reclamation would need to determine the most appropriate method to dispose of the timber. (REAL-18)

Through discussions with Klamath County Community Development, the zonings as established would not appear to be an issue in planning the construction of the reservoir once the land or interests in lands had been acquired.

At this point during the planning process, Reclamation does not foresee any issues from the real estate perspective that would result in a “show-stopper,” as most issues could be dealt with through a mitigated or negotiated process.

Hazmat Assessment

In 2006, Reclamation performed a Phase I Environmental Site Assessment of the proposed Long Lake Valley site within the scope of ASTM International Practice E 1527 and Departmental Manual 602 DM 2. The parcels below, all in Klamath County, were assessed (only a partial list of parcel numbers was available):

> R-3908-00000-00400-000, R-3908-00000-00600-000, R-3808-00000-03900-000, R-3808-00000-03600-000, R-3808-00000-03500-000, R-3808-00000-03100-000, R-3808-00000-02700-000, R-3808-00000-02900-000, R-3808-00000-02800-000, R-3808-00000-01800-000, R-3808-00000-01700-000, R-3807-00000-02600-000, R-3808-00000-01600-000, R-3808-00000-01400-000

Record Review

- Historical use—Undeveloped property, agriculture, drainage ditches, easements, logging in the surrounding hills, cattle grazing, and a home site
- Environmental liens—None on record
- Chain of title—Prior-use home site, agriculture, and logging
- Aerial photos—No recognized environmental conditions are seen in aerial photos.
- Encumbrances—None
- Authorizations—None on record

Environmental Records

The environmental records reviewed (table 10) cover the site, adjacent land, and other sites at a range of distances from the boundary of the property under assessment.

Table 10.—Environmental records

Records reviewed	Minimum search distance from property boundary	Agency	Yes	No
Emergency Response Notification System (ERNS)	On or near the property; search goes back to 2004	Klamath County Sheriff's Office		x
National Response Team incident summaries	Klamath County and surrounding area	National Response Center		x
National Priority List	Klamath County	Environmental Protection Agency (EPA)		x
Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS)	<5 miles	EPA		x
Site cleanup	Klamath County	EPA		x
Treatment, Storage, and Disposal Facilities (TSDF)	<1 miles	Yahoo maps and ODEQ.		x
Landfills and dumps	<10 miles	ODEQ		x
Underground storage tanks (UST)	<1 mile	ODEQ		x
Leaking UST (LUST)	<2.5 miles	ODEQ		x
Contaminated well record	<1 mile	ODEQ and Oregon Department of Water Resources		x
Oregon Department of Water Resources,section 303(d)	<1 mile	ODEQ		x
Resource Conservation and Recovery Act (RCRA) generators	<2.5 miles	EPA		x
Emergency Response Reports (SARA 304)	<3 miles	EPA		x

All data for these record searches are on file in Reclamation's Mid-Pacific Regional Office.

The nearest LUST is 2.5 miles from Long Lake Valley and poses no threat of contamination.

Interviews

Jim and Carol Creswell, the landowners, and the BLM, adjacent landowners, were asked the questions found in an Environmental Preliminary Analysis in person. The property is a small valley with two home sites. The valley is predominantly used for agriculture (growing hay and other grasses), cattle grazing, and a wetland that the Creswells have been creating over the past 40 years. The homes have septic systems with leach lines. Drinking water is provided by a well. The property owners have tested the well water, and it meets or exceeds the local drinking water quality standards. There is a 600-gallon above-ground No. 2 diesel tank located at the northeast end of the property. The No. 2 diesel is used for farming equipment. Being an above-ground tank, even if there have been drips in the past onto the ground, cleanup would be uncomplicated. No solid waste dumping was observed on the property, and dumping is unlikely because two roads access the property, both of which have locked gates.

The Klamath County Sheriff's Office reports no emergency incidents (no calls to 911 or the ERNS) that have involved hazardous materials near this property. The Klamath County Sheriff's computer records contain data going back to 2004.

Surrounding Analysis

The areas surrounding Long Lake Valley are either undeveloped or timber is harvested by two different logging companies. There are no industrial businesses near the Creswell property other than a rock quarry. All records searches and the interview with the Sheriff's Office, BLM, and Jim and Carol Creswell indicate there have been no accidents from the logging company, no accidents on the dirt road leading to the Creswell home site or adjacent lands, nor any illegal dumping of hazardous waste.

Inspection Strategy

General concerns for contamination on home site properties always include methamphetamine labs, improper pesticide use and disposal, and improper household chemical use and disposal. After inspecting the property and interviewing the homeowners, these issues are not of concern.

Site Inspection

Table 11 lists items searched for onsite.

Table 11.—Site inspection checklist

Inspection item	Onsite	Nearby
Dumps, especially with drums or containers	No	No
Other debris: household, farm, industrial waste, burned areas	No	No
Unusual chemical odors	No	No
Chemical storage tanks/stand pipes	No	No
Vegetation different from surrounding for no apparent reason, e.g. bare ground	No	No
Modified water bodies	No	No
Oil seeps, stained ground, discolored stream banks	No	No
Oil slicks on water, unusual colors in water	No	No
Machinery repair areas	No	No
Oiled or formerly oiled roads	No	No

Findings and Conclusions

The physical setting poses no significant threat. Precipitation flows downhill into the valley. The groundwater under the valley floor provides drinking and irrigation water for the area. From a pathway standpoint, there were no areas that would pose a threat of off-site contaminants except in the unlikely event of a timber-owned helicopter crash (aviation fuel). There are no public roads in the area, but it is remotely possible a vehicle can crash and contaminate the property. All surrounding property contains undeveloped land used for timber. Possible contamination from these sources could be fluid leaks from farm or timber equipment or vehicles, farm and household chemicals, and illegal dumping. No other possible contaminant sources were identified during the inspection.

This assessment has revealed no evidence of recognized environmental conditions in connection with this property. No cleanup actions would need to be performed on this property.

Recommendations for Additional Study

Prior to acquisition of the property, a Phase II assessment is recommended due to the size of the area. This Phase I assessment was performed at the early stages of the conceptual plan to identify possible cost-prohibitive recognized environmental conditions in connection with this property. (HAZMAT-1)

Hydrogeology

Uncertainty in the hydrogeologic nature of the Long Lake Valley setting, including the permeability and distribution of the various host rocks, as well as the location and nature (e.g., open or sealed) of fractures and fracture zones have led to the concern that if significant amounts of infiltration (or leakage) were to occur, lining all or part of the valley may be required so as to reduce water losses by infiltration, as well as to limit potential impacts on neighboring valleys.

A combination of software tools was applied to aid in evaluating the performance of the proposed reservoir. The computer program HydroGeoSphere (HGS) was selected to simulate the behavior of the proposed reservoir due to its capability to handle water flow in a surface and subsurface (ground) water system in a fully integrated manner (surface and subsurface water equations are solved simultaneously). For a detailed description of HGS, the reader is referred to Therrien et al. (2007). In HGS, the surface water regime is treated as a two-dimensional (2-D) depth-integrated overland flow domain, whereas the subsurface water regime is treated as a 3-D variably saturated (saturated/ unsaturated) flow domain. Some attributes of HGS are presented in appendix E in terms of fluid flow and numerical methods, as well as HGS's operation and input options.

ArcGIS geospatial software was used to:

- Integrate numerous geospatial databases that contain a wide variety of information from many providers

- Aid in the definition of the physical extents of the different geologic materials that are the basis for construction of the geologic conceptual model (an approximation of the field lithology)

- Aid in determining the location of the lateral extent and boundary conditions along the edge of the model area

- Visualize input data and HGS model results in order to better understand flow processes in the surface and subsurface water system under consideration.

TecPlot, a visualization software purchased by the Bureau of Reclamation, was also used as a visualization tool.

The criteria used for appraising the effectiveness of the proposed off-stream reservoir were twofold:

1. Is the reservoir able to hold water for a reasonable time (e.g., 30 years)?
2. Are there significant impacts on geological formations in the vicinity of Long Lake Valley (e.g., instability) or on surface water features in neighboring valleys (e.g., flooding in Wocus Marsh or Round Lake Valley)?

Geospatial Software and Databases

The ArcGIS software allowed for the integration of computer aided drafting (CAD) data provided by the Bureau of Reclamation, Mid Pacific Region, Division of Design and Construction, Geology Branch (Reclamation, 2006b). Map reference information based on topographic maps, aerial photography, field geology data (figure 34), soil information, precipitation (rainfall and snowfall), evapotranspiration (or ET, i.e., evaporation and transpiration), regional aquifer data, etc. were also included in the compiled databases. Table 12 provides a brief summary of the geospatial databases used in this appraisal study and appendix F contains detailed information on each database used in this study.

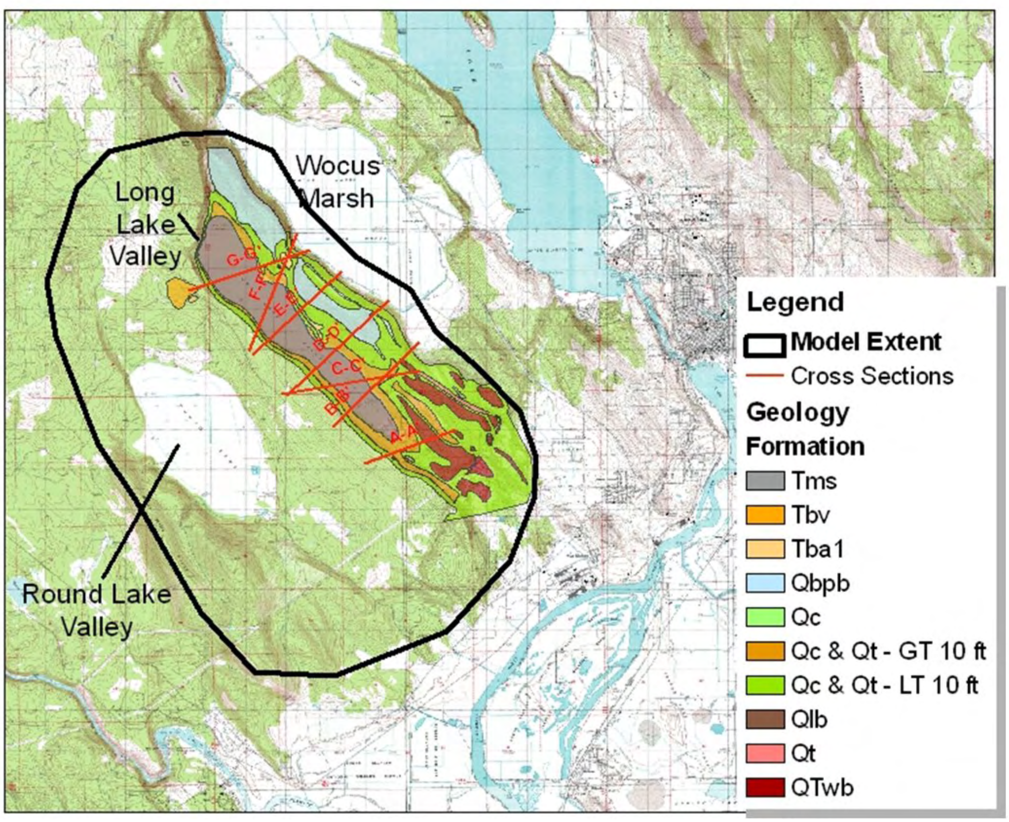


Figure 34.—Long Lake Valley geology and cross sections. Lithology descriptions provided by Reclamation (2006b).

Table 12.—Geospatial data used for the Long Lake Valley Reservoir modeling effort

Data	Brief description
Elevation (surface)	U.S. Geological Survey National Elevation Dataset (NED) used for surface elevations, contour generation, hill shade displays, model boundary location, etc.
Evapotranspiration	Various sources—tabular data, report data, California Irrigation Management System, etc.
Field geology (figure 34)	Reclamation field geology report converted from CAD format used for fault location, lithology contacts, lithology zone definitions, etc. (Reclamation, 2006b)
Map reference	U.S. Geological Survey, Digital Raster Graphics (topographic maps), National Agriculture Imagery Program (NAIP), etc.
Precipitation	30-year period of record (1961-1990) annual precipitation from Oregon State University
Heads (generalized regional water table)	U.S. Geological Survey, Water Science Center, Portland, Oregon, author Marshall Gannett

The geospatial databases were all transformed into a common projection (Universal Transform Mercator zone 10, North American Datum 1983, North American Vertical Datum 1988). The units for the geospatial data and the conceptual model were based on the International System (SI), in which the unit of length is the meter (m).

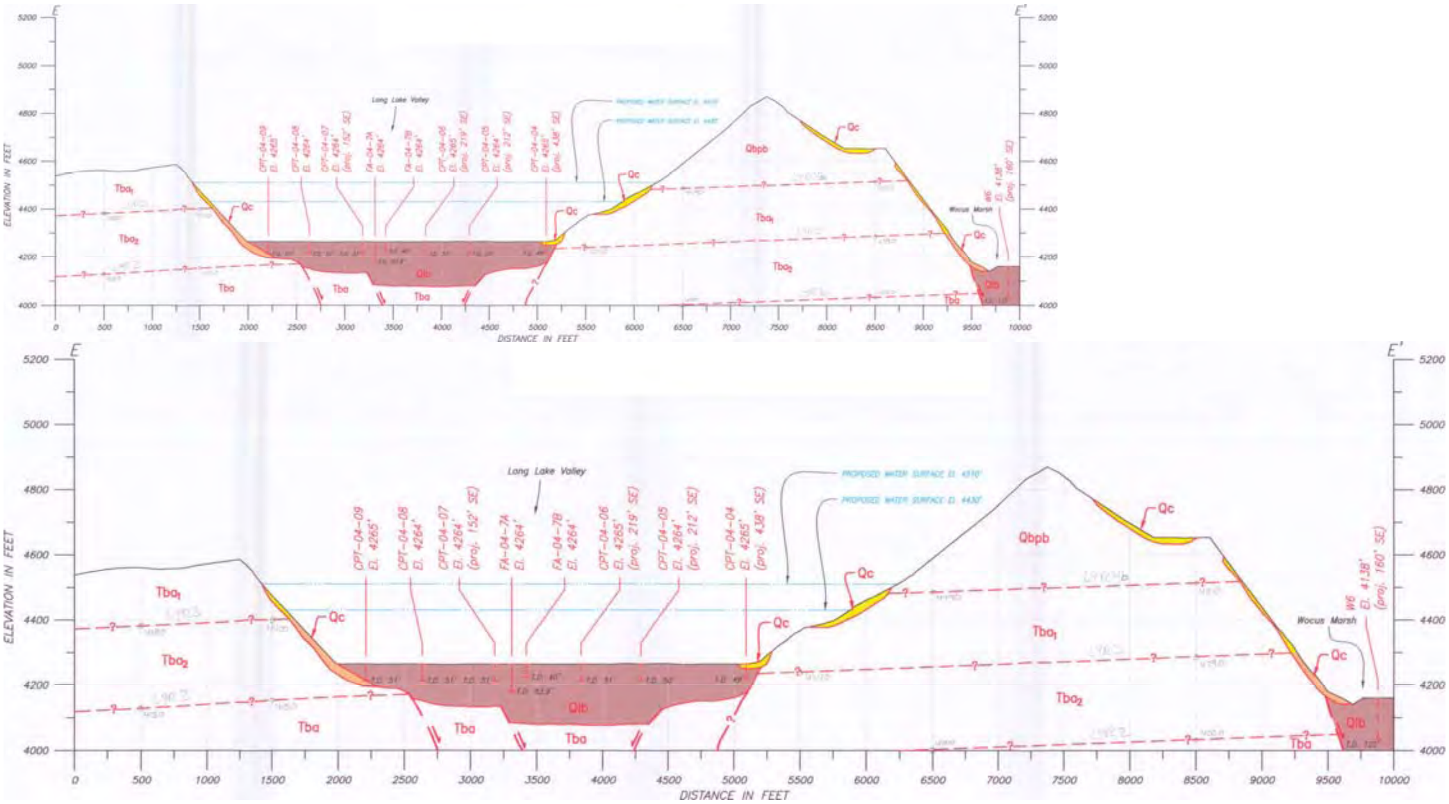
Conceptual Hydrogeologic Model

The conceptual hydrogeologic model is the best picture of how the surface/ subsurface water systems behave in and around Long Lake Valley, and it forms the basis for a numerical model.

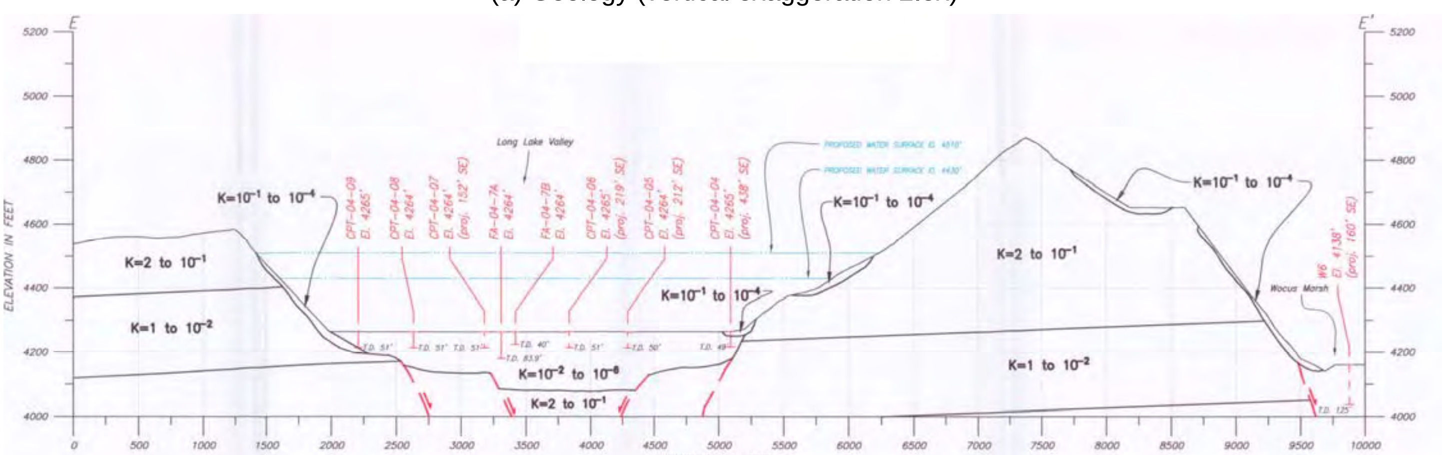
Geology

The geology of the Long Lake area is composed of a sequence of relatively flat-lying recent (Tertiary and Quaternary) volcanic and sedimentary rocks, which contain numerous subvertical faults. A thin veneer of unconsolidated, fine-grained sediments have been deposited in the Long Lake Valley basin and Wocus Marsh area and possibly also in the Round Lake Valley basin. Figure 34 is a geologic map of the Long Lake Valley area that shows the distribution of the various strata at ground surface and also the location of several geologic cross sections (Reclamation, 2006b).

An example of the subsurface geology is given in figure 35a for vertical cross section E-E′ whose location is shown in figure 34. Note that subvertical faulting in the valley floor, shown by arrows in figure 35a, has offset the strata (e.g., Tba2) on opposite sides of the valley, and produced a series of benches in the valley floor (e.g., see Tba).



(a) Geology (vertical exaggeration 2.5x)



(b) Hydraulic conductivity (K = ft^3/ft^2/day)

Figure 35.—Cross-section E-E' geology and hydraulic conductivity distribution.

Figure 35b shows zones of equal hydraulic conductivity (K) values. The K values indicate the ease with which water flows through a geologic material or layer, with higher K values indicating easier flow, and are one of the key parameters that govern the movement of water below ground. Therefore, it is necessary to accurately define the extents of each lithologic subsurface layer.

Note that K zones do not always correspond with lithologic zones. For example, the lithologic zones Qbpb and Tba1 on the right-hand (east) side of the valley (figure 35a) are lumped into a single K zone (figure 35b).

The lithologic surfaces and resulting lithologic layers representing the geologic conceptual model are an approximation of the field geology in the Long Lake Valley area, since their definition is based on currently available data. Additional field data may lead to a more accurate approximation of the field geology. The lack of lithologic data becomes more critical farther away from Long Lake Valley, and thus we have a less reliable understanding of the lithology at these locations. Construction of the geologic conceptual model was carried out using geographic information system (GIS) and visualization tools that are capable of extending the lithologic surfaces based on general trends. This is considered to be a necessary and reasonable extrapolation of the conceptual model geology to the edges of the model domain and is essential since the geology governs flow of subsurface water.

Hydrology and Hydrogeology

Surface relief is shown in figure 36. Annual precipitation in this area is estimated to be approximately 1.57E-03 m/day (22.5 in/yr). Estimates of evapotranspiration for the entire Klamath Basin are on the order of 70 percent of precipitation (Gannett et al., 2007). Over much of the year, there is no standing water in Long Lake Valley but it is assumed that at times of significant rainfall or spring snowmelt, intermittent streams and shallow lakes may form.

Long Lake Valley is a closed basin, such that surface water either disappears by evapotranspiration, or infiltrates the ground surface to become subsurface water flowing more or less vertically downward to the regional water table, which is located approximately 30.48 m (100 ft) or more below the base of Long Lake Valley. The regional generalized water table of Gannett et al. (2007) is relatively flat, with a gentle slope of 2 m/km (6.5 ft/mi) from north to south.

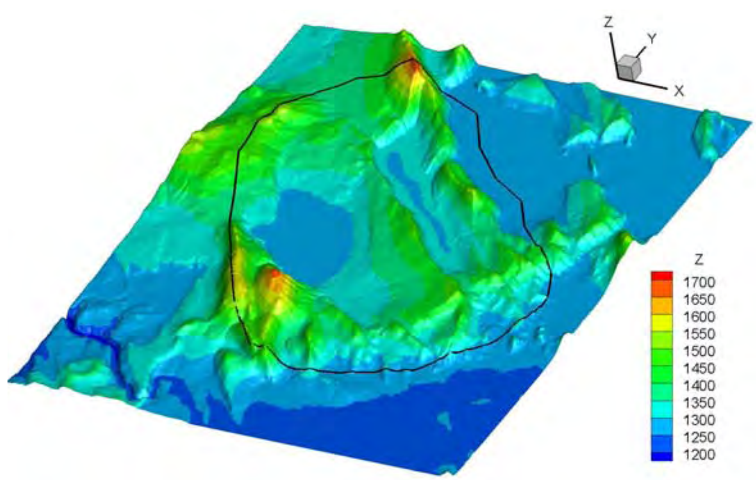


Figure 36.—Shaded relief (3 times vertical exaggeration), ground surface elevation (color fill) and model domain boundary (black line) North is represented by the Y axis.

Long Lake Valley is locally delineated by a surface water divide line that traverses the high points of the mountains bounding the valley. The divide line represents a closed polygon around the valley. The precipitation falling within the polygon flows along the valley slopes toward the valley floor where it infiltrates the valley floor or starts to pond within the valley. The precipitation falling on the outside of the eastern portion of the divide line generates the surface water drainage toward the east through Wocus Marsh/Klamath Lake and south to the Klamath River. It is noted that the drainage is mainly surface water along the slopes and infiltrates the subsurface water system in the low lying areas.

West of Round Lake Valley basin, surface water and deep groundwater drainage is likely westward to the Klamath River. In high areas, surface water flow predominates and mainly infiltrates the subsurface water systems in the low lying areas.

Model Setup

Model Extents

The first step in the modeling process is to define the extents of the model domain, both laterally and at depth. To do this, an understanding of the basic hydrologic and hydrogeologic features of the site is needed to place boundaries at naturally occurring features such as flow divides.

Very few field data are available regarding the location of the water table in Long Lake Valley; thus, the lateral extents of the model domain were defined based on the surface topography shown in figure 36. To the north, the boundary follows what is assumed to be a surface and subsurface water flow divide, where the bulk of water is assumed to be draining to the east to Klamath Lake. To the west, the entire Round Lake Valley is included, and the model boundary follows a surface water divide. To the east and south, the model extends to include a portion of Wocus Marsh and the floodplain of the Klamath River, respectively, which afford potential discharge zones for surface and subsurface water.

The upper surface of the model domain is the topographic surface shown in figure 36. The topography is constructed by means of the National Elevation Dataset for the surface of the Long Lake Valley area.

The base of the model domain is located at an elevation of 1190 meters (about 3900 feet) above mean sea level (MASL). This elevation was chosen so that a significant thickness of saturated porous medium would be present in the model domain. If the region of flow underlying the potential reservoir were too thin, water table mounding could be overestimated. This would tend to minimize infiltration from the reservoir, which is the main criterion for evaluating the performance of the reservoir.

Mesh Generation

The first step in the mesh generation procedure is to define the 2-D mesh, from which is extruded the 3-D mesh. As well as defining the domain boundary, it was also necessary to force element edges to fall along faults in the interior of the domain so that the mesh could be refined along these faults if necessary. Internal mesh boundaries (shown in green in figure 37) were therefore created to allow mesh refinement along faults. The faults and external and internal mesh boundaries are shown in figure 37.

A 2-D triangular element mesh containing 9,524 nodes and 18,782 elements was generated using the program GRID BUILDER (figure 38). The mesh was refined along the faults so that element sides were 30 m (98 ft) long, while a target length of 150 m (492 ft) was used for other regions in the domain.

This 2-D mesh was extruded to produce a 3-D mesh (figure 39). The base of the mesh is horizontal, at an elevation of 1190 MASL (3900 ft). The top of the mesh was constrained by the topographic surface. A third surface, located 10 m

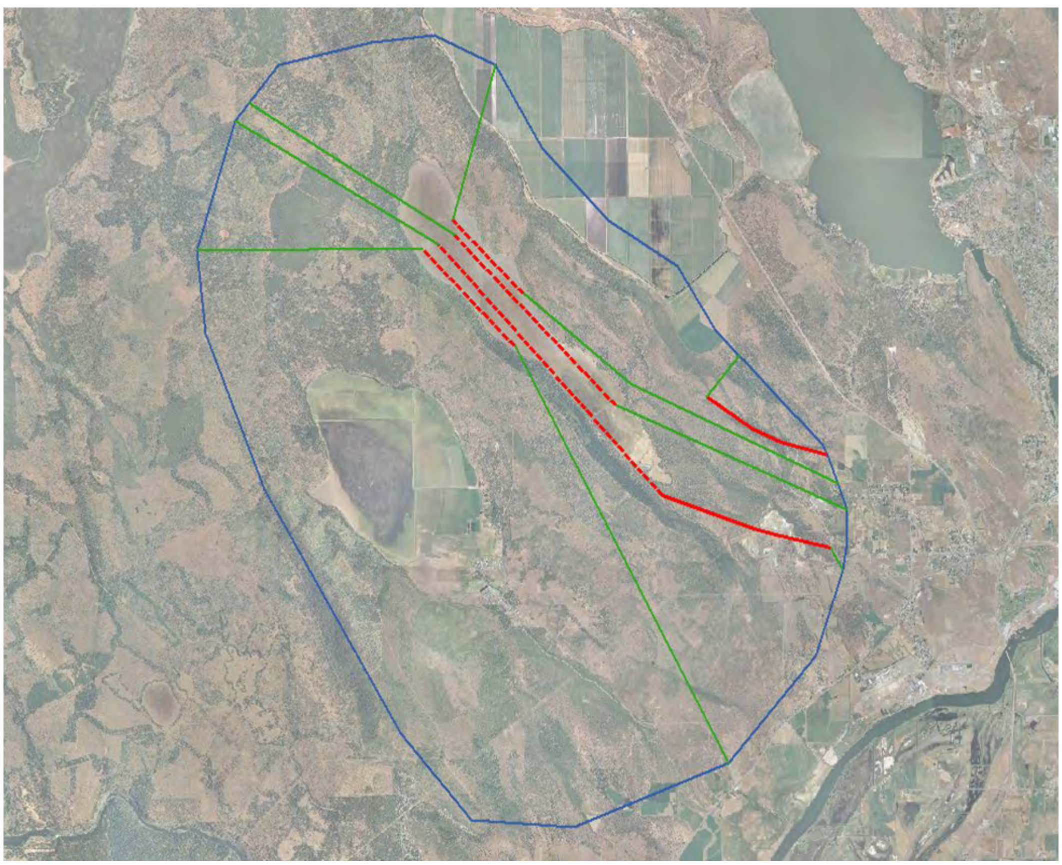


Figure 37.—Model domain boundary (blue line), faults (red lines) and meshing area boundaries (green).

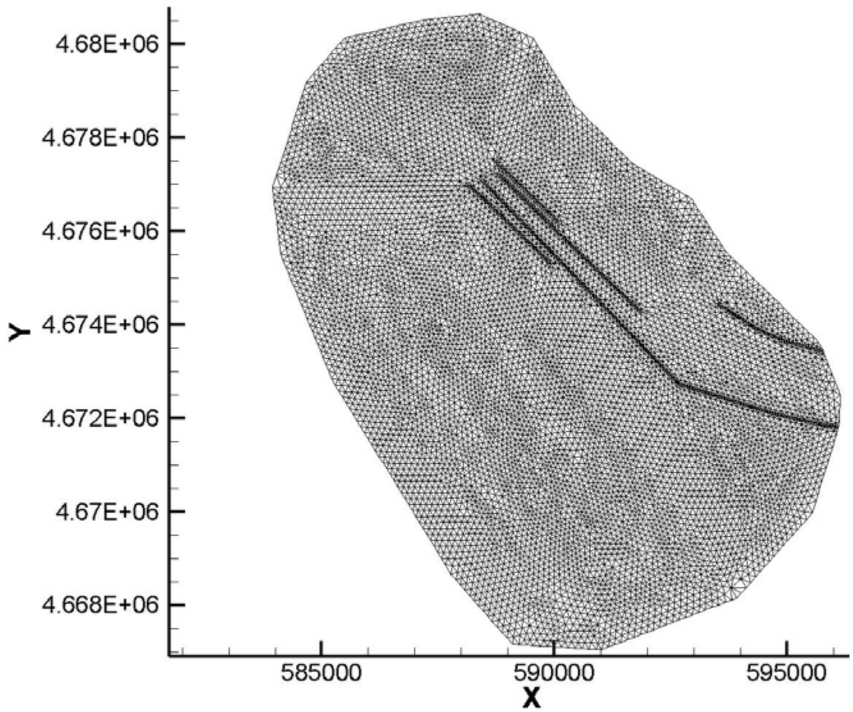


Figure 38.—2-D mesh with refinement along faults. North is represented by the Y axis.

(32.8 ft) below the topographic surface, was included. This surface was included so that the upper 10 m (32.8 ft) of the domain could be subdivided into 5 layers of elements vertically, and the element height would be a uniform 2 m (6.5 ft), which is necessary in order to accurately accommodate evapotranspiration. The lower portion was subdivided into 30 layers of elements, giving a total of 35 layers of elements.

Definition of Hydrostratigraphic Units

Based on the geologic information, the model was subdivided vertically into five main stratigraphic layers, represented here in the order in which they appear in the stratigraphic sequence (oldest to youngest geologic period as seen in figure 35b):

1. Tba (Tertiary) basaltic andesite

2. Tba2 (Tertiary) basaltic andesite

3. Tba1 (Tertiary) basaltic andesite

4. Qwtb (Quaternary) basaltic andesite of the Porter Butte formation and Qbpb (Quaternary) basaltic andesite of the Wocus Marsh formation

5. Qlb (Holocene to Pleistocene) lake bed sediments

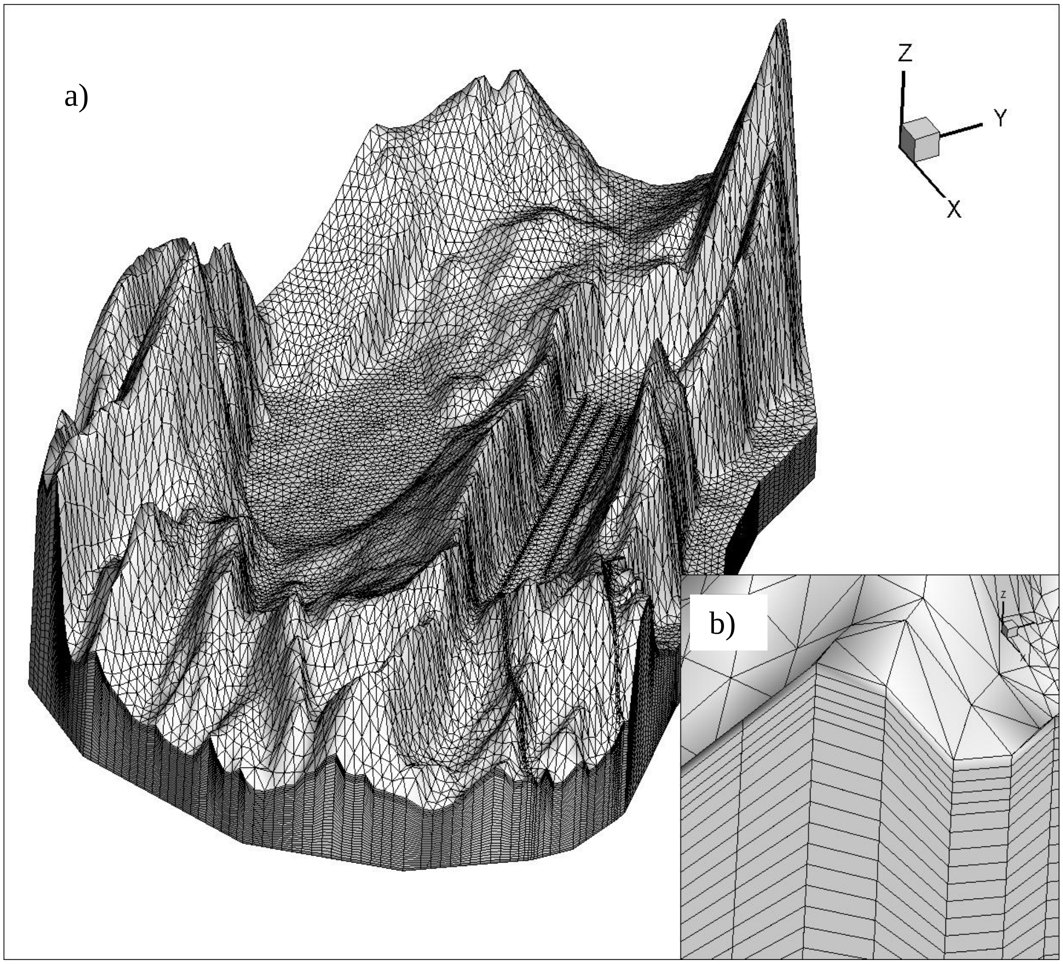


Figure 39.—3-D mesh (a) full-size (13 times vertical exaggeration) and (b) blow-up section of 3-D mesh. North is represented by the Y axis.

ArcGIS was used to construct complex surfaces, including offsets caused by faulting, that defined each hydrostratigraphic layer (i.e., that separate lithologic units with different material properties like K). Each surface was exported in a format compatible with the HGS program. After the grid generation step is complete, these surfaces were used to subdivide the 3-D mesh into different hydrostratigraphic zones.

In all, the model domain was subdivided into five hydrostratigraphic zones, as shown in figure 40a. Each zone was assigned a homogeneous, isotropic hydraulic conductivity as shown in table 13, where the given hydrostratigraphic zone numbers match the legend shown on figure 40a. The hydraulic conductivity was assumed to be at the upper end of the range provided by Reclamation (2006b). Again, this is a conservative value with respect to leakage from the reservoir, which will increase as K increases. All zones in the model were assigned a specific storage value of 1E-04 and a porosity value of 0.3.

a)

b)

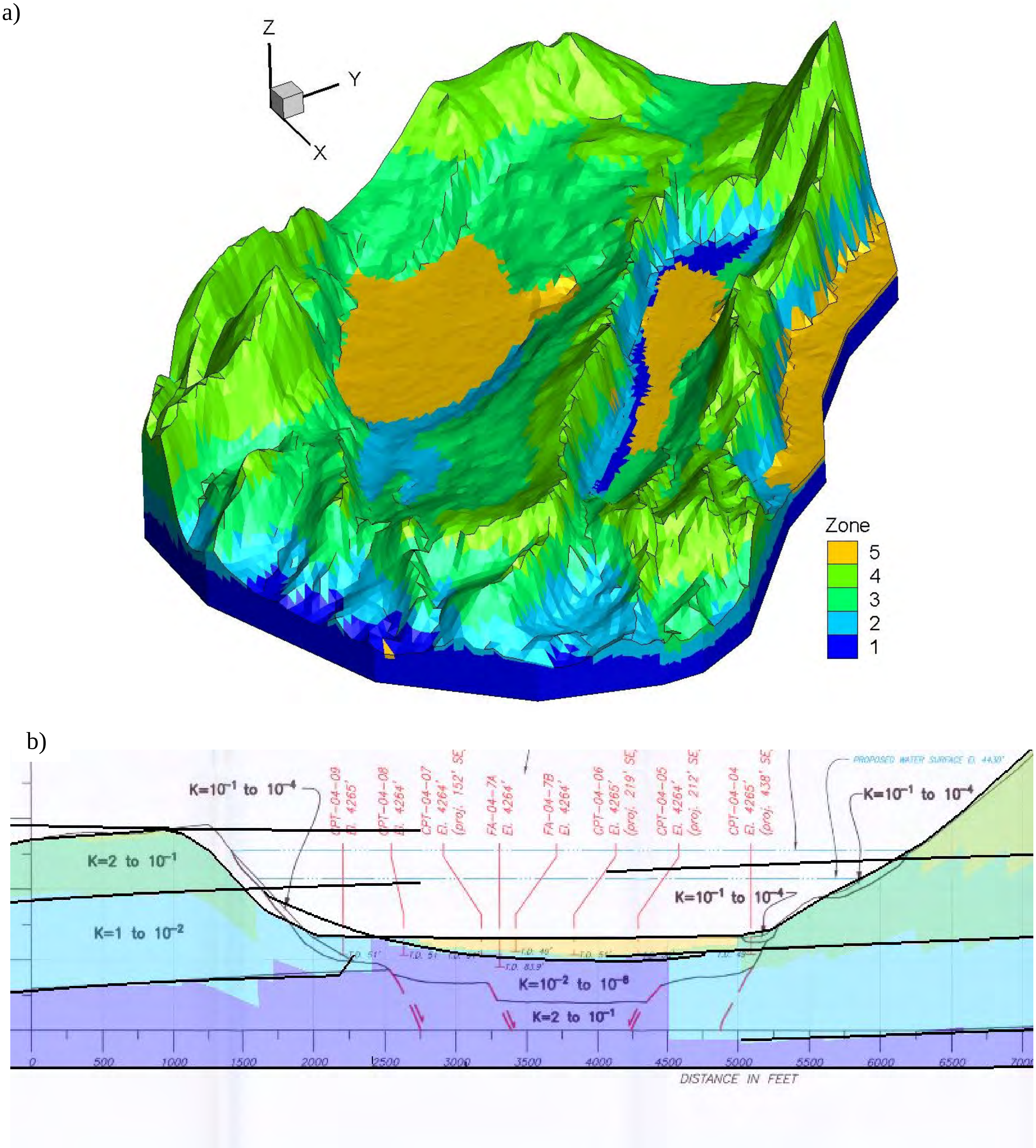


Figure 40.—K zone data for a) 3-D domain and b) along cross-section E-E' showing traces of ArcGIS lithologic surfaces (black lines) and HGS model zones (color fills).

Table 13.—Hydrostratigraphic zone numbers and formation names (Reclamation, 2006b)

Hydrostratigraphic zone number	Formation	K value (field)	
		ft/day	m/day
1	Tba basaltic andesite	2	0.6096
2	Tba2 basaltic andesite	1	0.3048
3	Tba1 basaltic andesite	2	0.6096
4	Qtwb basaltic andesite of Porter Butte and Qbpb basaltic andesite of Wocus Marsh	2	0.6096
5	Qlb (lake bed sediments)	0.01	0.003048

Although lake bed sediments were not observed in Round Lake Valley, it was assumed that they would also exist there, due to its similarity to Long Lake Valley. Approximately 15 m (49.2 ft) of lake bed sediments were included in the model as shown in figure 40a.

Figure 40b shows traces of the stratigraphic surfaces used to delineate the zones and the corresponding HGS element zonation along cross section E-E′. Also shown are the K zone data given in figure 35a. In some regions, correlation between the stratigraphic surfaces and the hydrostratigraphic zone boundaries in the model is poor because the stratigraphic surfaces are smooth but do not necessarily correspond to element edges. Mesh refinement in these regions could improve the fit, but at the cost of increased run-time. The thickness of the lake bed sediments in the HGS model, shown in figure 40b, is somewhat less than the thickness shown in figure 35a. Field borings reached a maximum penetration of approximately 15 m (49.2 ft) below ground surface, which is significantly less than the thickness shown in figure 40b. For the numerical model, a conservative approach (which promotes leakage from the reservoir) was used by assuming a minimum possible thickness for the low permeability lake bed sediments.

Unsaturated Flow Properties

When running HGS in variably saturated mode, tables of suction pressure versus saturation, and saturation versus relative permeability are required for each material. No field measurements of these parameters were available for the Long Lake Valley Reservoir lithologies, and so values were taken from the Rosetta-NRCS database (http://www.wsi.nrcs.usda.gov/products/w2q/water_mgt/Soil_Hydraulics/ Rosetta_NRCS.html).

For hydrostratigraphic zones 1 to 4 (basaltic andesite), a residual saturation of 0.1, and van Genuchten alpha and beta values of 0.2 m^{-1} and 1.15, respectively, were assigned.

For hydrostratigraphic zone 5 (lake bed sediments), a residual saturation of 0.1, and van Genuchten alpha and beta values of 2 m^{-1} and 1.7, respectively, were assigned.

Surface Flow Properties

No field measurements of surface flow properties were available so friction factors typical of grass (3.5E-5 $m^{-1/3}$ d) were assigned to the entire surface flow domain.

Evapotranspiration Properties

No field measurements of these parameters were available so parameters given by Panday and Huyakorn (2004) were used initially. These were adjusted during the calibration procedure described below.

Boundary Conditions

A uniform rate of precipitation, equal to the average annual rainfall, was applied to the entire surface flow domain at a rate of 1.57E-03 m/day (22.5 in/yr). Potential evapotranspiration (PET) was initially set to be 1.25 times precipitation or 1.96E-03 m/day (23.4 in/yr), and was also applied over the entire model domain. Although this value is higher than precipitation, the HGS model computes effective evapotranspiration at each timestep based on the current soil saturation, and so effective ET is usually less than PET, since extremes of saturation (i.e., very dry or very wet) tend to reduce ET.

The entire outer edge of the surface flow domain was assigned to be a critical depth boundary, which allows ponded water to flow out of the system. Since most of the model domain was chosen to correspond to a surface water flow divide, rainfall tends to flow into the domain such that there is no outflow for the most part of the surface domain outside boundary. Considering the flow domain, which is not a closed basin in comparison to Long Lake Valley, the main area where surface water has the potential to exit the system at a critical depth boundary is at Wocus Marsh, where either the water table is very shallow or ponded water exists.

A groundwater divide was assumed to correspond to the surface water divide, and so most of the lateral boundaries of the subsurface were specified as no-flow, as was the base of the domain. An exception was along the southern edge of the domain, in the region of the Klamath River floodplain, where a constant head of 1247 MASL (4091 ft) was assigned to the portion of the subsurface boundary located below this elevation (figure 41). This constant head value is approximately equal to the observed elevation of the water table at that location, and provides another potential outlet for water to discharge from the domain.

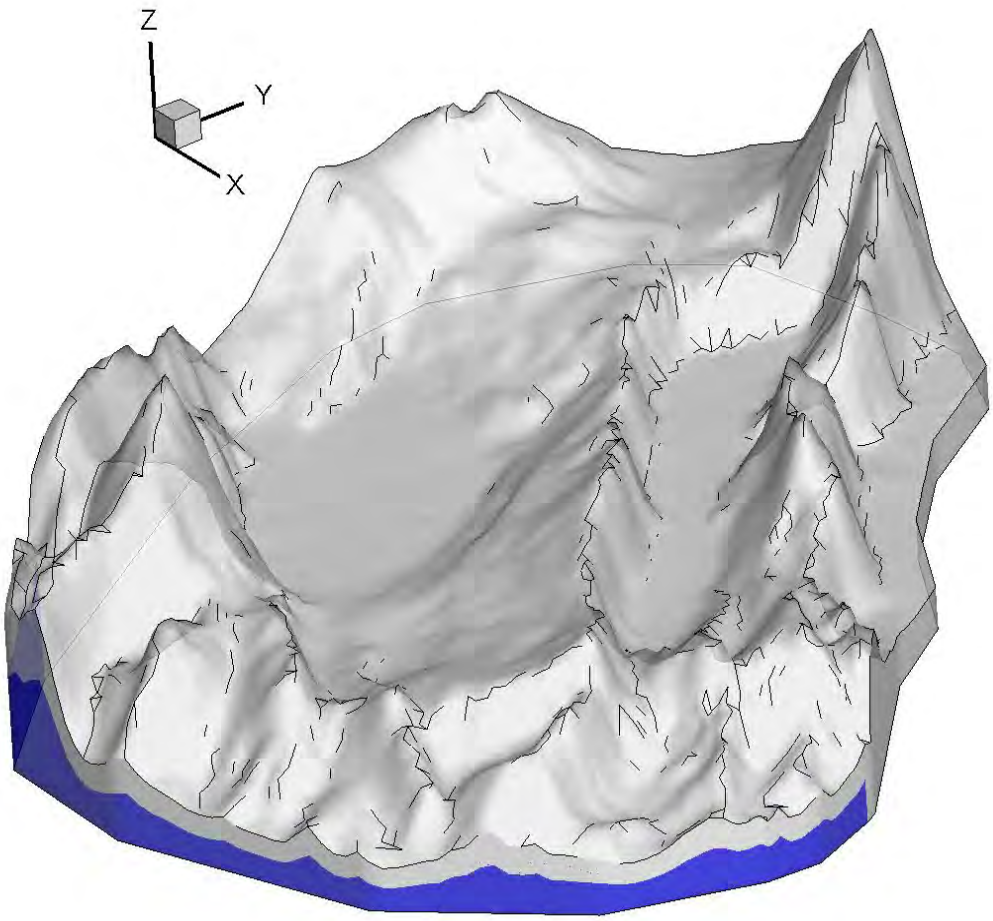


Figure 41.—Fixed head boundary condition of 1247 MASL near Klamath River (blue color fill). North is represented by the Y axis.

Steady-State Flow Model Calibration

With the given saturated and unsaturated material properties and boundary conditions described above, the HGS model was run in transient mode (i.e., water levels vary with time) for a time sufficiently long to allow the system to reach static equilibrium, also known as steady-state. The resulting predicted water table was then examined to see how well it compared to the generalized water table of Gannett et al. (2007) or the authors' website at http://pubs.usgs.gov/sir/2007/5050/. Their analysis was based on generalized water table elevations since sampling frequency varied with time and space and hence the water table elevations could not be developed for a particular point in time.

The main calibration target was that the elevation of the water table at the northern end of the model domain would be near 1280 MASL (4199 ft), and that there would be around 30 m (98 ft) of unsaturated zone below the base of Long Lake Valley.

The initial run resulted in an effective ET of about 65 percent, and the simulated water table was much higher than the generalized water table. Increasing potential ET resulted in more realistic simulated water table positions, but it was found that the initial value for transpiration limiting saturation of 0.2 (taken from Panday and Huyakorn, 2004) was lower than the residual saturation defined for the rock layers that outcrop at ground surface. Thus, transpiration was proceeding regardless of the saturation or pressure values at the surface, which could result in the formation of zones of unrealistically low hydraulic pressure. More reasonable values for transpiration limiting saturations were applied for the rock and lake bed sediments.

With these changes, the potential ET value of 1.25 times the annually averaged precipitation (1.57E-3 m/d, 22.5 in/yr) was applied, which resulted in an effective ET of about 94 percent (1.47E-3 m/d, 21.2 ft/d). The simulated water table does not seem to closely match the generalized water table shown in figure 42. Additional work is required to generate a closer match between the simulated and generalized water tables. However the simulated water table approximates the calibration criteria. The simulated water table, furthermore, looks reasonable based on boundary conditions used in this work,

Reservoir Performance Evaluation

The amount of stored water that is lost by infiltration through the sediments lining the bottom of Long Lake Valley has a direct impact on its capability to act reliably as a water supply reservoir.

The infiltration rate is controlled primarily by the hydraulic conductivity K of the sediments, and the larger the K value, the easier it is for stored water to seep through the geological material. Therefore, in this appraisal study, the upper end of the K range estimated by a Reclamation study (Reclamation, 2006b) was used to maximize infiltration from the reservoir and simulate the least favorable case.

The hydraulic gradient between the reservoir and the subsurface flow regime also affects the rate of infiltration. If there is no hydraulic gradient, then no infiltration occurs regardless of the hydraulic conductivity of the sediments lining the reservoir. For this reason, it is important to use a numerical model that can accurately simulate the complex flow processes taking place at the interface of the surface and subsurface water regimes and account for distribution of the various lithologic materials.

In the HGS model, equations describing the surface and subsurface water regimes are assembled into a single matrix and solved simultaneously. The two regimes are coupled through a relatively thin layer of porous material across which water

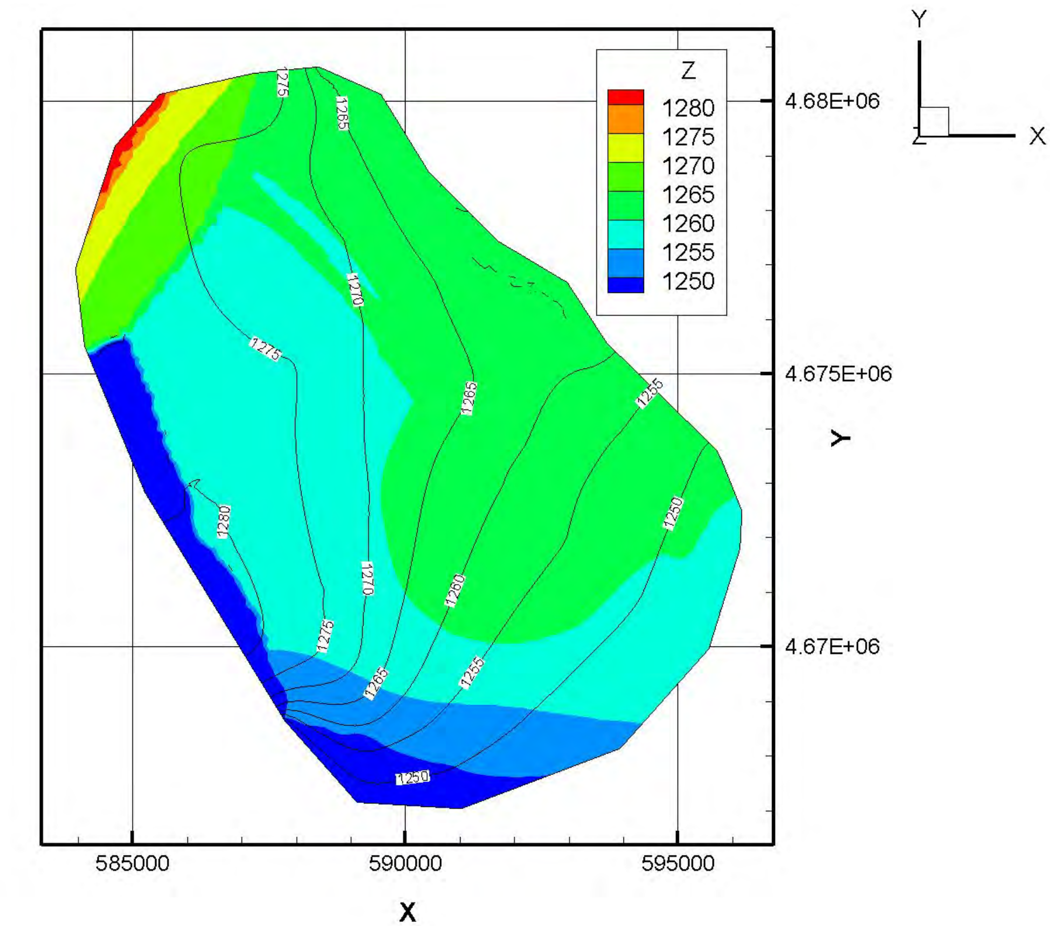


Figure 42.—Comparison of generalized (color flood) and simulated (contoured line) water table elevation (MASL). North is represented by the Y axis.

exchange takes place from surface to subsurface or vice versa, depending on local head gradients. By convention, a negative (-) exchange flux indicates that water is moving from surface to subsurface (i.e., infiltration), while a positive (+) exchange flux implies that water is moving from subsurface to surface (i.e., seepage).

The exchange flux results from a complex interaction of physical phenomena such as rainfall intensity, duration and distribution, evapotranspiration, hydrostratigraphy, current soil saturation, and topography, to name a few. The extent to which the HGS model input data matches the real hydrogeologic system determines the accuracy of the computed exchange flux.

The steady-state flow solution that was obtained during model calibration provides the initial condition for the surface and subsurface water regimes for subsequent HGS model runs that were designed to evaluate reservoir performance. In these evaluation runs, the boundary conditions and material properties used are identical to those used in the calibration step with the exception of a single condition or property. This change causes the flow system to move toward a new equilibrium state, which may or may not be reached depending on the amount of time the system is allowed to respond. At any time, the new flow solution can be compared to the original steady-state system in order to gauge the transient impact of the change.

Two scenarios were considered in the evaluation. The first, referred to here as the "natural system," has no engineered barriers to prevent infiltration from the reservoir, while the second, the "lined system," has a low permeability liner installed around the base of the reservoir.

Natural System

In the first evaluation scenario, Long Lake Valley Reservoir was filled by applying a volume of water at a rate of 2.45E6 m^3/day (1,000 ft^3/s) continuously for approximately 6 months (182 days). The application of water was then halted and the reservoir was allowed to drain for 30 years, which was chosen arbitrarily but was expected to be long enough to allow a significant amount of the water in the reservoir to seep into the subsurface domain. The variation of surface-water depth over time is shown in table 14.

Table 14.—Run 2 average water depth (elevation data accurate to roughly 7 m [23 ft]) within Long Lake Valley over time (Gannett, 2007)

	Average depth	
Time	meters	feet
Day 180	45.5	149
Year 1	42.5	139
Year 5	32.5	107
Year 10	25.5	84
Year 20	16.5	54
Year 30	9.5	31

The water level in the reservoir dropped approximately 13 meters (43.5 ft) within 5 years and 20 meters (65.5 ft) within 10 years. Considering that the reservoir would be filled more frequently than every 30 years, this suggests that the proposed reservoir has the potential to store water over a period of more than 5 years.

Figure 43 shows the simulated elevation of the water table, 1 day after the commencement of filling. The water table corresponds to the simulated zero isopressure surface. In regions where the simulated water level is above ground

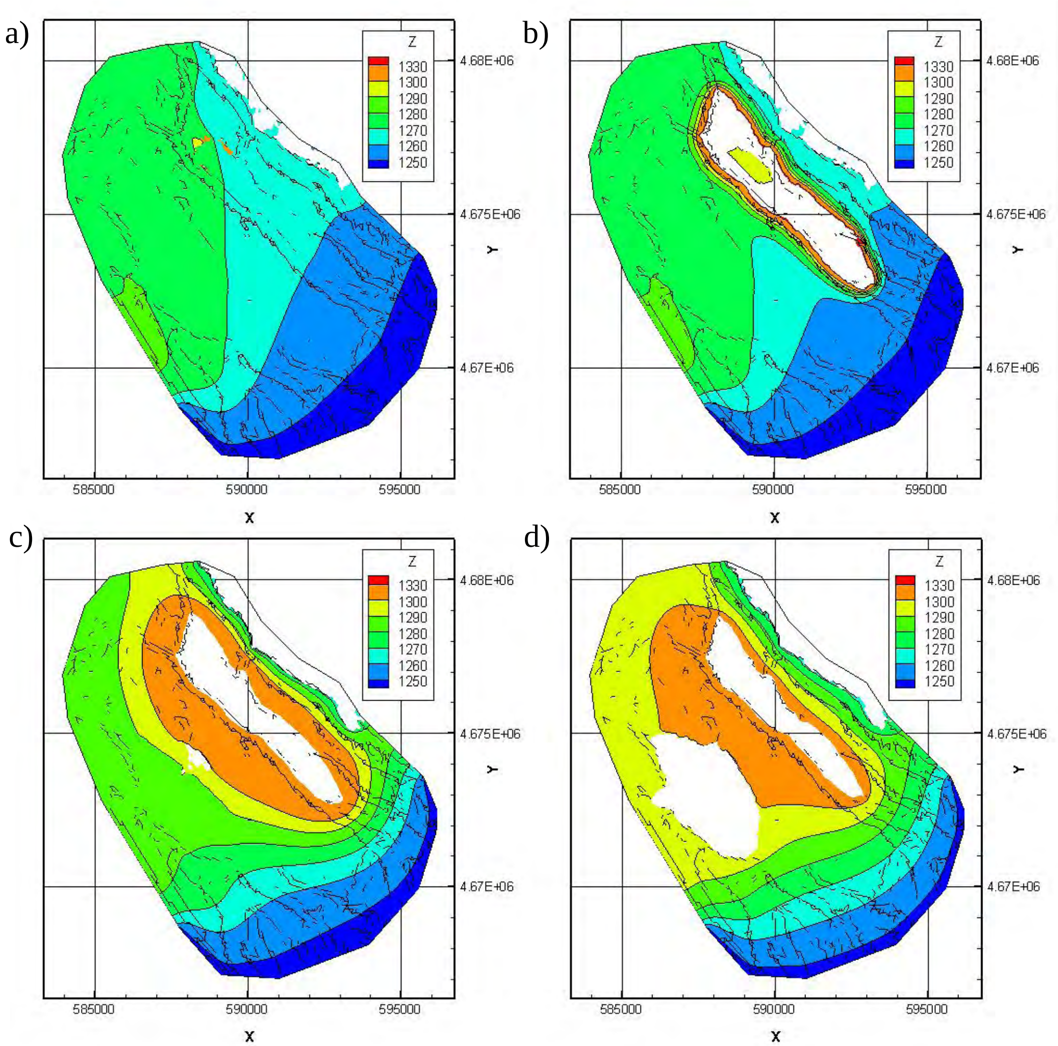


Figure 43.—Water table elevation (MASL) (a) after 1 day of filling, (b) after 6 months of filling (c) after 10 years of draining and (d) after 30 years of draining. North is represented by the Y axis.

surface (e.g., Wocus Marsh), the isosurface is absent, and no color is shown. figure 43b shows the water table elevation at 6 months, just after filling is complete, and the water table slopes steeply away from the reservoir. The small patch of the water table isosurface inside the reservoir area indicates that there is still a zone of negative pressure below the Long Lake Valley floor, likely in the low permeability lake bed sediments. Figure 43c shows the water table elevation after 10 years of draining. Although the average water depth in the reservoir has dropped to 25.5 m (83.6 ft), the water table mound is expanding laterally through the system, and the water table farther away from the reservoir is still rising and is now intersecting the surface water level in Round Lake Valley. Figure 43d shows the water table elevation after 30 years of draining. The water table is intersecting the surface water level over a significant portion of Round Lake Valley.

Figures 44a and 44b show the depth of surface water 1 day after the commencement of filling and after 6 months of filling is complete. In figure 44c, after 10 years of draining, surface water begins to appear in Round Lake Valley, and after 30 years of draining (figure 44d), the surface water there is approximately a 5 m (16.4 ft) deep.

Figure 45 shows the exchange flux of water between the surface and subsurface domains. For hydrologic conditions in Long Lake Valley and vicinity, annually averaged PET is, in general, larger than precipitation, and removes a large portion of it, resulting in a relatively small infiltration at a rate of 0 to 0.002 m/day (2 mm/day). This is indicated by the predominantly yellow fill of figure 45.

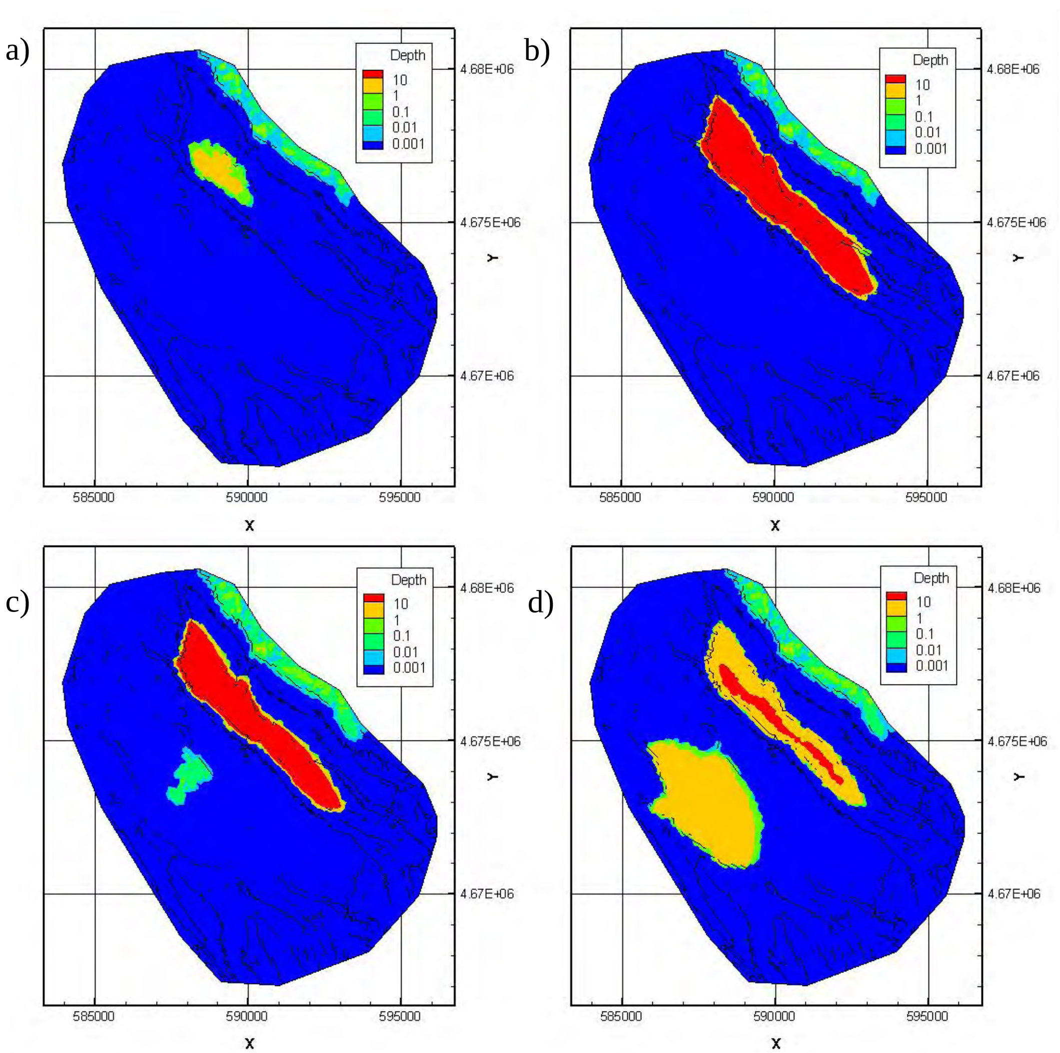


Figure 44.—Surface Water depth (m) (a) after 1 day of filling, (b) after 6 months of filling (c) after 10 years of draining and (d) after 30 years of draining. North is represented by the Y axis.

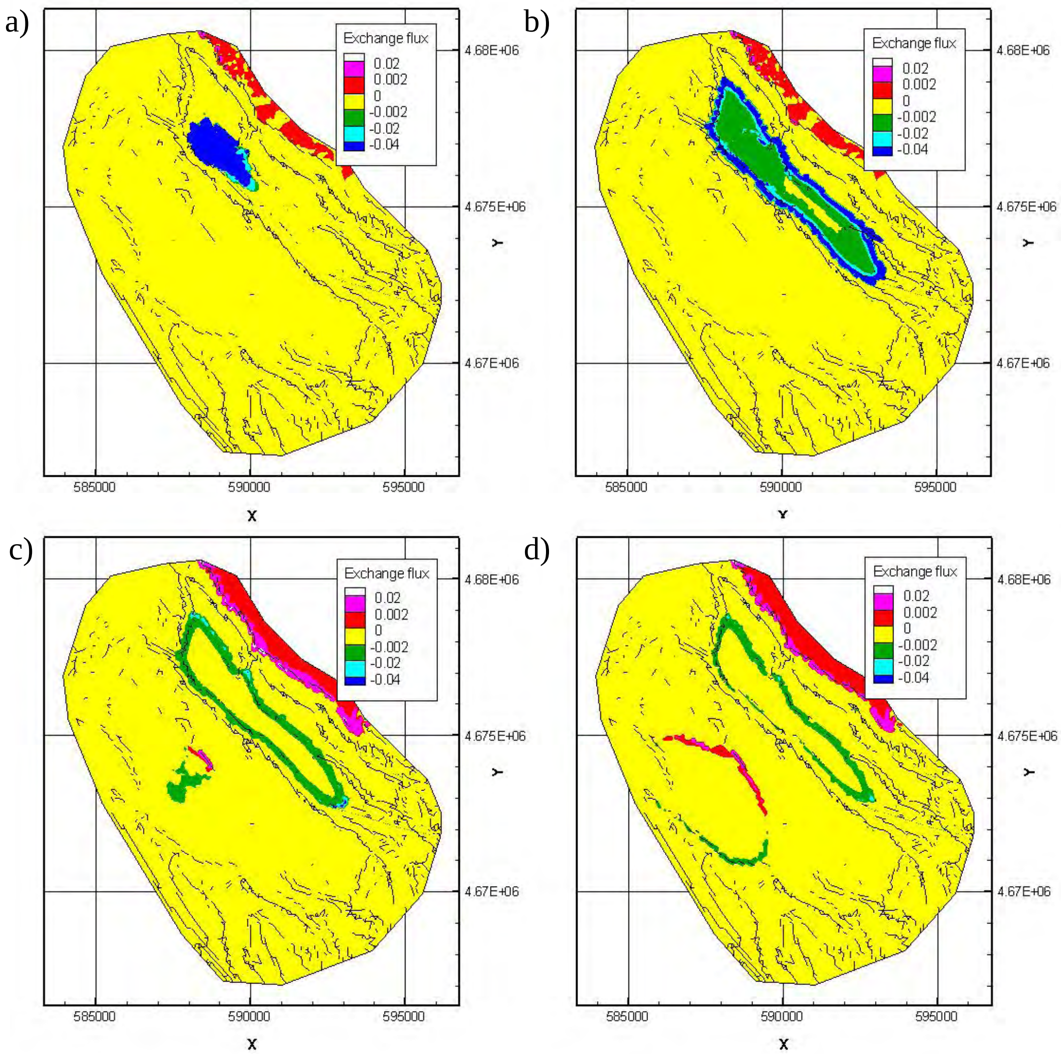


Figure 45.—Exchange flux (a) after 1 day of filling, (b) after 6 months of filling (c) after 10 years of draining and (d) after 30 years of draining. Negative values indicate infiltration to the subsurface. North is represented by the Y axis.

Figure 45a, 1 day after the onset of filling, shows that infiltration of at least 0.04 m/day (4 cm/day) occurs near the point at which water is being added to the reservoir. Figure 45b shows that after filling is complete, most of the infiltration occurs around the sides of the reservoir, probably due in part to the lower K of the lake bed sediments. In figures 44c and 44d, infiltration from the reservoir has declined to less than 0.002 m/day, most likely because hydraulic gradients around it are much lower, as the declining reservoir water level and the surrounding system equilibrate.

Positive exchange fluxes, indicating seepage of subsurface water regime to the surface water regime, are mainly located along the hill slopes beside Wocus Marsh and Round Lake Valley. In Wocus Marsh, the exchange flux is positive (red color) implying that seepage is occurring for the whole 30-year simulation period. In Round Lake Valley, seepage begins to appear after approximately 10 years of draining.

Figure 46 shows the exchange flux in the vicinity of Long Lake Valley Reservoir after 10 years of draining, in the form of a shaded relief map. Spots of higher infiltration can be seen at the south end of the reservoir, and in close proximity to Wocus Marsh. Patterns such as this could be useful in locating engineered features that are intended to reduce infiltration, such as the installation of a low permeability liner material.

The exchange flux patterns at Round Lake Valley indicate that water is seeping from the hill slope nearest the reservoir into the shallow pond, and then infiltrating farther away from the reservoir, as indicated by the region of green color fill in figure 46.

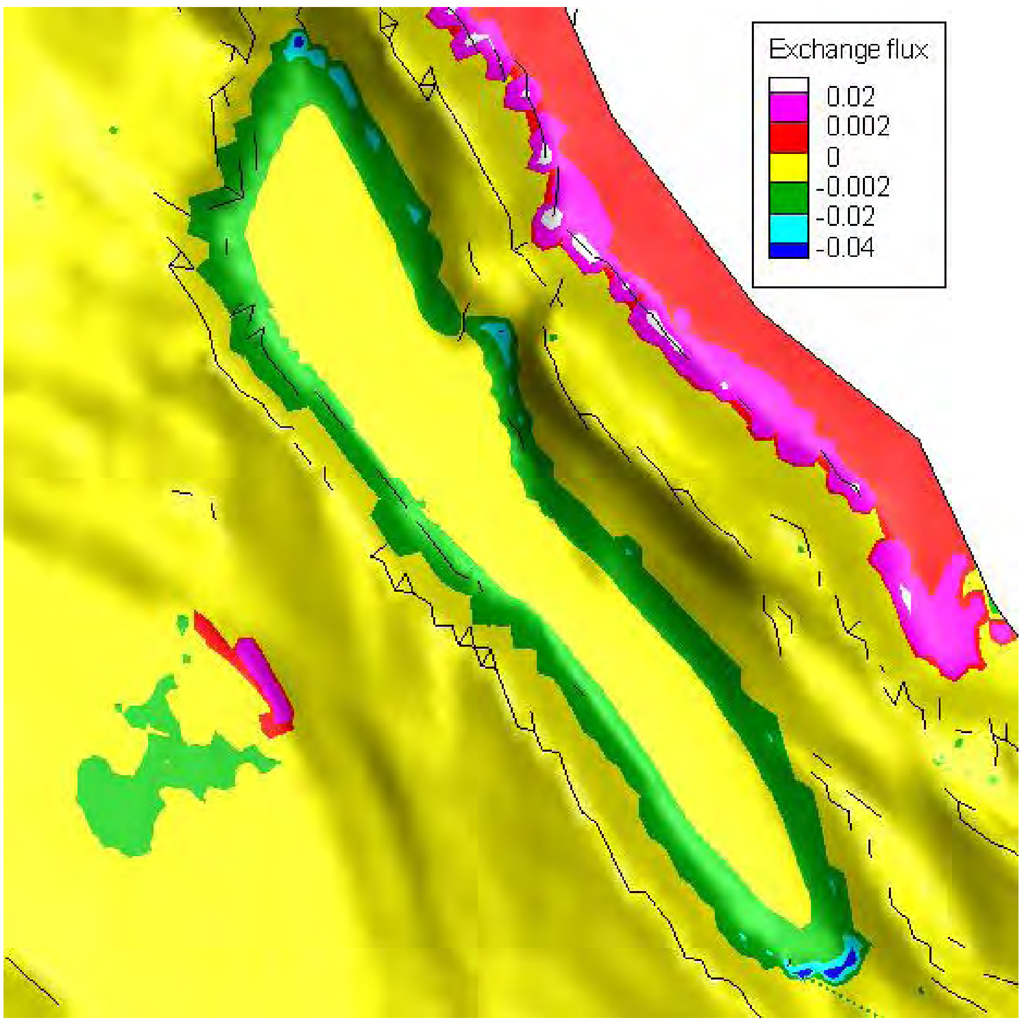


Figure 46.—Exchange flux near the Long Lake Valley Reservoir after 10 years of draining. negative values indicate infiltration to the subsurface.

Lined System

This scenario was identical in all respects to the "natural system" described above, with the exception that a low permeability layer of material with a hydraulic conductivity of 3.048E-10 m/day (1.0E-9 ft/day, essentially impermeable), was introduced as shown in figure 47. The liner was located at ground surface, and had a thickness of 2 meters.

After 30 years of draining, the predicted increase of the water table elevation is much less than for the natural system without a liner, as can be seen by comparing figure 48 with figure 43d. A small water table mound forms between the edge of the reservoir and Wocus Marsh.

This small mound (figure 49a) results when an outflow of surface water occurs from the lined portion of the reservoir at a point of lower elevation along the valley wall (figure 49b), and then forms a region of high infiltration (figure 49c).

Surface water depth for the entire domain after 30 years of draining is shown in figure 50. The reservoir is still completely full of water, and no surface water is present in Round Lake Valley.

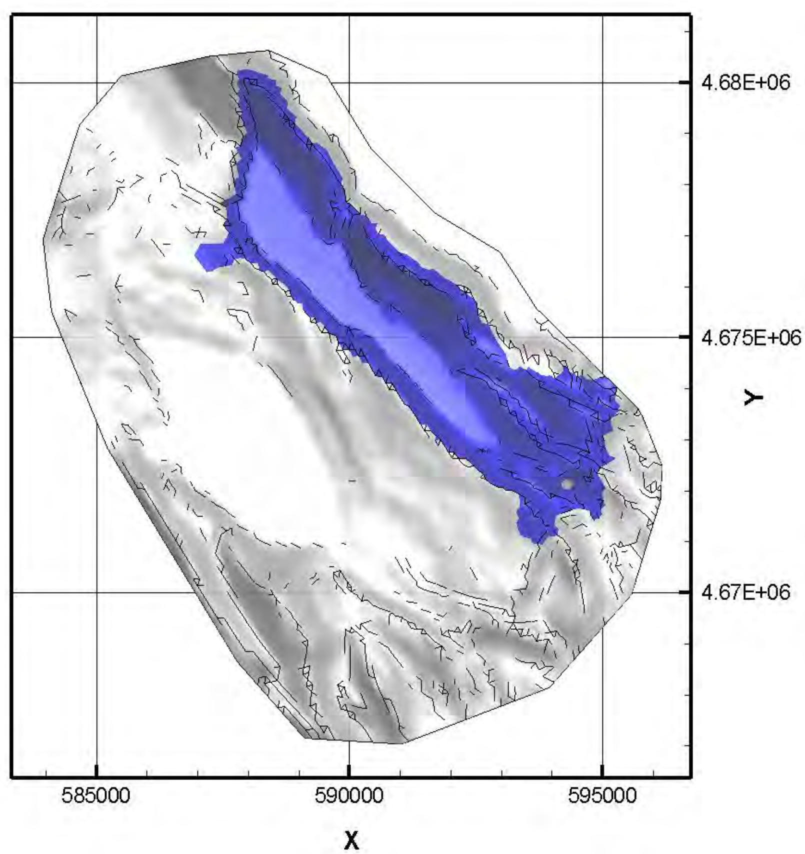


Figure 47.—Location of the low permeability liner. North is represented by the Y axis.

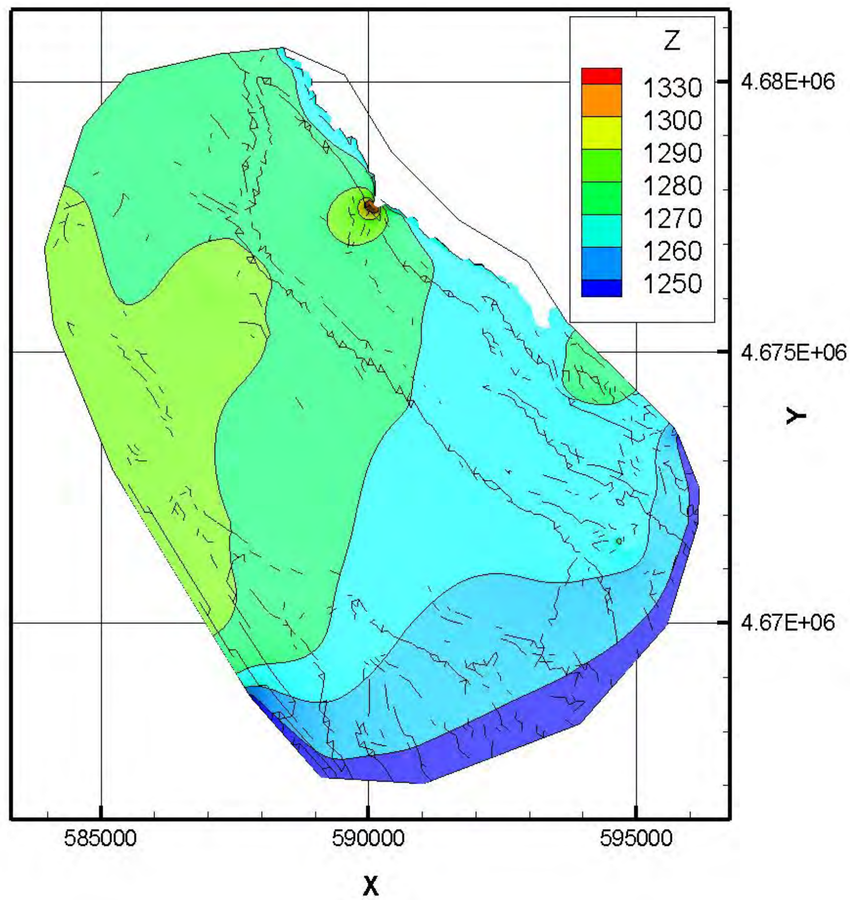


Figure 48.—Water table elevation (MASL) after 30 years of draining in a lined reservoir. North is represented by the Y axis.

Recommendations for any Post-Appraisal-Level Study

Simplifying assumptions were undertaken for an appraisal-level evaluation of:

- The capability of the proposed off-stream reservoir in Long Lake Valley to maintain a water supply over a reasonable period of time
- The impact that the stored water would have on Round Lake Valley
- The characteristic pattern of seepage in the Long Lake Valley area

Due to these simplifying assumptions, model results from this appraisal-level study are not detailed enough to provide for a full analysis of the surface/subsurface flow system and the optimal design of a liner for the proposed reservoir. Therefore, if a post-appraisal-level study is conducted, the following recommendations are made:

a)
b)
c)

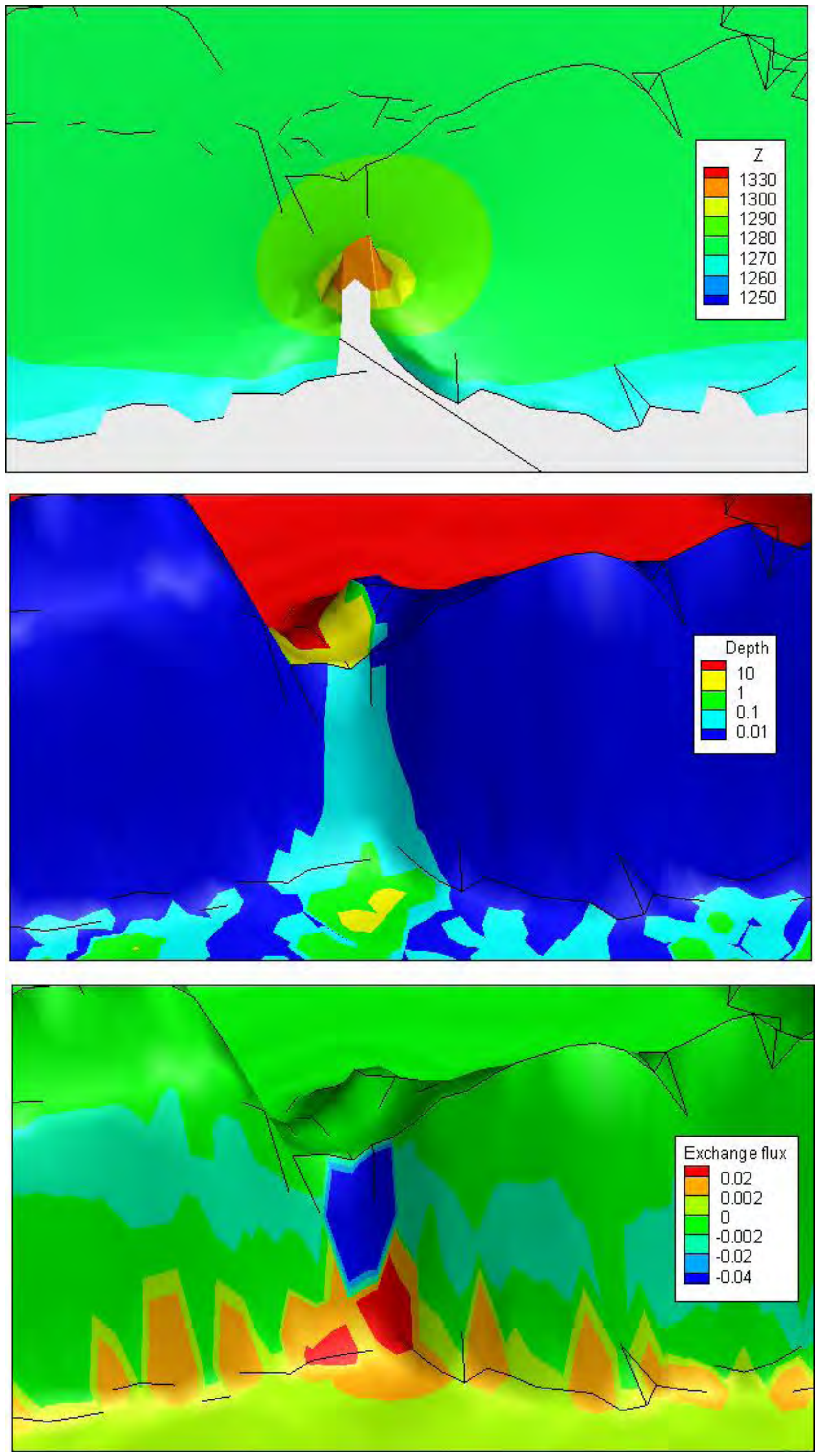


Figure 49.—(a) Water table elevation (MASL), (b) surface water depth (m) and (c) exchange flux between proposed reservoir and Wocus Marsh

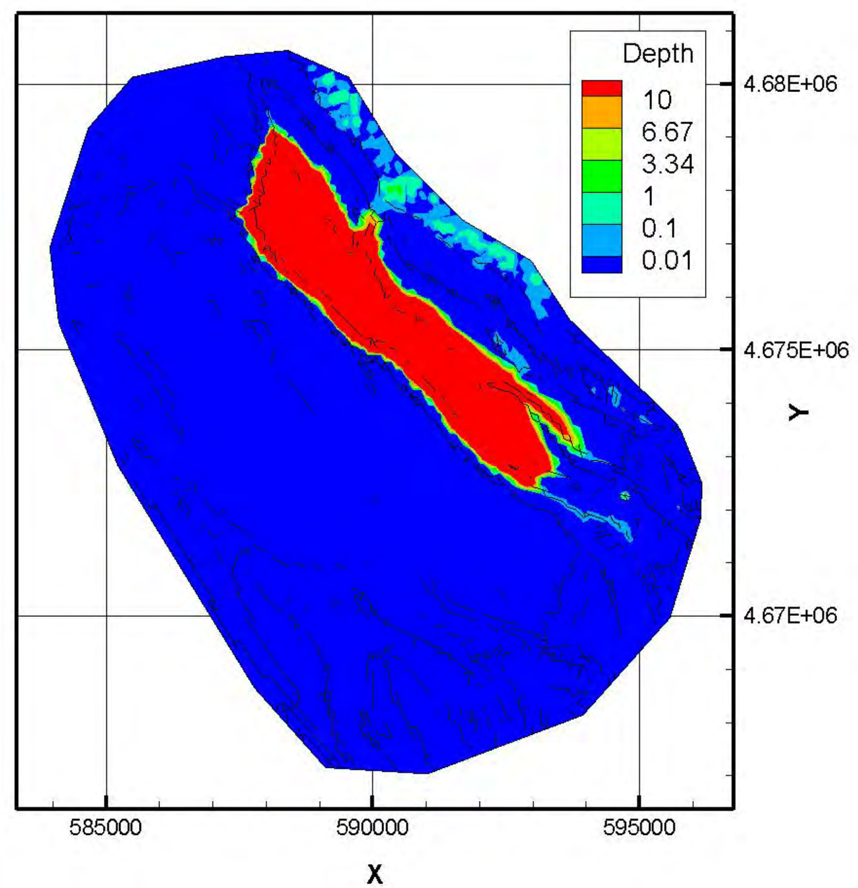


Figure 50.—Surface water depth (m) after 30 years of draining in a lined reservoir. North is represented by the Y axis.

- Collect existing regional data from literature and databases; evaluate these data, identify where regional and local data gaps exist and recommend data to be collected in the field. It has long been recognized that much of the water flowing into Upper Klamath Lake originates as groundwater discharge. Reclamation (1954, p.150), and Gannett et al. (2007) indicate that many streams in the Upper Klamath Basin have a large component of groundwater discharge, attributable to the substantial regional groundwater system that exists in the permeable volcanic terrain. For this reason, the basin is unique in this region. These studies were undertaken at the regional scale, whereas this appraisal study was performed at Long Lake Valley at a relatively small scale. At the post-appraisal level, the challenge will be to apply an understanding of the regional flow system to characterize flow conditions on a small scale. This question needs to be evaluated. (HYDROGEO-1)

- In this study, averaged annual values of precipitation (P) and evapotranspiration were applied as boundary conditions for the surface and subsurface water systems. For the area under consideration, annually averaged ET is greater than the annually averaged P that was used in the appraisal-level study. In reality, the Long Lake Valley area receives most of its precipitation in the fall and winter, and so ET is expected to be higher than P in spring and summer and less than P in the fall and winter. In order to account for this temporal variation of ET and P, it is recommended that the effect of applying monthly and/or daily ET and P be evaluated. If such data are available, ET and P will more closely approximate the field conditions. (HYDROGEO-2)

- Model grid: Based on the first recommendation above, the grid and boundary conditions will need to be re-evaluated in detail to more accurately reflect the effects of regional flow conditions on the small scale model. The principal recharge area in the Upper Klamath Basin includes the Cascade Range (Gannett et al., 2007). In this study, with the exception of the down gradient boundary near the Klamath River floodplain, the vertical subsurface boundary was treated as an impermeable boundary. This reduces the potential for groundwater flow in the Long Lake Valley area by removing possible flows from the regions north, west, and east of the model domain. It also limits the possibility that groundwater can exit the model domain to the east of Round Lake Valley, where Gannet et al. (2007) show a low in their generalized water table, indicating possible discharge to the Klamath River farther downstream. A possible exit point here could reduce ponding in Round Lake Valley and increase seepage from the reservoir. One possible option is to extend the model boundaries to the east, south, and west to Klamath Lake and the Klamath River, so that more natural boundary conditions may be applied. These concerns need to be addressed in any post-appraisal-level studies. (HYDROGEO-3)

- Calibration and/or sensitivity analysis of selected surface/subsurface flow parameters is recommended. This assists in understanding which parameters within the model create significant or minor impacts to the model. (HYDROGEO-4)

- Potential power generation that moves water from the reservoir to Upper Klamath Lake and back to Long Lake Valley is a possible alternative for Long Lake Valley. The effects of these operations need to be studied for a better understanding of how the proposed reservoir would respond to these operational rules. It is recommended that anticipated or predicted operational rules be applied in any post-appraisal studies. (HYDROGEO-5)

General Conclusions and Recommendations

As a result of the studies discussed in this report, the surface water reservoir located in Long Lake Valley, has been identified as a technically viable alternative for meeting the purpose and objectives of the appraisal activities, studies, and investigations phase of the UKBOS study. However, the preliminary BCRs did not show a positive result; therefore, we do not recommend that the LLV alternative move forward to feasibility-level studies at this time.

A more thorough determination of costs for LLV mitigation and other issues would be undertaken in the event that studies of the BCR for LLV conceptual plan features showed positive results.

This final appraisal report has identified and utilized current information, clarified issues, and clearly identified data gaps that exist for the potential conceptual plan in preparation for post-appraisal level studies process should the decision be made to proceed. "Show-stopper" issues or other issues that could have substantial mitigation costs or effects are described.

Summary of Uncertainties of Issues of Conceptual Plan Features, Findings, and Recommendations

Given the limited design data and information on the existing conditions for each feature site, the cost estimates and design assumptions are subject to some uncertainties. If the LLV planning process were to proceed to higher feasibility-level studies, some issues that would need further exploration and investigations have been indexed by topic area as follows:

- The location of the pumping plant—The same location as the 1970 proposal was assumed for planning purposes at this level. However, this site has not been determined as the optimal location and has been studied further within the tunnel/canal conveyance facilities optimization studies. (PP-1)

- Caledonia Canal and Wocus Drainage Canal—Data available on these features were minimal. Information on the canal existing conditions, capacity, operations, dimensions, and geologic conditions are needed to determine the most suitable design of this feature. The reconnaissance study did not examine if the present canal can handle the proposed pumping flow rates or if other improvements would be necessary. A specific inventory of potentially affected infrastructure also needs to be prepared. A subfeasibility-level optimization study was undertaken to further determine alternative conveyance facility combination types and alignment configurations. This optimization study took into consideration any and all existing design data and would be the basis for the final feasibility-level design decisions and the subsequent conceptual plan configuration. (CCSFF-1)

- Highway 140 modifications—Depending on the location of the canal intake structure, other modifications/relocations of the Highway 140 bridge may be necessary. (CCSFF-2)

- The foundation conditions at all identified features (fish facilities, canal conveyance, pumping plant, tunnel, reservoir lining, etc.)—If adequate foundation materials are not present at relatively shallow depths, then the cost estimates for the fish facility, canal, and pumping plant may be low. The Oregon Department of Transportation was consulted, and they shared design data information on their recently completed Highway 140 at Caledonia/Wocus Bay bridge design. These data were in turn provided to TSC staff who worked on the optimization study for alternatives for the conveyance facility type and alignment. (CCSFF-1 and 2)

- Access roads—Other road alignments may be preferred to provide access to the pumping plant, tunnel, and outlet works tower. Information on the proposed roads was limited. The extent of improvements needed for construction and long term operation and maintenance were estimated based on verbal descriptions of the existing roads. (AR-1)

- Biological input on the proposed fish facilities—The intake structure (with fish facility) was patterned after the designs for A-Canal Fish Screen. However, the remote location of the Caledonia Canal inlet area may warrant a different arrangement of these facilities. The precise location and arrangement of the fish bypass facility would need much more refinement. (CCSFF-3)

- Dead storage elevation—Conceptual plan water storage elevation 4430 feet has been cited as 350,000 acre-feet of storage. This estimation is correct based on the area-capacity curve, which indicates this amount. However, this figure does not reflect the usable storage amount. Reclamation set the tunnel invert elevation (elevation 4270 feet) at 10 feet above the average valley bottom elevation. According to the area-capacity curve (dated 8-27-69) the amount of storage available between elevations 4270 and 4430 feet is approximately 340,000 acre-feet. In the 1970 study scenario most similar to this appraisal study, a tunnel invert of elevation 4271 feet was used. Also, the minimum water surface was identified at elevation 4296 feet. The amount of "usable" storage available between elevations 4296 and 4430 feet is approximately 305,000 acre-feet. Apparently, the cited 350,000 acre-feet of storage is a nominal figure. Care should be taken when indicating the actual usable capacity of the conceptual plan. (RES-1)

- Reservoir storage—A potential exists for Long Lake Valley to hold up to 500,000 acre-feet. This should be further explored in post-appraisal-level studies. (RES-2)

- Reservoir lining—Further hydrogeology studies need to be undertaken to improve upon the modeling efforts that were started under the appraisal-level investigations into the capability for the Long Lake Valley Reservoir to hold water. The hydrology modeling efforts should also determine, with greater certainty and accuracy, the location and types of lining needed. The lining feature of a conceptual plan as large in scale as LLV could be very expensive. (RL-1)

- Power generation—The opportunity for power generation should be further explored and refined within post-appraisal-level studies and investigations. Discussion with potential operating entities or partners, private and public, should be pursued. (PP-2)

- A potential exists, through the Klamath Basin Restoration Agreement, that the Klamath Project could receive BPA power at a project use power rate. Such a scenario needs to be investigated in post-appraisal-level studies along with the facilities that would be necessary to transmit the power from BPA facilities at either Malin or Captain Jack switchyards near Malin, Oregon across the Klamath Project to the proposed LLV pumping plant. Investigative studies need to consider that the length of such transmission lines may fall under the jurisdiction of the Oregon Energy Facilities Siting Council. (EP-1)

- The appraisal-level hydrodynamic work focused on extreme operational scenarios, and therefore post-appraisal-level predictive modeling, if undertaken, should focus on more likely scenarios. (HD-1)

- Continue to work with OWRD to secure a water storage permit in the amount of storage at the LLV reservoir site. Determine the final reservoir size so that the water storage permit can specify the amount to be stored. (WR-1)

- Although detailed seismological analyses have been performed for the sequence, it is likely that additional analyses would provide more accurate information than is currently available. Additional analyses could include a simultaneous three-dimensional velocity model-hypocenter inversion and site response studies. Accuracy could improve for fault geometries, velocity structure, maximum depth of faulting, wave propagation, and site response characteristics. Analyses of this type also are recommended for any further site development studies. (ST-1)

- What effects the conceptual plan would have on cultural resources needs to be determined. The activities involved with the proposed off-stream storage conceptual plan have the potential to affect historic properties (36 CFR Part 800.3(a)). Reclamation would comply with the National Historic Preservation Act of 1966, as amended, which is the primary Federal legislation that outlines the Federal Government's responsibility for preserving historic properties (16 USC 470 et seq.). Compliance with Section 106, outlined at 36 CFR Part 800, requires a series of steps in consultation with Klamath Tribes and the Oregon State Historic Preservation Office. These steps would identify interested parties, determine the APE, conduct cultural resource inventories, determine if historic properties are present within the APE, assess effects on any identified historic properties, and resolve any adverse affects. (CR-1)

- If Long Lake Valley Reservoir is developed for water storage and perhaps hydropower purposes, the potential to develop the saddle area at the southeastern end of the reservoir for recreation should be more thoroughly evaluated. Vehicle access, private land acquisition, funding, operation and maintenance obstacles, hydropower operations, water levels, fish die-offs, and other factors could affect recreation opportunities and experiences. Such factors could need more investigation in a feasibility level of study for recreation which might be a beneficial use of Long Lake Valley Reservoir. (REC-1)

- Specific strategies for potential power generation operations should be added to the overall representation of Long Lake Valley Reservoir in future modeling for any post-appraisal level of study. A reservoir with 500-TAF capability should also be investigated through modeling to see if there are different benefits to be gained or different years of shortages that can be mitigated. Logic that carefully considers water supply forecasts and anticipated delivery shortages should be developed to determine how best to allocate Long Lake Valley Reservoir resources. Stochastic methods should be used to construct alternative hydrology traces to test potential strategies. (HYD-1)

- Convert the CE-QUAL-W2 model to more recent versions (v3.5 or v3.6) and test against existing simulation results. In addition, explore additional algae species representation and parameter selection, first order sediment processes, and other appropriate water quality modeling variables/processes that will be implemented in the CE-QUAL-W2 model. (WQ-1)

- Recently, additional geometric data has been acquired for Long Lake Valley Reservoir. This data should be used to update model geometry (and test). Also specify more detailed geometric representations of inlet and outlet works. If these elements require flow and water quality modeling to refine predesign consideration, identify a range of potential conditions. If treatment facilities are envisioned (e.g., discharge aeration, pretreatment aeration, in-reservoir oxygenation/aeration), identify location, capacity, and other pertinent features. (WQ-2)

- A wider range of operational information would better constrain the analysis. Define more comprehensive hydrology, inflows, outflows, and storage rules for Long Lake Valley. Operational elements may include fill rates, minimum pool volumes, reservoir storage rules, carryover storage targets, selective input and withdrawal, pumped storage schemes, and outlet tower design and operations. These elements may require water quality modeling to refine operations. (WQ-3)

- Evaluate local conditions at the Wocus Drain discharge point or terminus configuration. Specifically, explore potential local water quality impacts due to discharge to UKL from Long Lake Valley Reservoir and examine potential configurations, if applicable, that would minimize or ameliorate impacts. (WQ-4)

- Water quality boundary conditions could be improved through additional monitoring. Monitoring water quality in the Wocus Bay and Wocus Marsh region, including drains to the local area, would provide additional insight into potential water quality conditions of water imported to Long Lake Valley Reservoir. Parameters should include temperature, dissolved oxygen, pH, specific conductance, nutrients, organic matter, algae, and chlorophyll a and other necessary parameters to compliment model input. (WQ-5)

- Confirm any Long Lake Valley Reservoir water quality release benefits for a discharge point at Keno Dam to the Klamath River downstream of Keno Dam. (WQ-6)

- Additional, site-specific meteorological data can be collected in Long Lake Valley to assess local conditions. These conditions could be compared to long term meteorological stations in the vicinity (e.g., AgriMet KFLO). (WQ-7)

- Permitting and discharge requirements—Federal and State regulations should be evaluated to determine and document any permitting and water quality requirements related to the operation and discharge of water from the proposed reservoir. This evaluation should include potential regulatory issues related to in-lake chemical treatment (effects on fish and wildlife), sludge accumulation, and reservoir lining. (WT-1)

- Water quality modeling—A limnology model of the proposed reservoir should be developed to predict water quality as a function of inflows, outflows, storage volume, and treatment options. (WT-2)

- SolarBee pilot testing—Field pilot testing of multiple SolarBee units should be conducted over a 12-month period to collect performance data. Suitable testing locations should have water quality that is similar to UKL's, have significant temperature stratification due to depth of water, and be geographically close enough to have ambient conditions comparable to those at LLV. (WT-3)

- Laboratory bench tests for chemical precipitation—Laboratory bench tests using UKL water should be conducted to evaluate the best chemical coagulant (ferric chloride or alum), the optimum dosage, mixing requirements, characteristics of floc formation and settling, and sludge production. (WT-4)

- Alternative treatment and water quality management options—Additional strategies not included in the appraisal study may be appropriate for further consideration. Examples might be water treatment along the conveyance between UKL and LLV to address discrete spikes in poor water quality, source control measures for inflows to UKL, and management techniques of flow and storage to mitigate potential water quality degradation. (WT-5)

- As stated in the *Recreation Resources* section, visitor use cannot be predicted at this time; therefore, recreation benefits cannot be quantified for the appraisal-level study. Visitor use estimates influence recreation benefits, and Long Lake Valley Reservoir operations will greatly affect visitor use. Recreational benefits may be very minor due to the potential impacts of reservoir drawdowns. A more thorough study should be undertaken in post-appraisal-level investigations. (ECON _REC-1)

- Nonuse values reflect values individuals hold for a resource even if they will never actually use it (e.g., threatened and endangered species). Since the Lost River and shortnose suckers in UKL and coho salmon in the Klamath River are federally listed species, and Long Lake Valley Reservoir operations may affect them, nonuse values may be applicable to this study. However, nonuse values can be very difficult to estimate, requiring the application of complex survey approaches, with the results often proving to be highly contentious.

  In order to quantify fisheries benefits, it is necessary to obtain population and harvest estimates by fish species, type of harvest, and alternative from study team biologists. These data were not available for the appraisal study; therefore, fisheries benefits have not been calculated. (ECON_FISH-1)

- Land acquisition plan—During the acquisition planning and programming stage, there needs to be a comprehensive Land Acquisition Plan. Once the plan were drafted it would go through periodic reviews and revisions. Upon completion, it would need to be approved by the Regional Director or designee (Regional Realty Officer). (REAL-1)

- Relocation assistance planning—During preconstruction planning and prior to initiation of negotiations for the acquisition of any real property, a determination must be made whether the acquisition would result in the displacement of persons from their dwellings, businesses, or farm operations. Prior to the commencement of acquisition activities (including development of property descriptions, title examinations, appraisal, and negotiations) that would cause such displacement, a relocation plan would be developed. This plan would comply with 49 CFR Part 24, Subpart C Section 24.205, pursuant to the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. This topic refers to all acquisition methods. Depending on the acquisition method, relocation assistance could be part of a negotiated sale or in condemnation proceedings. (REAL-2)

- Landowner relations—It is imperative that within 6 months of Congress authorizing and funding the project, a reasonable effort be made to advise owners/occupants in the conceptual plan area. This advice would address the scope of the conceptual plan and the probable time when the lands or interests in lands or water rights would be acquired. This could be established through public meetings, personal contacts, etc. Pamphlets and brochures that contain information on the lands or interests in lands and water rights acquisition methods and procedures should be distributed to owners and occupants of the lands in the vicinity of the proposed acquisition area. (REAL-3)

- Determination of program needs—A 9-month minimum lead time (this may not be sufficient time in which to accomplish the real estate program due to the size and significance) is required. This would allow sufficient time to develop a realistic schedule for land and water rights acquisition and to comply with requirements for acquisition and relocation assistance planning to ensure availability of sufficient replacement housing. (REAL-4)

- NEPA and other environmental laws compliance—NEPA compliance would include, but not be limited to, preparation of an EA/FONSI or EIS/ROD, and completion of hazmat surveys/evaluations. In addition, other environmental laws, such as the National Historic Preservation Act and Endangered Species Act, require certain compliance measures. There must be confirmation of environmental law compliance before any construction activities may begin on the land or interests acquired. (REAL-5)

- Guide acquisition lines—Designation of interests in real property planned to be acquired may be established through the use of “guide acquisition lines,” “guide contour lines,” or “take lines.” These are lines established through Reclamation’s planning process that delineate the various lands and/or land estates to be acquired at different elevations both upstream (pool, etc.) and downstream (flood, etc.). (The term "guide acquisition line" is sometimes used in reference to safety of dams criteria.) Any maps or plans distributed should be labeled "Preliminary—Subject to Revision" when appropriate. For more detail, refer to the Reclamation Manual, LND 06-01(3)(K), p. 12. (REAL-6)

- Joint policy for reservoir conceptual plan lands—Reservoir conceptual plan land acquisition policy for the Department of the Interior and the Army is published in 43 CFR Part 8, which cites policy for subjects including, but not limited to:

    - Acquisition of the lands with adequate interest in lands necessary for the realization of optimum values for all purposes, including additional land areas for present and future outdoor recreational and fish and wildlife potentials.

    - Lands necessary for reservoir construction and operation (i.e., for permanent structures), lands below the maximum flowage line, and lands needed to provide for public access to the maximum flowage line.

    - Additional lands for correlative purposes (i.e., lands needed to meet present and future requirements for fish and wildlife as determined pursuant to the Fish and Wildlife Coordination Act), and lands needed to meet present and future public requirements for outdoor recreation, as may be authorized by Congress.

    - Easements in lieu of fee title (i.e., for lands lying above the storage pool, lands in remote portions of the conceptual plan area, and lands determined to be of no substantial value for protection or enhancement of fish and wildlife resources, or for public outdoor recreation). In some cases, it is to the financial advantage of the Federal Government to take easements in lieu of fee title.

    - Buildings for human occupancy as well as other structures that would interfere with the operation of the conceptual plan for any conceptual plan purposes are prohibited on reservoir conceptual plan lands. (REAL-7)

- Estates to be acquired—Reclamation would acquire estates in real property that are consistent with the joint policy and specific program requirements. In addition, Reclamation would provide that its water and land areas would, to the extent appropriate:

    - Be available to the public

- Provide appropriate public access
- Enhance recreation
- Promote fish and wildlife habitats
- Provide fishing access, if so desired
- Facilitate and encourage optimum use and utilization of all lands acquired

Reclamation typically desires the least amount of interest that allows management, operation, and maintenance of its facilities. Nothing is inherently better about having fee land compared to having an easement that gives Reclamation all the rights it needs. Lands or interests in lands that are acquired by the United States usually remain within the ownership of the United States even if management and operation and maintenance activities are transferred to an appropriate agency in the future. (REAL-8)

- Acquisition of fish and wildlife properties—Under the authority of the Fish and Wildlife Coordination Act, Reclamation is required to consult with the Fish and Wildlife Service during the planning of new conceptual plans so that wildlife resources receive equal consideration with other conceptual plan objectives. By statutory provision, the consideration of fish and wildlife values and the mitigation for any damage to those values must proceed concurrent with or before construction. Reports and recommendations from the Service and the head of the State wildlife resource agency may be provided to Reclamation detailing: (1) impacts to wildlife resources, (2) means to mitigate or compensate adverse impacts, and (3) enhancement measures. At this point during the planning process, acquisitions of fish and wildlife properties are not anticipated. (REAL-9)

- Flood hazard evaluations—In compliance with Executive Order 11988, requests to the Regional Director for approval to acquire or exchange lands or rights-of-way must be accompanied by a statement on flood hazards, including justification for anticipated construction of facilities and proposed land use within the floodplain. *(This requirement does not apply if such information, in accordance with Executive Order 11988, was included in the project feasibility report.)* (REAL-10)

- Land designation and/or legal descriptions—Consideration of the various estates to be acquired should lead to designation of the lands and/or land interests required for Reclamation purposes and preparation of legal descriptions and tracts maps including, but not limited to:

  - Land surveys, by a registered land surveyor for the delineation of all lands and land interests required for a project, should be expedited so that boundaries of land under Reclamation's jurisdiction can be obvious to Reclamation's management and to the public. The property boundaries should be monumented while construction funding is still available.

  - Early designation of sufficient lands (including mitigation of lands, habitat improvement areas, and recreational areas) for all authorized and planned conceptual plan purposes is essential in order to avoid additional land-purchase negotiations with the same owners.

  - Accurate descriptions of lands and interests of lands to be acquired would be prepared, checked, and certified together with an endorsement to that effect. A survey plat or tract map of the acquisition should also be prepared under the same standards as the description. (REAL-11)

- Ownership and title determinations—Title evidence must be obtained prior to acquisition of lands or interests in land or interests in water rights. Title evidence must conform to the 1992 Revised Department of Justice Title Standards, which include *Standards for the Preparation of Title Evidence in Land Acquisitions by the United States*, 1970; and *a Procedural Guide for the Acquisition of Real Property by Government Agencies*, 1972. Only approved abstracters and title companies may furnish title evidence. All title evidence must be submitted with the acquisition documents on each transaction for preliminary title opinions preparation by the Solicitors Office. Title evidence can consist of title insurance, abstracts of title, Torrens Certificates, or Memorandum of Ownership and Encumbrance. Evidence of title of property proposed to be acquired would be furnished by the Government at its expense, except where otherwise authorized by law or provided by contract (e.g., 40 U.S.C. 255, as amended). Prior to acquisition of lands or interests in lands or interests in water rights, both a Preliminary Title Opinion and Final Title Opinion must be submitted for approval for acquisition by the Solicitor. (REAL-12)

- Hazardous materials environmental site surveys—To comply with the Department of the Interior's Departmental Manual, two levels of hazardous materials environmental site surveys are specified for Reclamation (Phase I Site Survey and a Phase II Site Survey). Depending on the outcome of Phase I, a Phase II may need to be completed prior to acquisition. (REAL-133)

- Encumbrance of funds—The appropriate Reclamation finance office must be given notice of the appraised value to encumber the necessary funds. (REAL-14)

- Land owned by BLM—The United States owns two parcels, managed by BLM. These parcels consist of 45.79 acres and 354.52 acres, for a total of 400.31 acres. An acquisition by transfer from BLM to Reclamation would need to take place with these parcels. No specific form exists at present for acquisition by transfer. However, whenever a Federal agency transfers jurisdiction of real property to another Federal agency, the transfer document typically includes signatures from both agencies. These signatures document the transfer of management responsibility, adjustment in real property inventory records, and adjustment in financial records (six signatures total). Provisions of the Federal Property and Administrative Services Act of 1949, as amended, among other directives and standards typically govern transfers. Other specialized legislation may be enacted to provide authority for transfer of Federal lands. (REAL-15)

- Appurtenant water rights acquisition—The term "water rights acquisition" as used in this section, means acquisition of existing privately owned water rights, as opposed to obtaining new water rights, or a new water right authorization. Water rights acquisitions will use appraisal methods to determine fair market value and title abstracts to determine ownerships. Water rights would be acquired and used for beneficial use as soon as feasible to avoid forfeiture or abandonment of the rights under State law. Acquisition of permanent appurtenant water rights (water rights that have been applied to property for a beneficial use, and are thus pertinent to land), would be consistent with relevant regulations. These regulations are the Uniform Relocation Assistance and Land Acquisition Policies Act, as amended; implementing regulations (49 CFR Part 24); and Department of Justice publications. (REAL-16)

- Issuance of easements for utilities/transmission lines—There would be existing utilities/transmission lines crossing the land or interests in lands to be acquired. Once the lands or interests in lands were acquired, Reclamation would need to give PacifiCorp, or the appropriate power entity, an easement right-of-way for the transmission lines from the poles to the plants for operation and maintenance of the lines. Reclamation has recognized a potential location for a power line corridor, which can be seen on the detailed boundary map in figure 33. Other utility corridors may be utilized in the future, but have not been identified at this time. (REAL-17)

- Timber not needed for construction purposes—Once the proposed reservoir were authorized for construction and Reclamation had acquired the land and timber, then the merchantable timber may be sold if it were not required for construction purposes. This entails an intricate and time-consuming process that would need to be inserted into the construction time frame and depends on which type of ownership scenario the timbered land falls under. For example:

  - Pursuant to Reclamation Manual LND 08-02.8.A, the process would depend on whether the timber were within the boundaries of a national forest. If it were within the boundaries of a national forest, then Reclamation would need to submit a request to the Forest Service to make an appraisal and suggestions for the disposal of the timber. Then at the discretion of the Regional Director, a sale may be conducted either by Reclamation or the Forest Service.

  - If the timber were not within the boundaries of a national forest, and were withdrawn from public domain, then BLM would dispose of the merchantable timber in accordance with the provisions of 586 Departmental Manual 1.

  - Since the proposed reservoir is not within the boundaries of a national forest and Reclamation would most likely acquire the land and timber in fee title, then, Reclamation would need to determine the most appropriate method to dispose of the timber. (REAL-18)

- Prior to acquisition of the property, a Phase II hazardous materials assessment is recommended due to the size of the area. Phase I assessment was performed at the early stages of the conceptual plan to identify possible cost-prohibitive recognized environmental conditions in connection with this property. (HAZMAT-1)

- Due to simplifying assumptions, hydrogeologic model results from the appraisal-level study are not detailed enough to provide for a full analysis of the surface/ subsurface flow system and the optimal design of a liner for the proposed reservoir. Therefore, if the decision is made to proceed to post-appraisal-level studies. the following recommendations are made:

  - Collect existing regional data from literature and databases; evaluate these data, identify where regional and local data gaps exist and recommend data to be collected in the field. It has long been recognized that much of the water flowing into Upper Klamath Lake originates as groundwater discharge. Reclamation (1954, p.150), and Gannett et al. (2007) indicate that many streams in the Upper Klamath Basin have a large component of groundwater discharge, attributable to the substantial regional groundwater system that exists in the permeable volcanic terrain. For this reason, the basin is unique in this region. These studies were undertaken at the regional scale, whereas this appraisal study was performed at Long Lake Valley at a relatively small scale. Within post-appraisal-level studies, the challenge will be to apply an understanding of the regional flow system to characterize flow conditions on a small scale. This question needs to be evaluated. (HYDROGEO-1)

- In this study, averaged annual values of precipitation (P) and evapotranspiration were applied as boundary conditions for the surface and subsurface water systems. For the area under consideration, annually averaged ET is greater than the annually averaged P that was used in the appraisal-level study. In reality, the Long Lake Valley area receives most of its precipitation in the fall and winter, and so ET is expected to be higher than P in spring and summer and less than P in the fall and winter. In order to account for this temporal variation of ET and P, it is recommended that the effect of applying monthly and/or daily ET and P be evaluated. If such data are available, ET and P will more closely approximate the field conditions. (HYDROGEO-2)

- Model grid: Based on the first recommendation above, the grid and boundary conditions will need to be re-evaluated in detail to more accurately reflect the effects of regional flow conditions on the small scale model. The principal recharge area in the Upper Klamath Basin includes the Cascade Range (Gannett et al., 2007). In this study, with the exception of the down gradient boundary near the Klamath River floodplain, the vertical subsurface boundary was treated as an impermeable boundary. This reduces the potential for groundwater flow in the Long Lake Valley area by removing possible flows from the regions north, west, and east of the model domain. It also limits the possibility that groundwater can exit the model domain to the east of Round Lake Valley, where Gannet et al. (2007) show a low in their generalized water table, indicating possible discharge to the Klamath River farther downstream. A possible exit point here could reduce ponding in Round Lake Valley and increase seepage from the reservoir. One possible option is to extend the model boundaries to the east, south, and west to Klamath Lake and the Klamath River, so that more natural boundary conditions may be applied. These concerns need to be addressed in any post-appraisal-level studies. (HYDROGEO-3)

- Calibration and/or sensitivity analysis of selected surface/subsurface flow parameters is recommended. This assists in understanding which parameters within the model create significant or minor impacts to the model. (HYDROGEO-4)

- Potential power generation that moves water from the reservoir to Upper Klamath Lake and back to Long Lake Valley is a possible alternative for Long Lake Valley. The effects of these operations need to be studied for a better understanding of how the proposed reservoir would respond to these operational rules. It is recommended that anticipated or predicted operational rules be applied in any post-appraisal-level studies. (HYDROGEO-5)

Conclusions

As a result of the appraisal studies, a technically viable, albeit fiscally poor, surface water storage reservoir alternative at Long Lake Valley has been investigated and found to meet the purpose and need identified in the UKBOS studies. This is not withstanding any unmitigatable potential impacts or effects pending investigation of uncertainties clarified within the appraisal-level studies. The LLV alternative should not move forward to feasibility-level studies at this time. Instead, it should be more thoroughly investigated in post-appraisal-level studies if deemed necessary.

Early in the UKBOS planning process, it was held that potential conceptual plan features would comprise a very large portion of any of the scoped KBWSI and that further costs associated with mitigation features and other issues costs would be compared at a later date. Mitigation features involve wetlands, land acquisition, reservoir lining, energy, water quality, fish and wildlife species of concern and their habitat protection, easements, rights-of-way, relocations, and other social impacts. Based on this information, it was then held that the most cost-effective studies would be those that determined BCR of conceptual plan features first. If the conceptual plan features BCR studies showed positive results, then a more thorough determination of the costs of mitigation and other issues would be undertaken as adding more costs would only serve to make a BCR worse. In the case of LLV, the BCRs, as determined through the appraisal-level conceptual plan features costs development are very poor, ranging from 0.01:1 to 0.04:1.

Water treatment issues were discussed and uncertainties were listed for the case where a decision is made to conduct post-appraisal-level studies for LLV. Water treatment facilities would be expensive to build and maintain, and the additional costs could serve to make BCRs even worse.

Given the high degree of interest in LLV as a potential storage location, a post-appraisal- (or pre-feasibility-) level conceptual plan optimization study was undertaken. This study addressed uncertainties raised in appraisal-level studies of the conceptual plan features, investigated BCR trends, and proved highly beneficial as an initial screening element before proceeding with potentially much more expensive full feasibility-level studies. The feasibility-level studies, if undertaken, would then investigate all uncertainties and accommodate as many recommendations arising from this final appraisal report as possible while leading to a final feasibility and NEPA report, which would contain recommendations to inform stakeholders and Congress.

While conducting the UKBOS study and associated investigations, Reclamation, to the extent possible and practicable, is following its defined “planning process” consistent with *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G; Water

Resources Council, 1983). At the same time, Reclamation is attempting to interject enough flexibility in the planning process to accommodate the dynamics of ongoing water discussions pertaining to the Upper Klamath Basin.

The appraisal- or higher-level studies could show that UKBOS alternatives studied at those planning levels are not viable for meeting the purpose and objective of the UKBOS studies, which are mainly to meet the needs of water storage in the Upper Klamath Basin. In that case, Reclamation would revisit the reconnaissance-level studies, given compelling need and justification, to investigate the feasibility of alternatives other than LLV. These new investigations would be more thorough than either early investigations or investigations under the current feasibility study authorization (P.L. 106-498).

In addition, the Klamath Basin Restoration Agreement calls for Reclamation to continue the search for water storage alternatives in the Upper Klamath Basin.

The planning process authorized under the Enhancement Act and scoped for purpose and needs within the UKBOS study has not been concluded even though the recommended post-appraisal optimization study showed negative results for a surface water storage reservoir or variations at LLV. Reconnaissance-level UKBOS investigations of the non-LLV alternatives will be revisited. In essence, the process would be reiterated until all viable alternatives have been investigated or eliminated through screening. Only after examining all UKBOS alternatives from the reconnaisance level and finding that none of them passed revised, updated screening criteria, would a concluding report for all UKBOS studies be developed.

Should the recommendation be made to proceed to higher feasibility-level studies, KBAO staff would coordinate with other public agencies, private consulting contractors, and other entities as needed and appropriate throughout the feasibility phase. NEPA compliance, as well as preliminary scoping of the design alternatives/scenarios for accomplishing the LLV surface water storage reservoir or other alternative conceptual plan would also be performed.

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The team leader at the TSC in Denver was Al Bernstein. The TSC's Lelon Lewis edited this report.

Appendix A—Hydrodynamic Study

In cooperation with the Bureau of Reclamation

Preliminary Study of the Effect of the Long Lake Valley Project Operation on the Transport of Larval Suckers in Upper Klamath Lake, Oregon

By Tamara M. Wood

Open-File Report 2009–1060

U.S. Department of the Interior
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Conversion Factors and Datums

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter (m^3)
meter (m)	3.281	foot (ft)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Vertical coordinate information is referenced to the Upper Klamath Lake Vertical Datum (UKLVD), which is used by the Bureau of Reclamation for reporting the elevation of Upper Klamath Lake.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

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Preliminary Study of the Effect of the Long Lake Valley Project Operation on the Transport of Larval Suckers in Upper Klamath Lake, Oregon

By Tamara M. Wood

Abstract

A hydrodynamic model of Upper Klamath and Agency Lakes, Oregon, was used to explore the effects of the operation of proposed offstream storage at Long Lake Valley on transport of larval suckers through the Upper Klamath and Agency Lakes system during May and June, when larval fish leave spawning sites in the Williamson River and springs along the eastern shoreline and become entrained in lake currents. A range in hydrologic conditions was considered, including historically high and low outflows and inflows, lake elevations, and the operation of pumps between Upper Klamath Lake and storage in Long Lake Valley. Two wind-forcing scenarios were considered: one dominated by moderate prevailing winds and another dominated by a strong reversal of winds from the prevailing direction.

On the basis of 24 model simulations that used all combinations of hydrology and wind forcing, as well as With Project and No Action scenarios, it was determined that the biggest effect of project operations on larval transport was the result of alterations in project management of the elevation in Upper Klamath Lake and the outflow at the Link River and A Canal, rather than the result of pumping operations. This was because, during the spring time period of interest, the amount of water pumped between Upper Klamath Lake and Long Lake Valley was generally small. The dominant effect was that an increase in lake elevation would result in more larvae in the Williamson River delta and in Agency Lake, an effect that was enhanced under conditions of wind reversal. A decrease in lake elevation accompanied by an increase in the outflow at the Link River had the opposite effect on larval concentration and residence time.

Introduction

Long Lake Valley, a dry lakebed in the Upper Klamath Lake basin (fig. 1), is being studied by the Bureau of Reclamation as an offstream storage reservoir to augment water supplies in the Klamath River basin in dry years. Because moving water to and from the proposed Long Lake Valley (LLV) offstream storage would affect how water moves through Upper Klamath Lake (UKL), and because the existence of the LLV storage has the potential to change how UKL is managed in terms of the elevation of the lake and the outflows at Link River and the A Canal, it is unknown whether or how the construction of the LLV storage could affect the pathways and travel time of endangered Lost River and shortnose sucker larvae that enter UKL after spring spawning. Larval retention in shoreline areas of Upper Klamath Lake, where emergent vegetation provides cover from predators, is preferable for survival of the species to emigration from the lake (and therefore loss to the population) by way of passive transport in wind-driven currents (Cooperman and Markle, 2004; Markle and others, 2009). The reconnection of the Williamson River delta in October 2007 will likely result in much additional high-quality rearing habitat for larval suckers spawned in the Williamson River. Therefore, any alteration of

Klamath Project operations that has the potential to either increase or decrease the concentration of larval suckers and their residence time in high-quality habitat in UKL and Agency Lake system, and thereby diminish or enhance their chances of survival, is of interest.

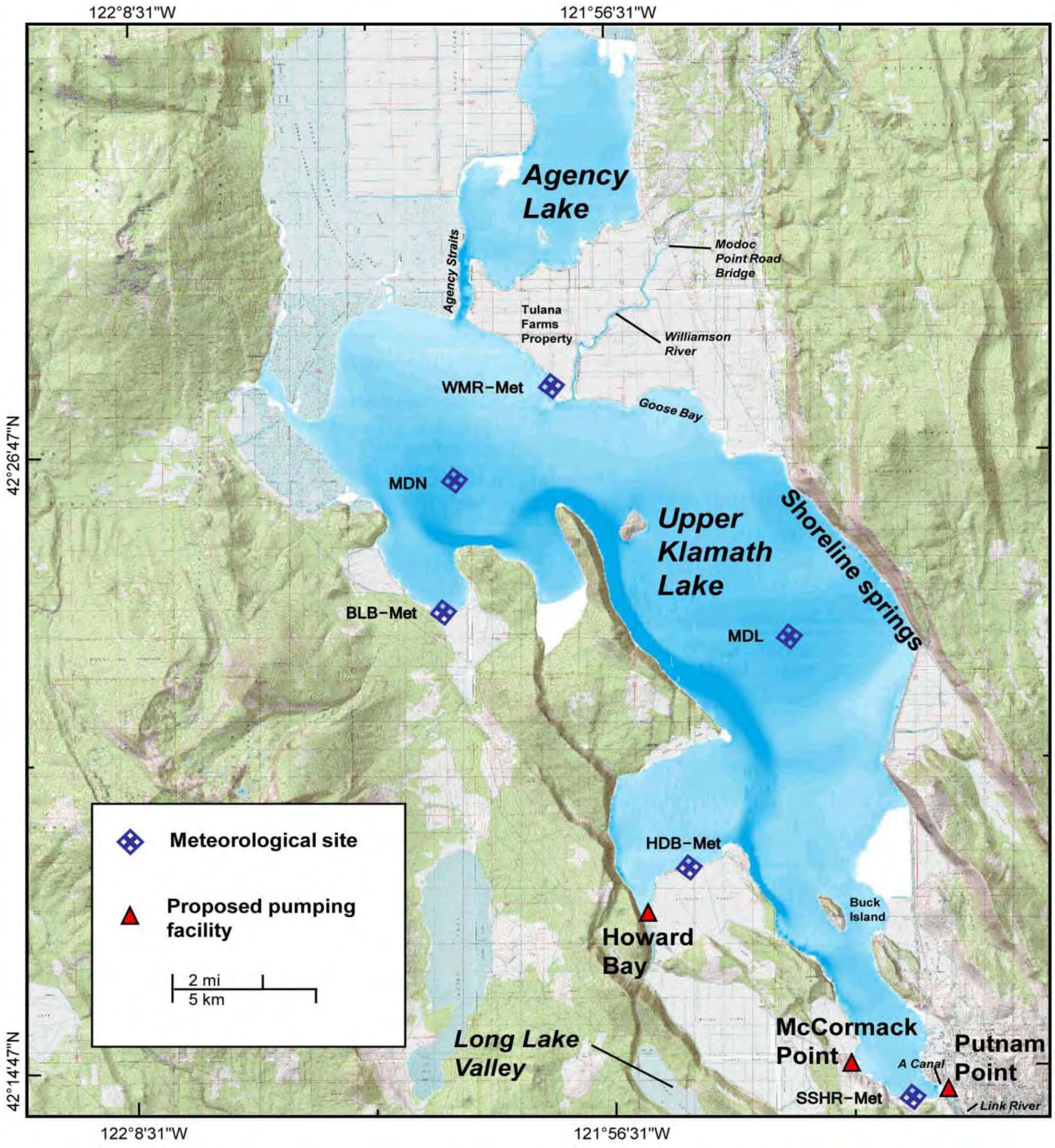

Figure 1. Map of Upper Klamath and Agency Lakes, Oregon, showing meteorological stations and proposed locations of Long Lake Valley pumping facilities. As a result of wetland restoration efforts, much of what is shown here as dry land in the Williamson River delta is now inundated.

The Bureau of Reclamation used the Water Resources Integrated Modeling System (WRIMS) to simulate project operations from 1961 through 2006 on a monthly (August–February) and twice monthly (March–July) basis (Nancy Parker, Bureau of Reclamation, written commun., 2009). This work has provided a simulated history of lake elevation and outflow at the Link River and A Canal, both with and without the Long Lake Valley storage in place, under the assumption that the project was managed according to the Proposed Action as described in the 2008 Biological Assessment (Bureau of Reclamation, 2008). Because project operations prior to 2008 were managed according to different rules from those in the 2008 Biological Assessment, the WRIMS simulation of lake outflow and elevation without the Long Lake Valley storage (denoted the No Action scenario in this report) differs from the actual gauged measurements during those years.

The U.S. Geological Survey (USGS) developed a hydrodynamic and heat transport model of UKL for the purposes of understanding the hydrodynamics of the lake and how the hydrodynamics affect water quality (Wood and others, 2008). This model can be used to explore, through experimentation with numerical tracers, passive transport through the lake under varying conditions of wind speed and direction, and varying inflows, outflows, and lake elevation. It is possible, therefore, to use this model to explore how the transport of sucker larvae might be affected by the construction of the LLV offstream storage, under the assumption that the larvae are transported passively through the system.

Purpose and Scope

This report describes a set of numerical experiments that are designed to explore the possibility that the LLV storage could affect the retention of larval fish in UKL. The results are exploratory in the sense that they are designed to determine, for a reasonable range of conditions, whether it is likely that the project will have a large effect on larval sucker transport and, if so, whether further, more rigorous study of the problem is warranted. This study has not attempted to consider all the possible extremes in conditions, but rather a manageable range in both wind forcing and basin hydrology as described below.

The appraisal study of LLV identified three possible locations for pumping facilities. In the model runs presented here, only the location in Howard Bay (fig. 1) is considered. Because all of the proposed sites are located in the southern end of the lake, the differences in the results would be small except for locations in Howard Bay and south of Buck Island, so it was considered more important for this exploratory work, and given the time constraints of this study, to use the model runs to determine possible differences in outcome based on a range in basin hydrology and wind forcing. The appraisal study also evaluated several scenarios for the amount of storage in LLV and the maximum capacity of the pumps. The model simulations discussed in this report used only the WRIMS results for the scenario in which it was assumed that the storage in LLV would be 500,000 acre-ft (6.2×10^8 m^3), and the maximum pump capacity would be 2,000 ft^3/s (57 m^3/s).The scope of this work is limited to the assumption that the sucker larvae travel passively in the current and that there are no other loss terms.

Design of Numerical Experiments

A 1-layer version of the UnTRIM hydrodynamic model of the lake described in Wood and others (2008) was used in order to speed computation time. The use of a 1-layer model removes the effects of water temperature (and therefore density) on the flow. These effects are important for understanding the transport of some water quality constituents, particularly dissolved oxygen and buoyant cyanobacteria (Wood and others, 2006; Wood and others, 2008). In this case, because it is assumed that larvae are transported passively, and that thermal stratification of the water column would not affect their vertical distribution, the benefit of being able to run many more simulations in the available time outweighs the loss of accuracy that occurs by using a 1-layer model.

The numerical grid has been further modified from that described in Wood and others (2008) to represent the Tulana Farms portion of the Williamson River delta that was reconnected to the lake when the levees around the delta were breached in October 2007 (fig. 1). Thus the configuration of the Upper Klamath Lake and Agency system in the hydrodynamic model reflects current rather than past conditions, but it is based on design elevations at the remaining levees around the delta. In the process of implementing the reconnection of the delta, those remaining levees were lowered even though the design of the project had called for them to remain unaltered. There is some inaccuracy, therefore, in the simulation of the connection between the Williamson River, the delta, and Agency Lake at elevations above approximately 4,140.5 ft, as that is the nominal elevation of the remaining levees (Heather Hendrixson, The Nature Conservancy, written commun., 2009).

A challenge of this study was to be able to run the hydrodynamic model of Upper Klamath Lake under past conditions of inflow, outflow, and lake elevation as simulated by the WRIMS model during years for which the wind data needed to force the model are not available. Early spring wind data to force the model have been collected around the lake since 2006, but the basin hydrology as simulated by the WRIMS model for the Long Lake Valley appraisal study considered years dating back to 1961. All of the years that were of most interest in terms of the effects of installing the project on the basin hydrology were prior to 2005. In order to deal with this mismatch between the availability of wind data to force the model and the basin hydrology, a strategy was adopted to decouple the wind forcing from the basin hydrology; that is, the wind data used to force the model was taken from the data available since 2006, and the basin hydrology (Williamson River inflow, Link River and A Canal outflow, and lake elevation) was taken from the WRIMS modeling effort. Six scenarios of basin hydrology and two scenarios of wind forcing were selected. In all cases, the time period of the model runs was between May 8 and June 30, in order to capture the period during which larval suckers are expected to enter the lake (Ellsworth and others, 2008; Ellsworth and others, 2009).

Numerical tracers were used to simulate the passive drift of the larvae. These numerical tracers are the numerical analogue of a dye tracer experiment. They are “injected” into the modeled system at the Williamson River boundary and at locations representing springs where spawning takes place along the eastern shoreline. The numerical tracers used in these simulations represent passive (no behavior) and conservative (no sources or sinks) drift. The transport of these tracers through the system also depends on the boundary conditions. Because of the limitations inherent in assuming passive and conservative drift, and because the determination of how many larvae are actually entering the system (a boundary condition) is inexact, the results of the simulations are expressed in relative terms rather than in terms of actual numbers of larvae.

Wind-Forcing Scenarios

The wind-forcing functions for the model were constructed from data collected between May 8 and June 30 of 2006 and 2007. The wind over the lake is interpolated from the values at six meteorological stations on and around the lake (fig. 1) as described in Wood and others (2008). Data have been collected from these six stations since 2005, but are available for early May only since 2006. Because the time constraints of the study limited the number of model runs, the number of unique wind-forcing scenarios was limited to two. These 2 years had contrasting conditions: there was a strong reversal of winds from their prevailing direction for several days during May 20–24 and June 2–4 of 2006, whereas May and June of 2007 were characterized by moderate winds primarily from the northwest (fig. 2).

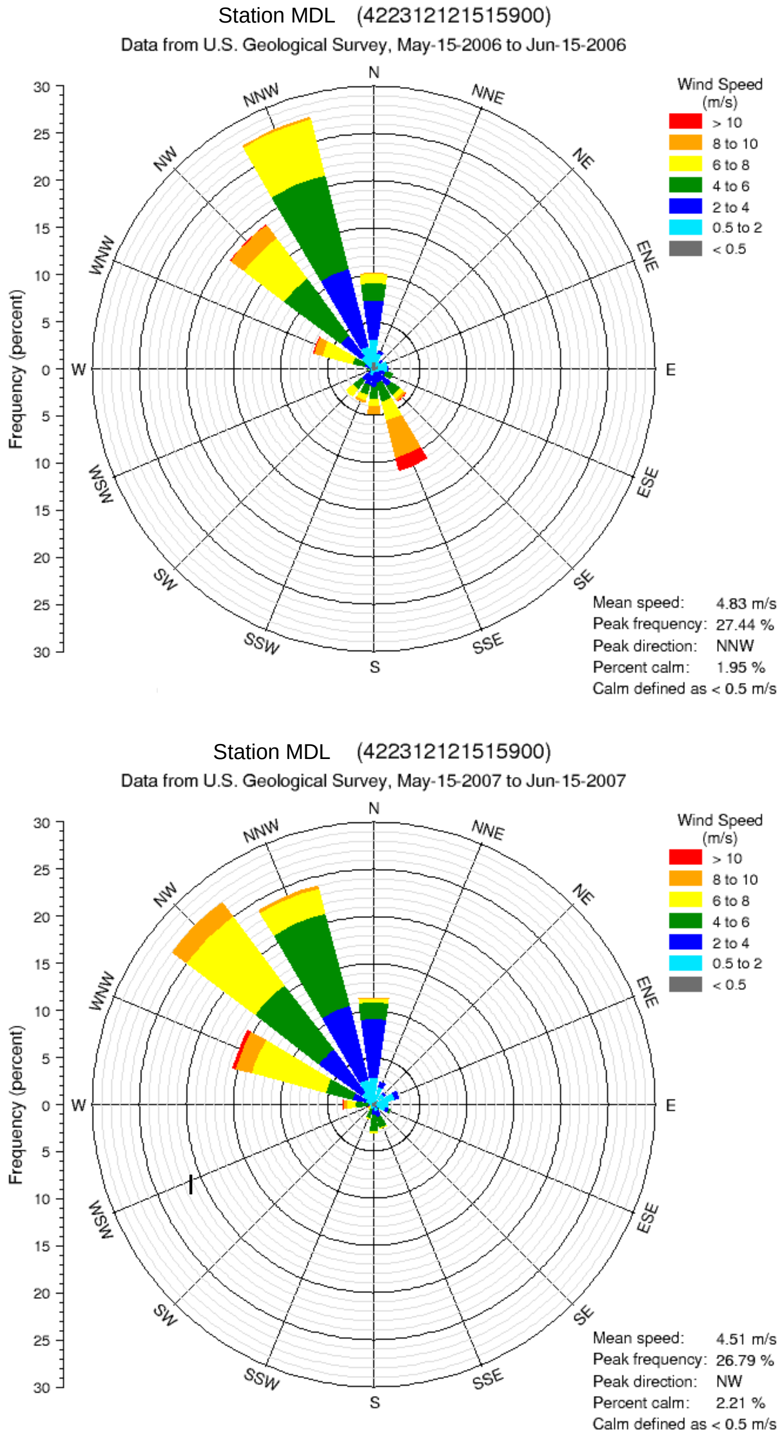

Figure 2. Distribution of wind direction and speed at site MDL, Upper Klamath Lake, Oregon, May 16–June 15, 2006 and 2007.

Basin Hydrology and Pumping Scenarios

The basin hydrology used in the model runs (outflows from the lake and lake elevation) was based on the hydrologic modeling of the Klamath Project operations that was done for the appraisal level study of the LLV project using the Water Resources Integrated Modeling System (WRIMS, Nancy Parker, Bureau of Reclamation, written commun., 2009). The WRIMS study produced, on a twice-monthly basis from March through July, and on a monthly basis otherwise, values for pumping between UKL and LLV, values for the outflows from UKL at A canal and the Link River, and lake elevation. The model was run between 1961 and 2006 under the assumption of No Action and under the assumption that the LLV project had been in place since 1961. From these 46 years of model results, 6 years were chosen to use as input to the UKL hydrodynamic model (table 1) because they represented a range in conditions, as follows:

- In 1991 the increase in the total outflow (the sum of A Canal and the Link River) from the lake during May 16–June 15 with the LLV project in place was the greatest compared to that under the No Action scenario.
- In 1995 the decrease in the outflow from the lake was the greatest compared to that under the No Action scenario (fig. 3).
- The year 1992 was characterized by both the lowest total outflow from the lake and the lowest lake elevation, both with the LLV project in place and under the No Action scenario (figs. 3 and 4).
- The year 1983 was characterized by both the highest total outflow from the lake and the highest lake elevation, both with the LLV project in place and under the No Action scenario (figs. 3 and 4).
- The year 1985 was one of 13 years that were characterized by the maximum amount of pumping from LLV to UKL (15,320 acre-ft or 19×10^6 m^3) during May 16–June 15 and at the same time was characterized by the largest decline in lake elevation with the project in place compared to that under the No Action scenario (fig. 4).
- The year 1989 was characterized by the maximum pumping from UKL to LLV (4,850 acre-feet or 6×10^6 m^3) during May 16–June 15 out of all 46 years of WRIMS simulation.

In general, the period of interest between mid-May and mid-June is not the time when the most transfer of water would be expected, either from LLV to UKL or from UKL to LLV. Pumping to fill LLV is most likely to occur in the early spring prior to the period when the larval drift starts, and pumping from LLV into UKL is most likely to occur in the late summer and fall.

Table 1. Basin hydrology characteristics determined by the Water Resources Integrated Modeling System, Upper Klamath Lake, Oregon, for May 16–June 15 with the Long Lake Valley project and with No Action for 6 years selected for model scenarios. [taf=thousands of acre-feet; ft=feet]

		No Action		With LLV Project			
Year	Williamson River Inflow (taf)	Lake Elevation (ft)	Outflow (Link River plus A Canal) (taf)	Lake Elevation (ft)	Outflow (Link River plus A Canal) (taf)	Pump From LLV to UKL (taf)	Pump From UKL to LLV (taf)
1983	200.91	4,143.17	227.92	4,143.16	227.4	0	0.52
1985	91.62	4,142.89	161.32	4,142.45	173.13	15.32	0
1989	107.12	4,143.04	151.98	4,142.99	151.72	0	4.85
1991	52.87	4,141.26	102.42	4142.50	136.76	10.32	0
1992	15.60	4,138.43	68.28	4,140.62	68.28	0	0
1995	126.52	4,143.14	153.78	4,142.98	139.56	0	0

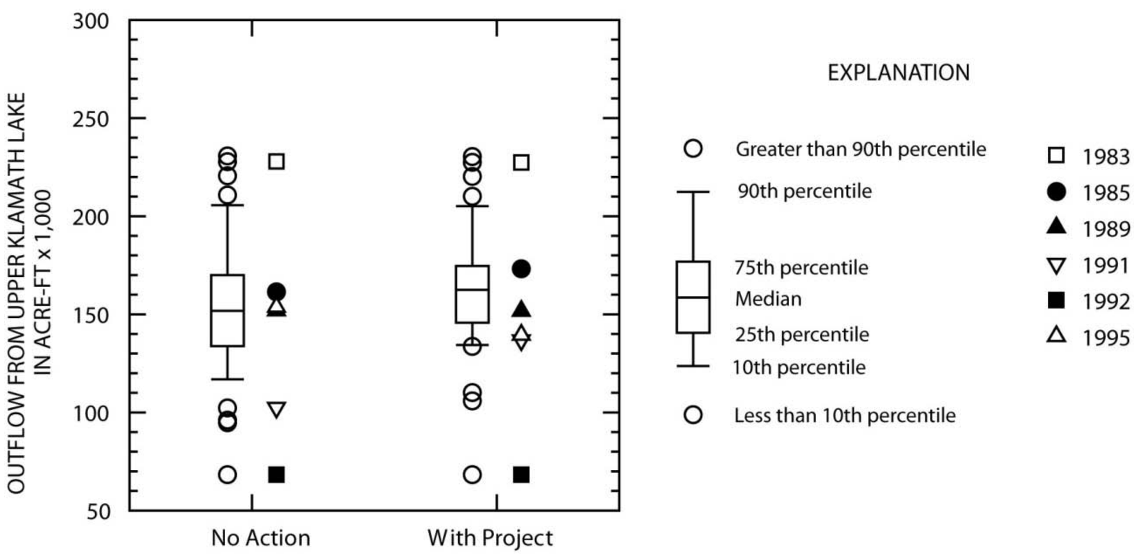

Figure 3. Simulated outflow from Upper Klamath Lake, Oregon, (Link River and A Canal combined), May 16–June 15, 1961–2006 (left) and for the individual years shown (right). Values were determined using the Water Resources Integrated Modeling System with the proposed offstream Long Lake Valley storage (With Project) and without (No Action).

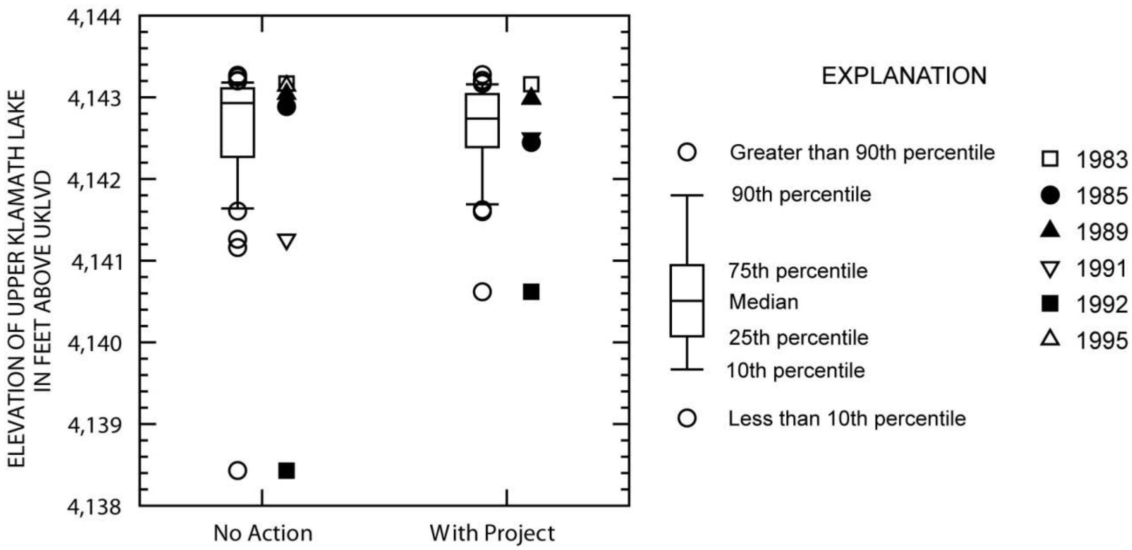

Figure 4. Simulated elevation of Upper Klamath Lake, Oregon, May 16–June 15, 1961–2006 (left) and for the individual years shown (right). Values were determined using the Water Resources Integrated Modeling System with the proposed offstream Long Lake Valley storage (With Project) and without (No Action). UKLVD, Upper Klamath Lake Vertical Datum.

Because of the discrepancy between the monthly or twice-monthly time step used by WRIMS and the 2-minute time step used in the UnTRIM model, output of the WRIMS model was converted to a daily time step, which is the normal resolution for inflows to the model. The lake elevation was linearly interpolated to a daily time step by assigning the WRIMS value to the midpoint of the monthly or 2-week time step. Volume outflows (A Canal and Link River) were first converted to discharge by dividing by the length of the time step and then linearly interpolating to a daily time step by assigning the resulting discharge value to the midpoint of the monthly or 2-week time step. An example of the resulting lake elevation and daily mean outflow discharge is provided in figure 5. Pumping operations were first converted from volume to discharge by dividing by the length of the time step and then spread evenly over each day of the time step. Inflow at the Williamson River would not be managed under project operations, so daily mean data from USGS gaging station 11502500 was used as the inflow at the Williamson River for both the No Action scenarios and the scenarios with the LLV project in place to preserve the true variability at that boundary.

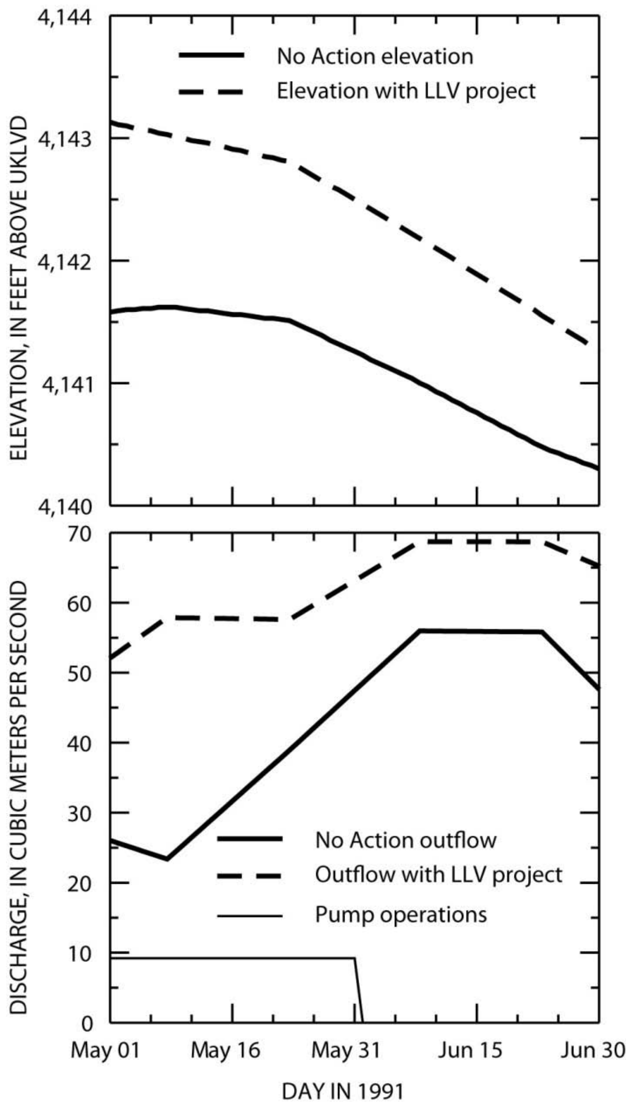

Figure 5. Daily mean values of lake elevation and discharge used in the hydrodynamic model simulations with the Long Lake Valley (LLV) offstream storage (With Project) and without (No Action), May 1–June 30, 1991, Upper Klamath Lake, Oregon. UKLVD, Upper Klamath Lake Vertical Datum.

Larval Sucker Scenarios

Williamson and Sprague River Spawners

A challenge in designing the numerical experiments was to develop boundary conditions for the numerical tracers that would provide a valid representation of larval drift down the Williamson River through time (which is highly variable from year to year) given that measurements of larval drift are available only since 2004 (Ellsworth and others, 2008; Ellsworth and others, 2009). In the absence of definitive rules for how the timing of drift varies with other quantifiable variables such as air temperature or Williamson River discharge, it was decided that the quantitative comparison between the various model runs would be most meaningful if the timing of the input at the Williamson River was kept the same for all of the simulations. Data collected since 2004 show that the drift of sucker larvae into Upper Klamath Lake from the Williamson River usually occurs between late April and mid-June in two distinct peaks, the first of which is dominated by Lost River suckers and the second of which is dominated by shortnose suckers (Ellsworth and others, 2008; Ellsworth and others, 2009). For example, in 2006 the first peak, dominated by Lost River suckers, occurred on May 17, and the second, dominated by shortnose suckers, occurred on June 9 (Ellsworth and others, 2009, table 4).

The second aspect of the boundary conditions that had to be determined was the peak concentration. Again, lacking rules for how the number of larvae in the drift vary from year to year based on other measurable variables, it was decided that to facilitate comparisons between model simulations and between tracers in the same simulation, the most straightforward approach would be to set the concentration of each tracer such that the same amount of each tracer (number of larvae) would always be put into the model system. That number was estimated from 2006 Lost River sucker drift data as follows: The mean larval concentration of 1.7 larvae per cubic meter was assumed to apply for 4 hours every day between 4 and 8 hours after sunset for the 36 days from May 15 through June 20 (values determined from various figures and tables in Ellsworth and others, 2009). During this same period, the average discharge through the Williamson River as measured at USGS gage 11502500 was 42.2 m^3/s. Multiplying the mean larval concentration by the average discharge results in an estimate of 3.7×10^7 Lost River sucker larvae passing by the

Modoc Point Road bridge. This number was rounded up to 10^8, which provided a convenient number to work with as it produced concentrations at the boundary in the range of 0–10. These numbers are not intended to be accurate predictions of the number of larvae entering Upper Klamath Lake, for at least two reasons. First, the larval densities measured by Ellsworth and others (2009) were collected near the surface at the thalweg, where densities were known to be greatest (Tyler and others, 2004), and therefore the concentration applied to the entire discharge should be lower. Second, no account is taken of any loss terms due to predation between the Modoc Point Road bridge and Upper Klamath Lake.

Two numerical tracers were used to simulate populations spawning in the Williamson and Sprague Rivers. An example of how the source concentration of these tracers varied in time between May 8 and June 30 for one basin-hydrology year (1991) is provided in fig. 6. Each tracer was put into the Upper Klamath Lake model in the form of a normal curve in time. The concentration of the first tracer peaked on May 20 and represented the first peak of larvae entering Upper Klamath Lake by way of the Williamson River, dominated by Lost River suckers. The second tracer peaked on June 7 and represented the second peak of larvae entering Upper Klamath Lake from the Williamson River, dominated by shortnose suckers. Thus 80 percent of tracer 1 is put into the system by May 22, and 80 percent of tracer 2 is put into the system by June 9; these dates match approximately the dates for 80 percent of the measured input of Lost River and shortnose larvae, respectively, in 2006 (Ellsworth and others, 2009; fig. 3). The timing of these peaks was the same for every basin-hydrology year. The peak concentration of each tracer, however, was unique in each basin-hydrology year and was calculated so as to always result in a total of each tracer of 10^8 larvae entering Upper Klamath Lake with the Williamson River flow during the course of the simulation (fig. 6).

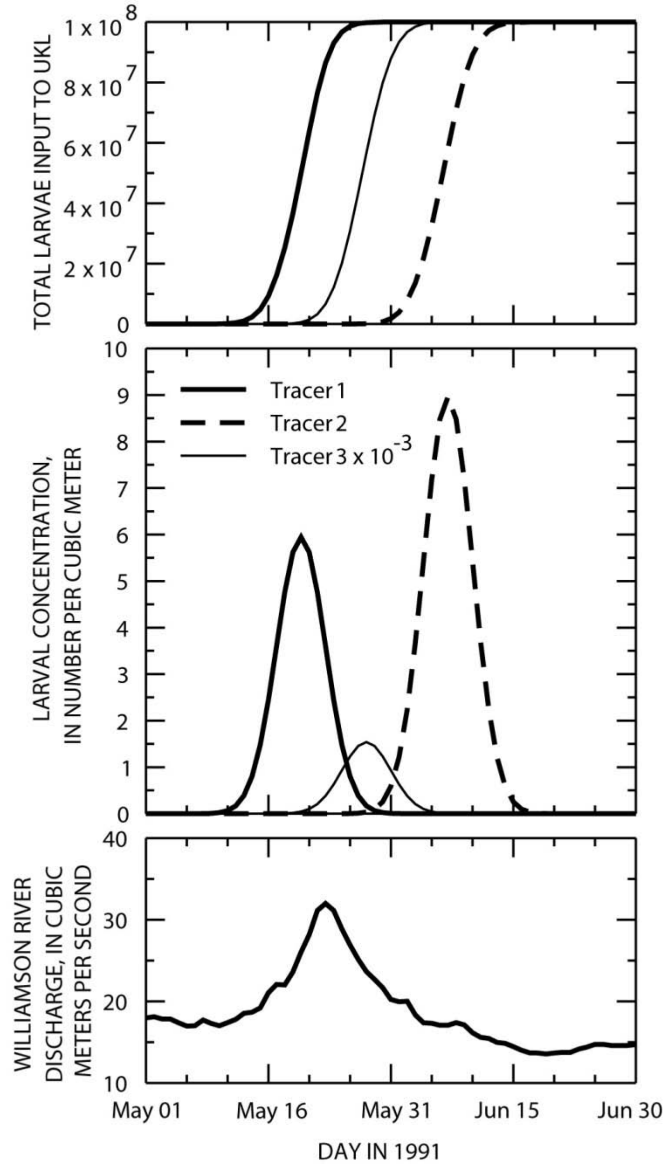

Figure 6. Williamson River discharge, concentration of three tracers used in the hydrodynamic model simulations, and the accumulated amount of each tracer entering the model system from May 1 through June 30, 1991, Upper Klamath Lake basin, Oregon. The concentration of tracer 3 has been divided by 1,000 in order to appear on the same scale as tracers 1 and 2. UKL, Upper Klamath Lake.

Shoreline Springs Spawners

A third tracer was used to represent the swim-up (the process of leaving the sediments and becoming entrained in the currents) of larvae from five shoreline spring locations (fig. 1). Lost River sucker larvae typically are abundant at the shoreline springs between early April and late May, whereas shortnose suckers are scarce at the shoreline springs (Alex Wilkins, Bureau of Reclamation, written commun., 2009). Therefore only one tracer was used to represent swim-up from the shoreline springs. This tracer peaked on May 28 and was input into the model using a very small discharge that would not affect the water mass balance. The concentration of this tracer was the same in every basin-hydrology year and like the other two tracers was calculated so as to result in a total of tracer 3 of 10^8 larvae entering Upper Klamath Lake during the course of the simulation (fig. 6). Few data are available on which to base an estimate of the number of larvae originating at the springs, so the value of 10^8 is arbitrary and was chosen only for consistency with the other two tracers.

Results

The amount of each of the three tracers (representing numbers of larvae) in the entire UKL and Agency Lake system for the scenario represented by each combination of basin hydrology and wind forcing is shown in figure 7 as the percent difference between the scenario with the LLV project in place and with No Action. The differences shown in the figure are calculated for each tracer at 20 days after the peak input (June 9 for tracer 1, June 27 for tracer 2, and June 16 for tracer 3). Negative percent differences indicate that at 20 days after the peak input of tracer, there were fewer larvae in the entire model system in the simulation with the LLV project in place than in the No Action simulation using the same hydrology and meteorology. Positive percent differences indicate that at 20 days after the peak input of tracer there were more larvae in the entire model system in the simulation with the LLV project in place than in the No Action simulation using the same hydrology and meteorology. Negative differences result when the larvae move through the lake and out at either the Link River or A Canal faster with the LLV project in place or are captured in the pumped discharge to LLV. Positive differences result when the larvae move through the lake and out at either the Link River or A Canal slower with the LLV project in place.

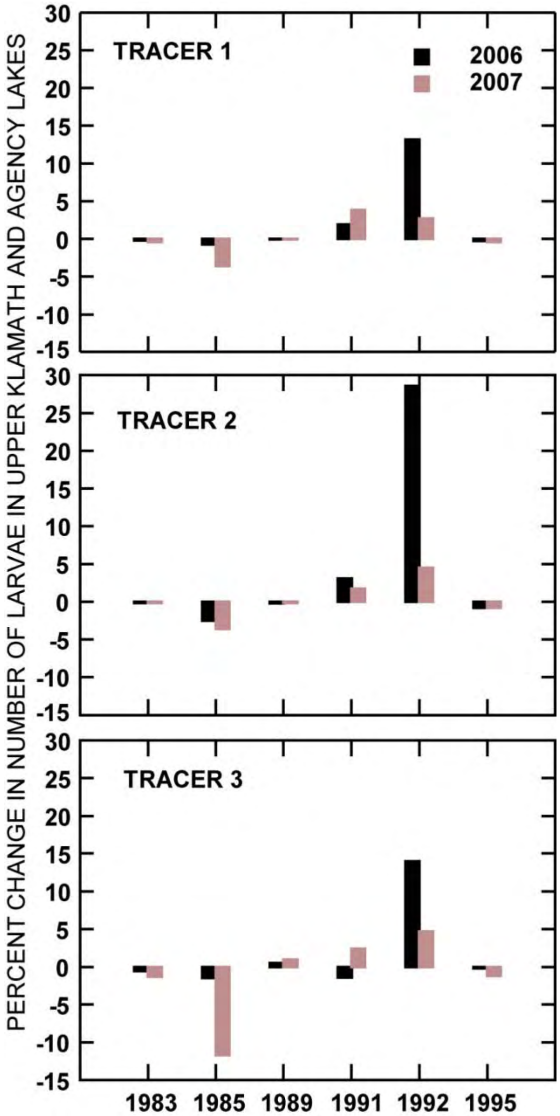

Figure 7. Percent difference in the amount of each tracer in the Upper Klamath Lake, Oregon, model system compared to the No Action scenario 20 days after the peak concentration in the boundary inflow for each tracer. The percent difference is calculated for each combination of basin hydrology and wind forcing.

The data used to produce the graphs in figure 7 are also presented in table form in column 1A of table 2 and are converted to a fraction of the total amount of each tracer input to the modeled system (10^8 larvae) in column 1B. Three years—1983, 1989, and 1995—show small differences, indicating that the operation of the LLV project would not have much effect under those basin hydrology conditions. The three remaining basin hydrology years—1985, 1991, and 1992—show larger differences due to the operation of the LLV project. The 6 years can be summarized in more detail as follows:

- The percent difference is small and negative for 1983 (rows 1, 2, 13, 14, 25 and 26 of table 2), the year characterized by the highest lake elevation and outflow.
- The percent difference is small for 1995 (rows 11, 12, 23, 24, 35 and 36 of table 2), the year characterized by the largest decrease in outflow with the LLV project in place.
- The percent difference is small but positive or negative (between –0.2 percent and 1.0 percent) for 1989 (rows 5, 6, 17, 18, 29 and 30 of table 2), the year characterized by the maximum pumping from UKL to LLV.
- There were large negative differences (as much as –11.7 percent) for 1985 hydrology (rows 3, 4, 15, 16, 27 and 28 of table 2), the year characterized by the maximum pumping from LLV to UKL and the largest decline in lake elevation compared to the No Action scenario.
- Large positive differences (as much as 28.6 percent) were found for 1992 hydrology (rows 9, 10, 21, 22, 33, and 34 of table 2), the year characterized by the lowest lake elevation and lowest outflow.
- The percent differences for 1991 hydrology (rows 7, 8, 19, 20, 31, and 32 of table 2), the year characterized by the largest increase in outflow with the LLV project in place, ranged between –1.4 percent and +3.8 percent, being positive for the two tracers originating in the Williamson River and positive or negative for the tracer originating at the shoreline springs, depending on the wind forcing used.

Further temporal and spatial detail regarding the model results are provided in table 2 in columns 2A/B–5A/B.

Table 2. Change in the number of larvae in four areas of Upper Klamath Lake, Oregon, and in all areas combined, with the Long Lake Valley project in place relative to a No Action scenario for six hydrology scenarios and two wind-forcing scenarios; values were calculated 20 days after the peak input of the tracer into the model system.

["A" columns indicate the percent change in value from No Action, calculated as $100*(N_{wp}-N_{na})/N_{na}$; "B" columns indicate the change as a fraction of the total number of larvae put into the system, calculated as $(N_{wp}-N_{na})/10^8$. N_{wp}=number of larvae in the scenario with the Long Lake Valley project in place; N_{na}=number of larvae in the No Action scenario. %, percent. Exponents are expressed as "E" followed by the power of 10; for example, -1.9E-03 is -1.9×10^{-3}]

	Scenario		All areas		North Lake		South Lake		Williamson River Delta		Agency Lake	
Row	Basin Hydro-logy	Wind Forcing	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
TRACER 1												
1	1983	2006	-0.2%	-1.9E-03	-0.2%	-3.0E-04	-0.3%	-2.7E-04	-0.2%	-2.0E-05	-0.4%	-5.0E-04
2	1983	2007	-0.4%	-2.7E-03	-0.4%	-6.0E-04	-0.7%	-4.8E-04	-0.4%	-5.0E-05	-0.9%	-4.2E-04
3	1985	2006	-0.7%	-6.6E-03	0.2%	3.0E-04	3.7%	4.1E-03	11.3%	6.7E-03	-14.7%	-3.0E-02
4	1985	2007	-3.6%	-3.0E-02	-4.1%	-7.7E-03	-6.2%	-6.7E-03	8.2%	4.1E-03	8.6%	6.2E-03
5	1989	2006	0.0%	0.0E+00	1.0%	1.7E-03	0.8%	8.0E-04	-1.2%	-7.2E-04	-3.4%	-7.0E-03
6	1989	2007	-0.1%	-5.0E-04	0.8%	1.4E-03	-0.7%	-7.0E-04	-1.2%	-6.4E-04	-4.4%	-3.7E-03
7	1991	2006	1.9%	1.8E-02	-7.4%	-1.1E-02	-10.7%	-1.3E-02	20.5%	1.8E-02	56.3%	8.8E-02
8	1991	2007	3.8%	3.2E-02	0.7%	1.3E-03	7.8%	8.0E-03	15.6%	1.0E-02	27.6%	2.1E-02
9	1992	2006	13.2%	1.1E-01	-24.0%	-4.7E-02	30.2%	2.5E-02	234.0%	9.1E-02	735.1%	1.5E-01
10	1992	2007	2.7%	1.8E-02	4.3%	7.2E-03	1.9%	9.6E-04	0.7%	1.4E-05	16.6%	5.1E-07
11	1995	2006	-0.3%	-2.5E-03	1.0%	1.7E-03	1.1%	1.2E-03	-1.6%	-8.2E-04	-5.7%	-1.2E-02
12	1995	2007	-0.4%	-3.6E-03	-0.3%	-5.0E-04	-1.3%	-1.5E-03	2.1%	9.2E-04	-1.6%	-1.3E-03
TRACER 2												
13	1983	2006	-0.2%	-1.4E-03	-0.2%	-4.0E-04	-0.5%	-4.1E-04	0.8%	1.8E-04	0.0%	1.0E-05
14	1983	2007	-0.2%	-1.2E-03	-0.2%	-3.0E-04	-0.4%	-3.5E-04	0.7%	1.3E-04	-0.3%	-1.0E-04
15	1985	2006	-2.5%	-2.2E-02	-0.2%	-3.0E-04	-5.1%	-5.5E-03	-8.6%	-7.5E-03	-11.1%	-8.1E-03
16	1985	2007	-3.6%	-3.1E-02	-2.1%	-3.7E-03	-4.7%	-5.0E-03	-9.3%	-6.2E-03	-10.0%	-7.3E-03
17	1989	2006	-0.2%	-2.0E-03	0.2%	4.0E-04	-0.7%	-8.0E-04	-0.2%	-2.2E-04	-1.6%	-1.3E-03
18	1989	2007	-0.2%	-1.7E-03	0.0%	0.0E+00	-0.7%	-8.0E-04	-0.6%	-4.5E-04	-0.3%	-2.4E-04
19	1991	2006	3.1%	2.6E-02	0.1%	2.0E-04	8.6%	8.2E-03	7.6%	8.7E-03	31.1%	1.8E-02
20	1991	2007	1.7%	1.4E-02	0.9%	1.5E-03	11.7%	1.1E-02	0.4%	3.2E-04	18.0%	1.1E-02
21	1992	2006	28.6%	1.9E-01	16.8%	2.4E-02	70.1%	3.3E-02	12497.6%	1.1E-01	247699.0%	4.4E-02
22	1992	2007	4.5%	3.0E-02	8.9%	1.3E-02	4.9%	2.5E-03	618.8%	1.1E-04	1420.3%	2.9E-07
23	1995	2006	-0.8%	-7.5E-03	1.0%	1.6E-03	-1.1%	-1.3E-03	-1.1%	-7.3E-04	-8.7%	-7.6E-03
24	1995	2007	-0.8%	-7.0E-03	0.2%	3.0E-04	-2.4%	-2.7E-03	-4.0%	-2.3E-03	-3.7%	-2.9E-03
TRACER 3												
25	1983	2006	-0.6%	-2.8E-03	-0.6%	-9.0E-04	-0.6%	-2.6E-04	-1.8%	-1.3E-05	-1.8%	-8.1E-07
26	1983	2007	-1.3%	-3.8E-03	-1.3%	-1.1E-03	-1.4%	-3.4E-04	-2.2%	-6.2E-06	-2.4%	-4.8E-07
27	1985	2006	-1.5%	-1.0E-02	-1.3%	-2.6E-03	-3.1%	-1.7E-03	-20.0%	-8.1E-04	-20.3%	-1.1E-04
28	1985	2007	-11.7%	-6.3E-02	-10.2%	-1.6E-02	-11.5%	-5.4E-03	-31.0%	-9.1E-04	-31.8%	-1.3E-04
29	1989	2006	0.5%	3.5E-03	0.5%	9.0E-04	0.3%	1.4E-04	-1.1%	-5.3E-05	-3.9%	-2.6E-05

Row	Scenario		All areas		North Lake		South Lake		Williamson River Delta		Agency Lake	
	Basin Hydro-logy	Wind Forcing	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
30	1989	2007	1.0%	5.4E-03	0.8%	1.3E-03	0.8%	3.7E-04	-0.7%	-2.3E-05	-1.3%	-6.7E-06
31	1991	2006	-1.4%	-9.8E-03	-0.9%	-1.8E-03	0.6%	3.5E-04	63.6%	1.9E-03	134.6%	4.0E-04
32	1991	2007	2.4%	1.2E-02	2.8%	4.0E-03	6.7%	2.8E-03	92.4%	1.7E-03	126.0%	2.9E-04
33	1992	2006	14.0%	9.2E-02	26.8%	4.6E-02	7.1%	3.9E-03	11016.2%	3.8E-03	6792.7%	3.8E-04
34	1992	2007	4.7%	2.4E-02	6.8%	8.6E-03	2.5%	1.0E-03	983.5%	4.6E-10	990.2%	2.0E-13
35	1995	2006	-0.2%	-1.4E-03	-0.1%	-2.0E-04	-0.7%	-3.9E-04	-8.1%	-3.5E-04	-9.3%	-5.3E-05
36	1995	2007	-1.2%	-6.8E-03	-1.2%	-2.0E-03	-2.0%	-1.0E-03	-10.1%	-3.3E-04	-10.0%	-4.1E-05

The total number of larvae in the system was calculated as a function of time in four subregions of the Upper Klamath Lake and Agency Lake model system (fig. 8). These results are presented in figures 9–14. In each graph, the information from a single model run is compared against the same conditions of wind forcing and basin hydrology under the No Action scenario. The differences among 1983, 1989, and 1995 are generally too small to be seen (figs. 9, 11, and 14), consistent with the small percent change in number of larvae for those years shown in table 2, column 1A.

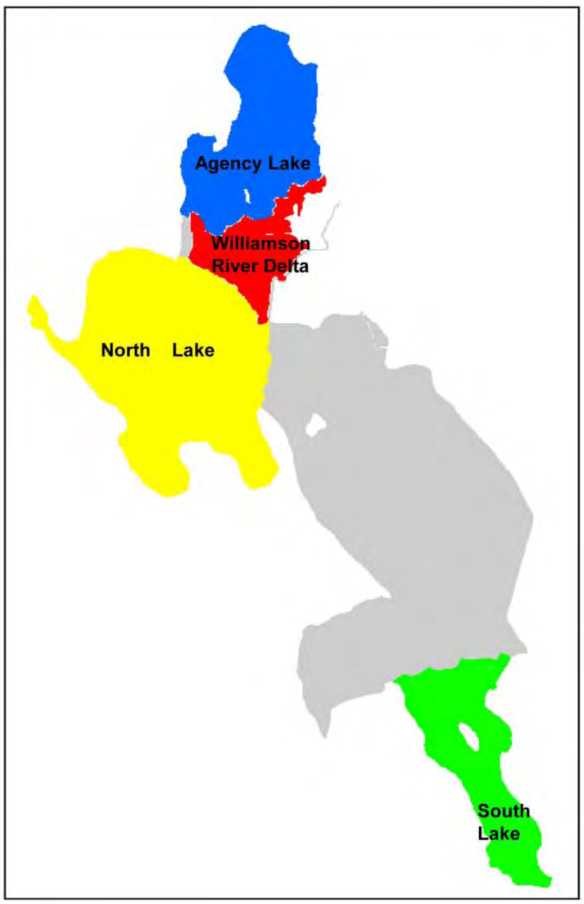

Figure 8. Four areas of Upper Klamath and Agency Lakes, Oregon, defined for the purposes of tracking the amount of each tracer in subareas of the model system.

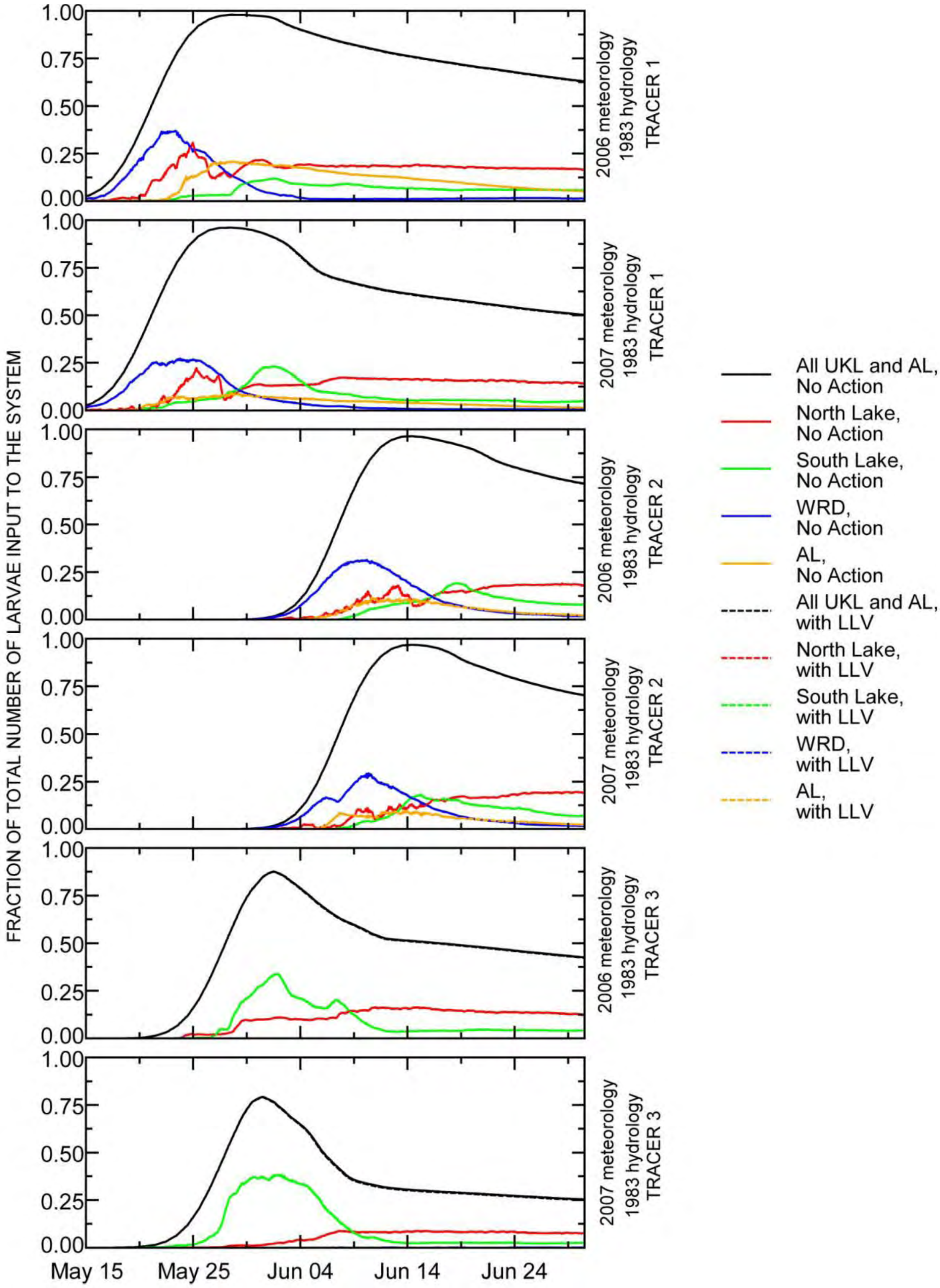

Figure 9. The fraction of larvae in the entire model system and in four subareas of the model system for all model runs that used the 1983 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

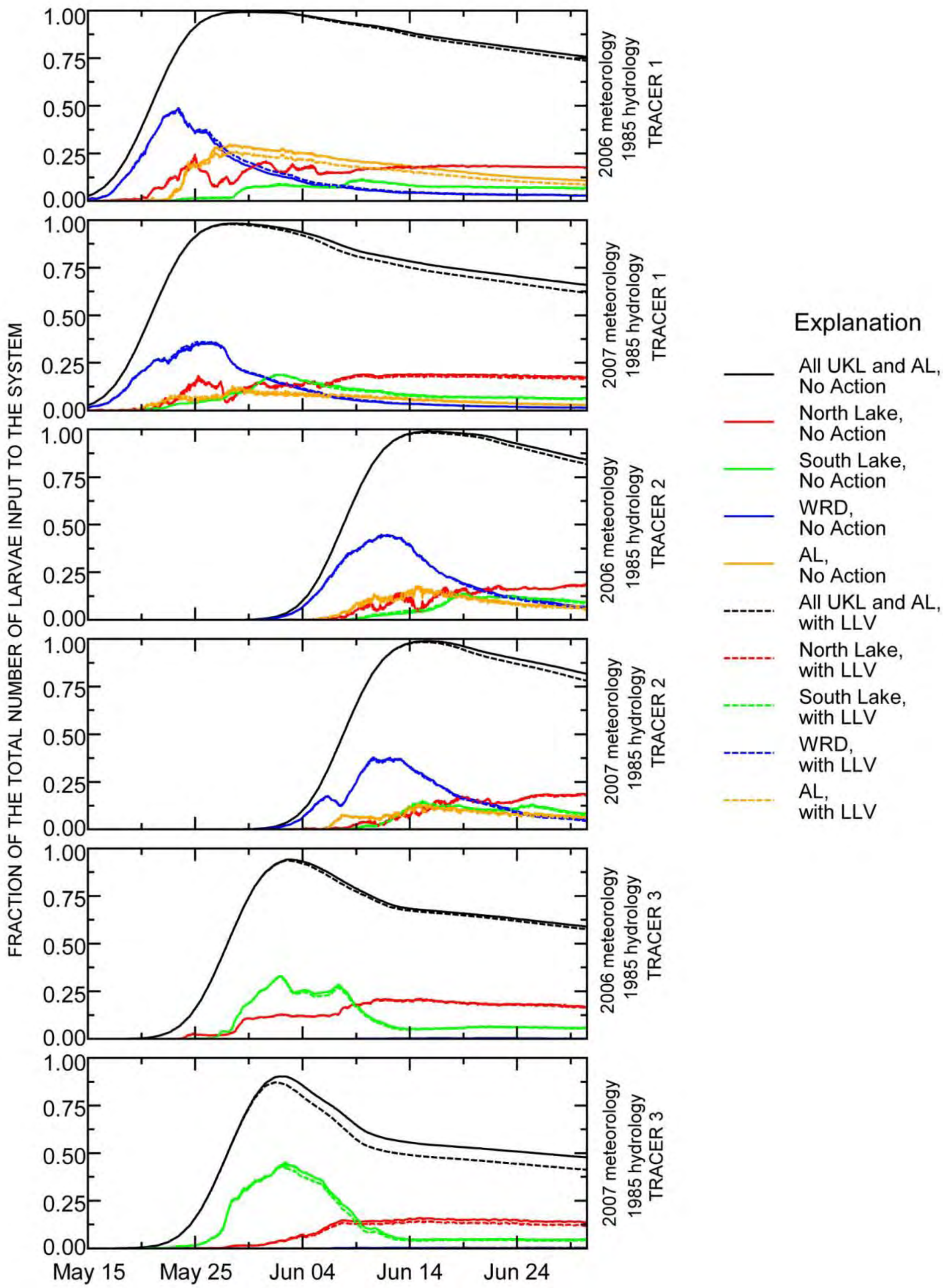

Figure 10. The fraction of larvae in the entire model system and in four subareas of the model system, for all model runs that used the 1985 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario, and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

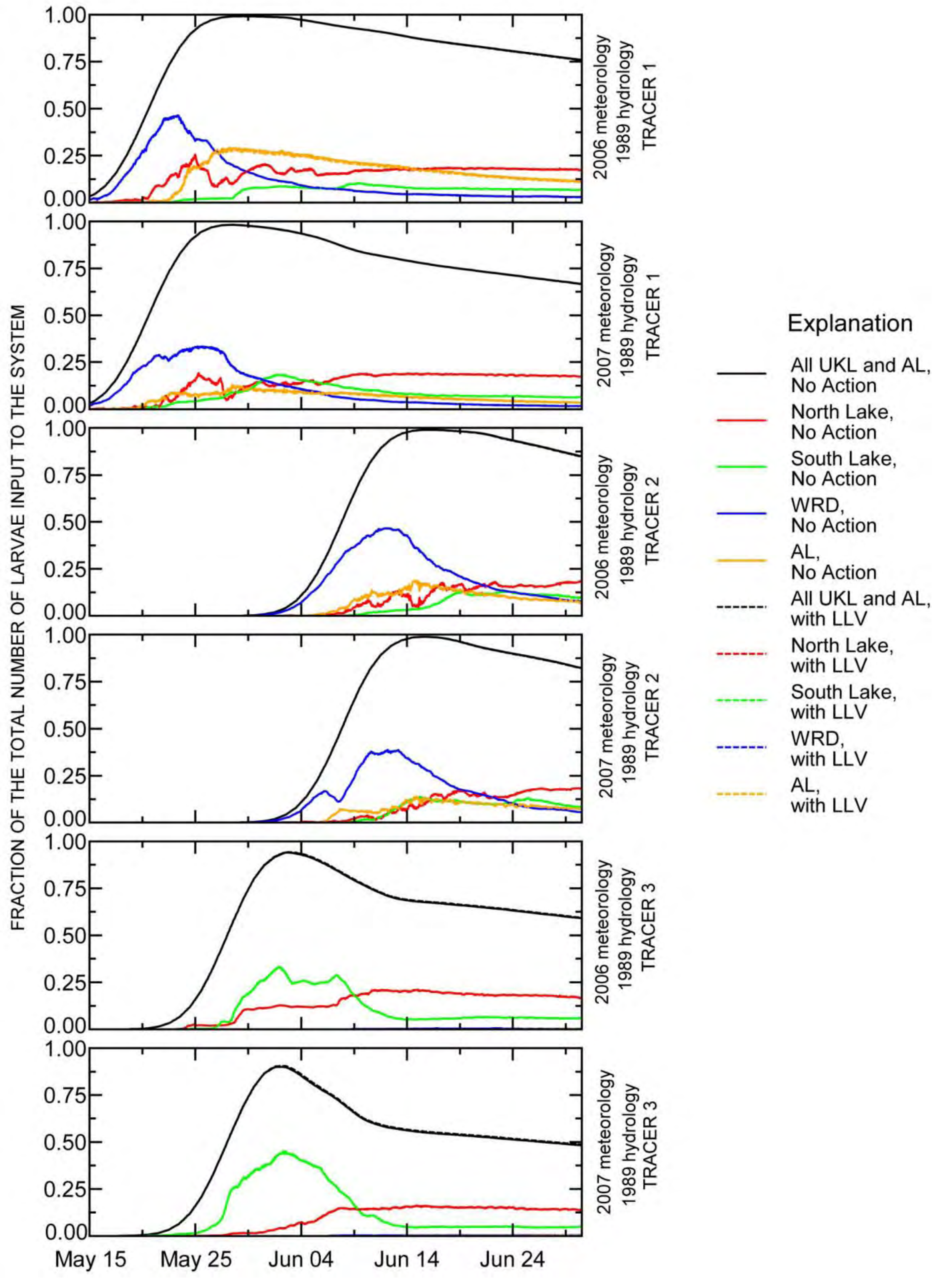

Figure 11. The fraction of larvae in the entire model system and in four subareas of the model system, for all model runs that used the 1989 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario, and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

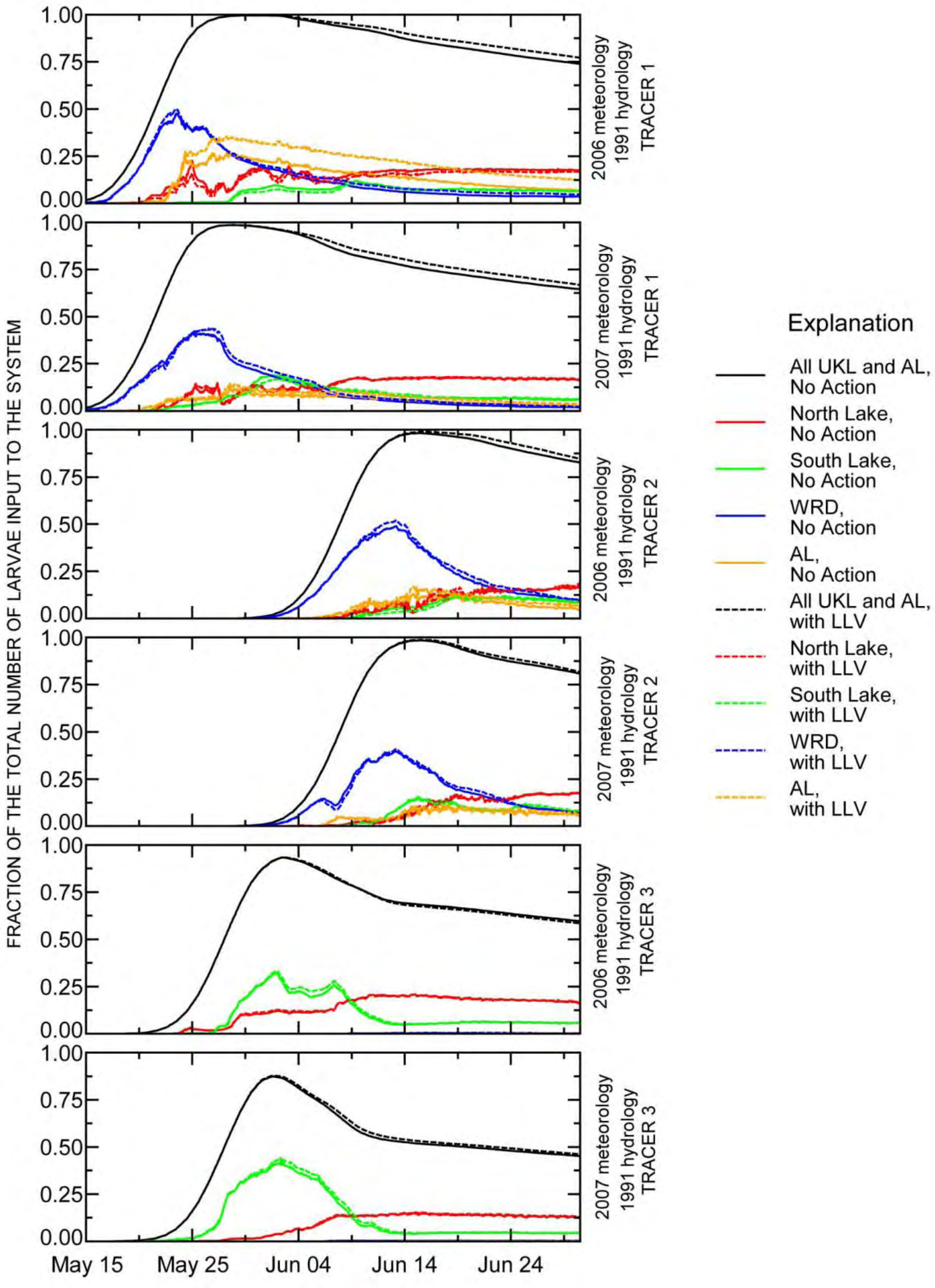

Figure 12. The fraction of larvae in the entire model system and in four subareas of the model system, for all model runs that used the 1991 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario, and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

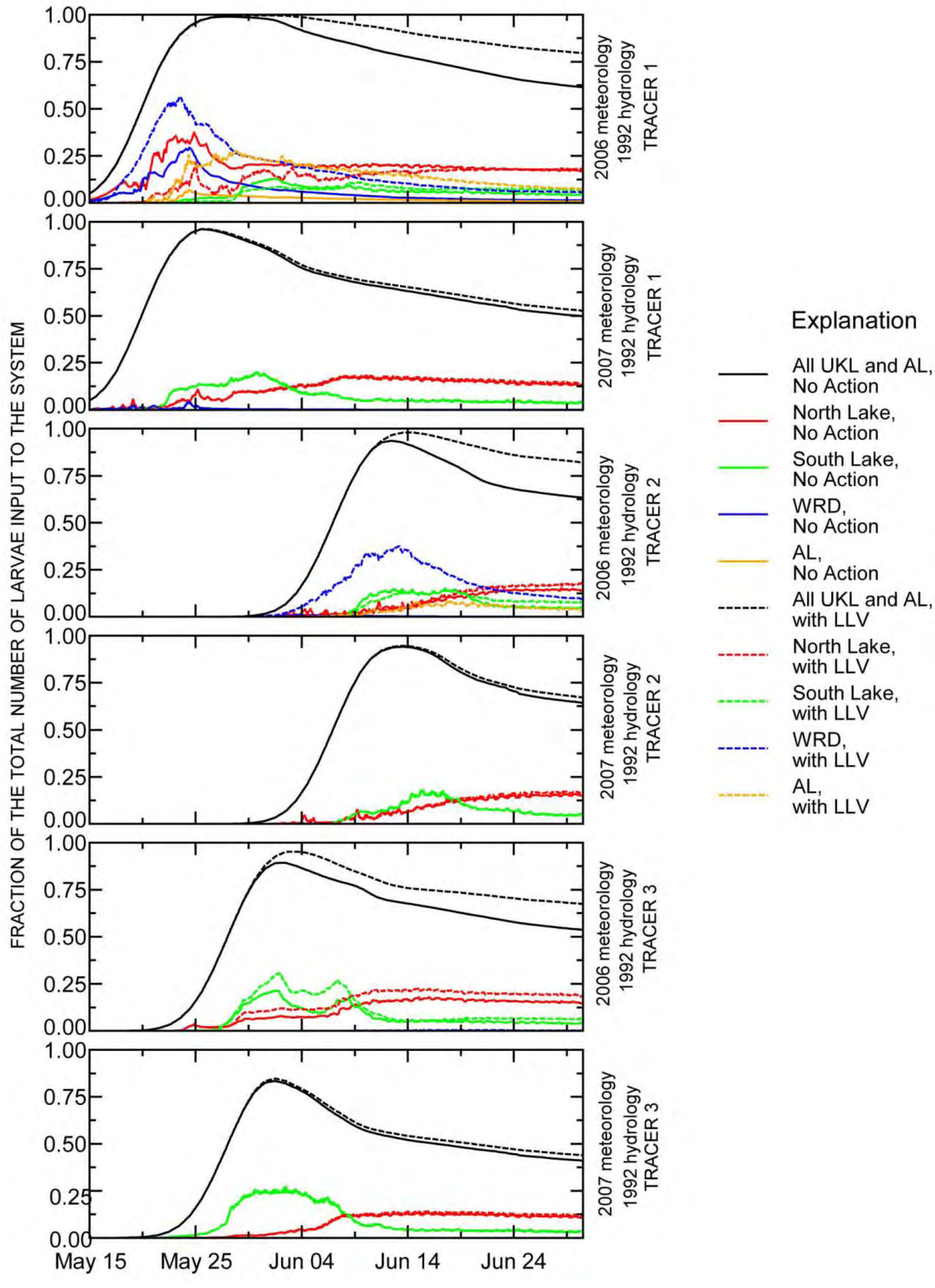

Figure 13. The fraction of larvae in the entire model system and in four subareas of the model system, for all model runs that used the 1992 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario, and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

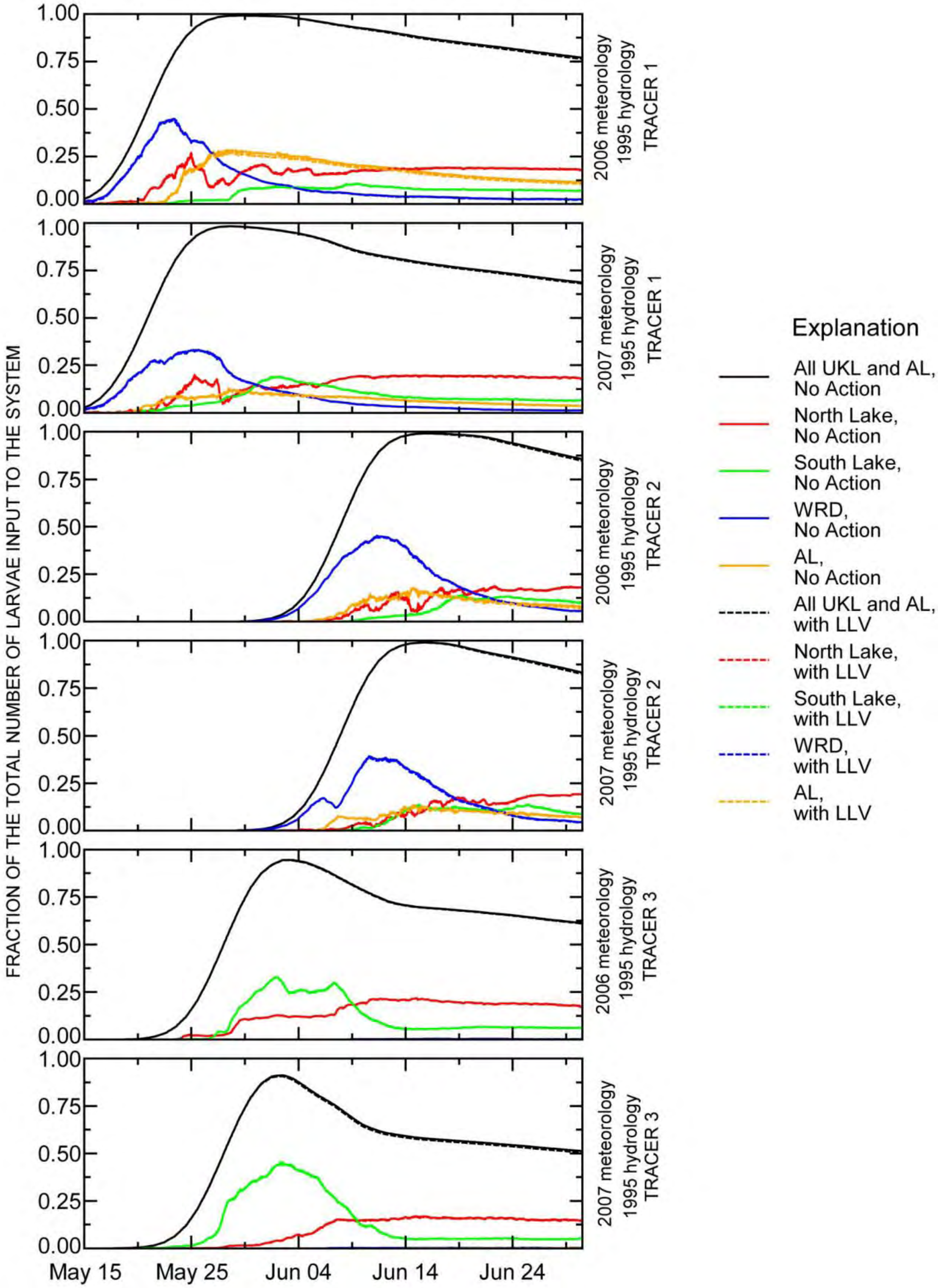

Figure 14. The fraction of larvae in the entire model system and in four subareas of the model system, for all model runs that used the 1995 hydrology for the Upper Klamath Lake basin, Oregon. In each panel, the fraction of larvae as a function of time is shown for both the No Action scenario, and the scenario with the LLV project in place. UKL, Upper Klamath Lake; AL, Agency Lake; WRD, Williamson River delta; LLV, Long Lake Valley.

The largest positive differences in 1991 and 1992 for tracers 1 and 2 originating in the Williamson River are in Agency Lake (table 2, rows 7–10 and 19–22, columns 5A/B), indicating that the operation of the LLV project resulted in more larvae passing through those areas, relative to the scenario without the project. Note that very large percent differences in the "A" column can result from a very small fraction of larvae in the "B" column, which is the case, for example, in the Williamson River delta and Agency Lake in 1992, when 2007 wind forcing was used (table 2, rows 10, 22, and 34, column 5B). The 1992 results show clear differences between 2006 and 2007 wind forcing, because the lake elevation in that year is so low that the connection between the Williamson River channel and the Delta is restricted. The wind reversals of 2006 are more effective at moving water northward from the Williamson River mouth into the Delta and into Agency Lake than the prevailing winds of 2007, which tend to move water from the mouth of the Williamson River southward along the eastern shoreline of the lake. The largest positive differences for tracer 3, which originates at the shoreline springs, are greatest in the northern part of the lake (figs. 12 and 13; table 2, rows 31–34, columns 2A/B) except in the case of 1991 hydrology and 2006 wind forcing, for which the largest positive difference is in the Williamson River delta, but overall the amount of tracer relative to No Action is less (table 2, row 31, columns 1A/B and 4A/B).

The largest negative differences in 1985 for tracers 1 and 2 originating in the Williamson River are greatest in Agency Lake or north lake (fig. 10; table 2, rows 3, 15 and 16, columns 5A/B, row 4, columns 2A/B); negative differences for tracer 3 are greatest in the north (table 2, rows 27 and 28, columns 2A/B). Negative differences for model runs using 1985 hydrology are greater when 2007 wind forcing was used compared to 2006 wind forcing.

Four animations at *http://or.water.usgs.gov/klamath/llv_movies.html* show the concentration of tracer 1 in the model system through time. The first animation, H1985_M2007_T1_noaction, shows the model simulation for 1985 basin hydrology and 2007 wind forcing (prevailing winds) under the No Action scenario, and H1985_M2007_T1_diff shows the difference between the model simulation with the LLV project in place (maximum pumping to UKL and largest lake elevation decline) and the No Action scenario. Similarly, H1985_M2006_T1_noaction shows the model simulation for 1985 basin hydrology and 2006 wind forcing (wind reversal between May 20 and 24 and again between June 2 and 4) under the No Action scenario, and H1985_M2006_T1_diff shows the difference between the model simulation with the LLV project in place and the No Action scenario. In these animations, relative changes in time are more meaningful than the value of larval concentration at any point in time or space because no predation or other loss terms have been included. (Note that very high and low static concentrations in the upper part of the Williamson River delta and in eastern Goose Bay, respectively, are artifacts of the plotting program and are not meaningful.)

Discussion and Conclusions

During spring, when larval suckers drift into Upper Klamath Lake through the Williamson River or swim up from the springs along the eastern shoreline, the direct pumping to and from the proposed Long Lake Valley storage is not likely to be the aspect of the project operations that most affects larval drift and residence time in the lake. Because most of the pumping to fill LLV is likely to occur in early spring before the larval drift starts, and because most of the pumping into UKL from LLV is likely to occur in the late summer and fall, pumping velocities during May and June will usually be small. The availability of the LLV storage will, however, change the way that the elevation of UKL and the outflow at the Link River and A Canal are managed, and those are the aspects of project operations that have the most potential to affect larval transport and residence time during May and June.

The results of the exploratory model runs described in this report indicate that change in lake elevation as a result of project operations could have a large effect on larval transport and residence time in the lake during May and June; this is particularly true if the lake elevation in spring is low enough, as it was during 1992, that the connection between the Williamson River and the recently reconnected Williamson River delta is restricted. In general, even when lake elevation is above the remaining levees that surround the delta, higher lake elevation leads to more of the Williamson River inflow moving into and through the delta and into Agency Lake as well. This was evident in model runs that used 1991 hydrology. The WRIMS simulation of operations showed that a 1.2-ft increase in lake elevation and a 34,300 acre-ft (42.3×10^6 m^3) increase in lake outflow would have resulted with the LLV project in place. The increase in outflow would have been expected to decrease the residence time of larvae in the northern parts of the lake prior to the breaching of the levees at the Williamson River delta, but with the reconnection of the delta, the increase in lake elevation instead resulted in more transport through the delta and Agency Lake, such that concentration in those areas of larvae that entered the lake from spawning sites in the Williamson River increased rather than decreased. Thus, these model runs indicate that the effect of LLV project operations on Williamson River larvae, if the project is built, will be quite different now that the delta has been reconnected than it would have been prior to that reconnection.

To some extent that effect may be overestimated in the model simulations presented here, particularly at elevations close to full pool, because the model grid uses design elevations for the remaining levees surrounding the delta. In the process of implementing the reconnection, the remaining levees were lowered below the elevation designated in the reconnection plans. To make the simulations more accurate, future modeling efforts to predict the effects of LLV project operations should be done after the final surveyed elevations are available and have been incorporated into the model grid.

The model simulations using 1985 hydrology, in which LLV project operations result in an increase in outflow from the lake and a decrease in lake elevation, demonstrate the opposite effect. In that scenario, the concentration of larvae in most areas of the lake decreased relative to the No Action scenario.

The speed and direction of the wind blowing over the lake can have a significant effect on the results. This is because a wind reversal tends to move water entering the lake from the mouth of the Williamson River northward along the shoreline, whereas prevailing winds tend to move the water southward along the shoreline. Thus in the simulation using 1992 hydrology, 2006 meteorology resulted in a greater increase in the larval concentration in the Williamson

River delta and Agency Lake relative to No Action than 2007 meteorology, because water flowing northward from the mouth of the Williamson could enter these areas through breaches in the levees and through Agency Straits. In the simulation using 1985 hydrology, 2006 meteorology resulted in a smaller decrease in the overall larval concentration in the lake relative to No Action than 2007 meteorology, because the wind reversals tend to slow the exit of water at the southern end of the lake.

The limitations of this study are substantial. Although the model simulations can estimate the changes in larval concentration in UKL as a whole and in various subregions as a result of LLV project operations under a range of hydrologic and meteorological conditions, those estimates are not intended to represent the real numbers lost or gained. Rather, the results represent the potential for loss or gain due to LLV project operations that would be superimposed on other losses to the larval population, including predation and other causes of mortality. The average survival of larval suckers between 10 and 15 mm length, for example, has been estimated to be 18 percent (Markle and Dunsmoor, 2007). Compared to the decreases larval concentration due to mortality, therefore, the losses or gains due to LLV project operations resulting from model simulations, which range to as much as 29 percent in the lake overall, are smaller although not insignificant. Prediction is made more complicated by the fact that predation itself is a function of water depth (and, therefore, lake elevation) and vegetation (Markle and Dunsmoor, 2007). Changes in lake elevation due to the operation of the LLV project can, therefore, affect predation rates, both because of the direct effect of elevation on depth, and because, as has been shown by this work, elevation can affect the concentration of larvae in the Williamson River delta, where vegetation may reduce predation losses. Future efforts to use modeling to assess the potential effect of project operations on larval drift and retention would benefit from the inclusion of a predation loss term in the transport equation, with predation rates that can be varied by water depth and location.

A second limitation of this study is the assumption that drift is entirely passive. Although this seems reasonable for small larvae, the drift measurements made in the Williamson River show that the larvae have some ability to limit their drift to nighttime hours; thus, a behavioral component is indicated. This type of behavioral component could be included in future modeling studies if the rules governing the behavior (such as whether the behavior occurs at all or only at certain water depths, or is limited by water velocity) can be developed with some confidence.

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Appendix B—*Long Lake Valley Storage Project, Oregon—Probabilistic Seismic Hazard Analysis, for Feasibility Design*, Technical Memorandum No. 86-68330-2007-01, January 2007

RECLAMATION

Managing Water in the West

Technical Memorandum No. 86-68330-2007-01

Long Lake Valley Storage Project, Oregon

Probabilistic Seismic Hazard Analysis for Feasibility Design

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

January 2007

MISSION STATEMENTS

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

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

Bureau of Reclamation
Technical Service Center
Seismotectonics and Geophysics Group

Technical Memorandum 86-68330-2007-01

Probabilistic Seismic Hazard Analysis for Feasibility Design
Long Lake Storage Project, Oregon

Prepared By

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Geologist   Date

Roland LaForge   1/8/07
Geophysicist   Date

Peer Review

Dean Ostenaa   1/9/07
Geologist   Date

Probabilistic Seismic Hazard Analysis for Feasibility Design, Long Lake Valley Storage Project, Oregon

1.0 INTRODUCTION

This Technical Memorandum provides screening-level ground motion parameters, in the form of a probabilistic seismic hazard analysis (PSHA), for use in feasibility designs and analyses for proposed offstream pump-storage facilities and/or structures located in and adjacent to Long Lake Valley, near Klamath Falls, Oregon (**Figure 1-1**). The results of this study are based on a review of existing data and limited analysis of vertical aerial photographs contained within the files of the Seismotectonics and Geophysics Group. No site visits were made and no new geologic field studies were conducted as part of this analysis.

Previous Reclamation seismic hazard studies in the Klamath Falls area include the deterministic study by Hawkins et al. (1989) for Fish Lake and Fourmile Lake dams (northwest of Klamath Falls) as well as similar studies by Klinger et al. (1990, 1996) for Clear Lake and Gerber dams to the east (**Figure 1-1**). Reconnaissance-level studies of several of the faults in the area were also conducted by the senior author of this memorandum as part of seismic hazard studies for Clear Lake Dam (Anderson, 1999, unpublished data). Geomatrix (1995) conducted a state-wide seismic hazard study for the State of Oregon while Schapiro et al. (2002) did the first site-specific PSHA in the area for Gerber, Link River Diversion, Fish Lake, and Savage Rapids Diversion dams as part of Comprehensive Facility Reviews for these Reclamation structures. The present study for the Long Lake Valley area builds upon these earlier seismic hazard investigations and presents the results as hazard curves of peak horizontal acceleration (PHA) and 1-second spectral acceleration (1-sec SA). At the present time, no dams or other critical structures are planned as part of the Long Lake Valley Storage Project. Facilities may include pumping plants, tunnels, and canals, but it is not known exactly what or where their locations might be. Therefore, we have assumed a somewhat arbitrary area basically within the center of Long Lake Valley (**Figure 1-1**) for the "site" location.

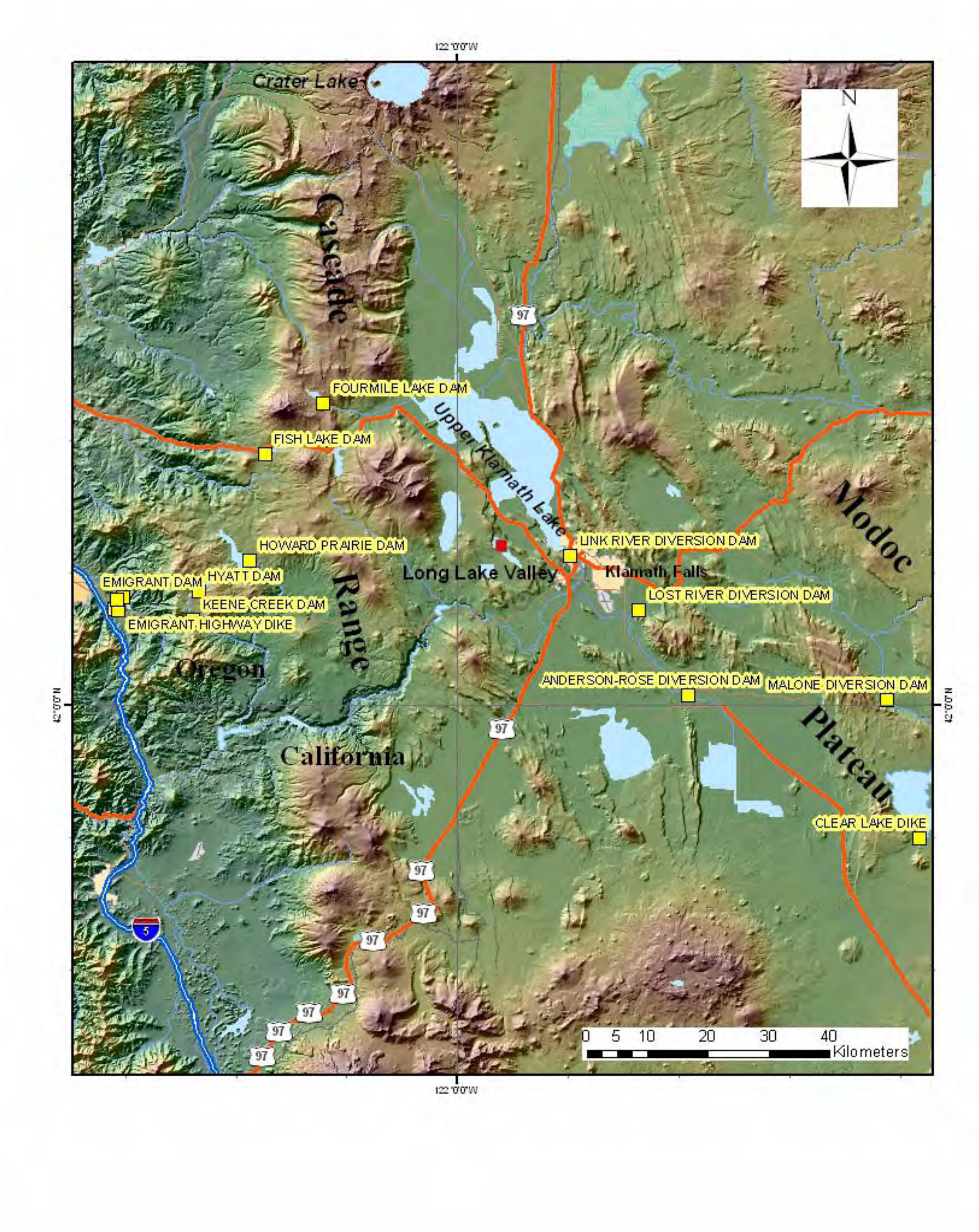

Figure 1-1 Map showing the location of the Long Lake Valley site (red square) as well as other Reclamation facilities in southern Oregon and northern California.

2.0 GEOLOGIC AND SEISMOTECTONIC SETTING

Long Lake Valley is located approximately 8 km west of Klamath Falls, in south-central Oregon (**Figure 1-1**). This area of southern Oregon, usually referred to as the Klamath graben, is situated immediately east of the Cascade Range, at the western edge of the Modoc Plateau section of the Basin and Range. The Klamath graben is a 130-km-long by 10- to 25-km-wide structural depression bounded by a series of normal faults (**Figure 2-1**). Intra-graben faults are also present. Quaternary faulting is assumed for many of the faults associated with the graben but documented evidence regarding their age and activity is limited. The Quaternary age assessment is based primarily on the young age of the volcanic rocks that comprise the various fault blocks (Pliocene and Miocene), the steep escarpments associated with them, and reported fault scarps to the north of Upper Klamath Lake (Hawkins et al., 1989) and within the lake itself (Colman et al., 2000). In addition, the Klamath Falls area has been the site of several historic earthquakes, including two events of M~6.0 about 20 km northwest of the city in September 1993 (Braunmiller et al., 1995). Surface rupture did not accompany these events, although significant damage was reported in Klamath Falls. The only reported surface effect was a 10-km-long zone of ground cracks on the west side of the graben north of Long Lake Valley (Wiley et al., 1993).

2.1 Klamath Graben

As the name implies, the Klamath graben is bounded by major faults or fault zones on both sides, with Upper Klamath Lake as the dominant feature within the graben (**Figure 2-1**). Recent studies and compilations (Personius, 2002a, 2002b, and 2002c; Schapiro et al., 2002; Weldon et al., 2002) typically identify two or three major fault zones associated with the graben: 1) the north-striking West Klamath Lake fault system on the northwest; 2) the north-northwest-striking East Klamath Lake fault system on the northeast; and 3) a generally northwest-striking zone of faults that is present from southern Klamath Lake, southeast through the Klamath Falls and Long Lake Valley areas, and southeast into the basin of Lower Klamath Lake. For the most part, all three fault systems appear to be comprised of individual, north-south to north-northwest striking fault segments that are generally 10 to 25 km long. For this study we have further divided the southern portion of the graben into two distinct zones, the Southwest Klamath Lake and the Southeast

Klamath Lake fault zones. In addition, we term the West Klamath Lake fault the Upper West Klamath Lake and the East Klamath Lake the Upper East Klamath Lake fault zones.

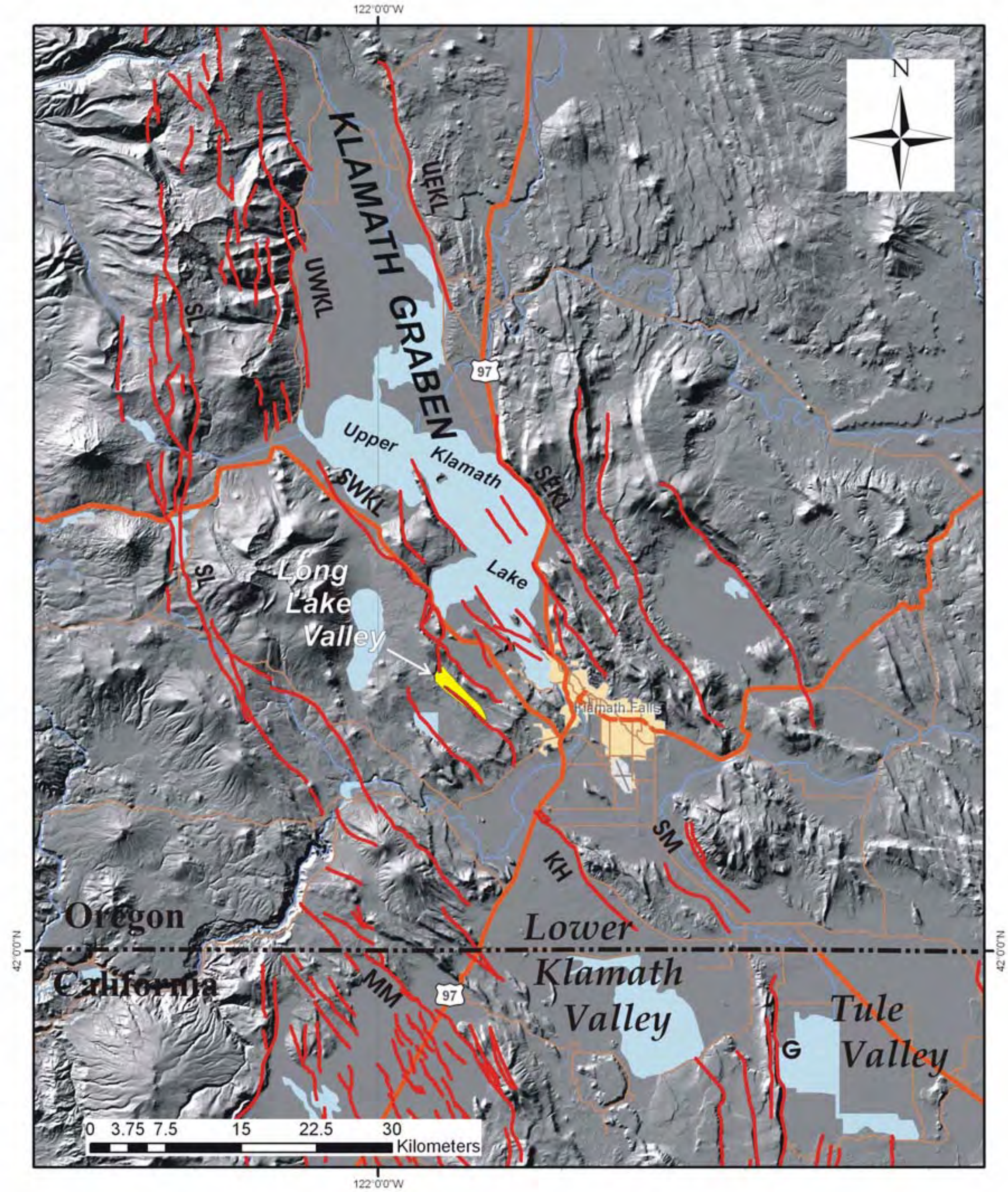

Figure 2-1 Map of known and suspected Quaternary faults in the Klamath graben region. Identified faults and faults zones are: G, Gillem; KH, Klamath Hills; MM, Mahogany Mountain; SEKL, southeast Klamath Lake; SL, Sky Lakes; SM, Stukel Mountain; SWKL, southwest Klamath Lake; UEKL, upper east Klamath Lake; and UWKL, upper west Klamath Lake. Faults from U.S. Geological Survey, Quaternary fault data base.

2.2 Long Lake Valley

Long Lake Valley is a northwest-trending, 7-km-long by 1-km-wide closed basin located near the south-western margin of the Klamath graben (**Figure 2-1**). The valley is bounded on the northeast by a ridge of tilted Pleistocene and Pliocene volcanic rocks that separates it from the valley containing Wocus Marsh (**Figure 2-2**). On the southwest, a similar ridge of tilted Pleistocene and Pliocene volcanic rock separates Long Lake Valley from Round Lake Valley. Both ridges are bounded on the northeast by down-to-the-northeast normal faults (Sherrod and Pickthorn, 1992; Hladky and Mertzman, 2002) assumed to be of Pleistocene age (Hladky and Mertzman, 2002). Long Lake Valley and the adjoining Wocus Marsh and Round Lake Valleys are filled with an unknown thickness of fine-grained lacustrine sediments and ash fall tuffs.

For this report, we have informally named the fault that bounds the southwest side of Wocus Marsh the Wocus Marsh fault, while the fault that bounds the southwest side of Long Lake Valley is termed the West Long Lake Valley fault. Total displacement associated with either fault is not known precisely, as there are no known drill holes that penetrate the valley sediments. Based on the cross-sections of Hladky and Mertzman (2002), vertical displacement associated with the Wocus Marsh fault could be about 250 m while vertical displacement on the west Long Valley fault may be approximately 150 m. Based on the mapping of Sherrod and Pickthorn (1992) and Hladky and Mertzman (2002), both the Wocus Marsh and West Long Lake Valley faults appear to be parts of the Southwest Klamath Lake fault zone of the Klamath graben.

Assuming an age of about 2 Ma for the inception of faulting (i.e., the Pliocene-Pleistocene age for the basalt of Wocus Marsh), the long-term slip rate estimate for the Wocus Marsh fault is about 0.125 mm/yr while the slip rate for the west Long Valley fault is about 0.075 mm/yr. Obviously, large uncertainties exist with these estimates because of the lack of information regarding the depth of valley fill, the exact age of the displaced volcanic units, and the age of the inception of faulting. However, the above estimated slip rate for the Wocus Marsh fault (> 0.1 mm/yr) is comparable to the estimated slip rates discussed below under seismic sources for the Southwest Klamath Lake fault zone.

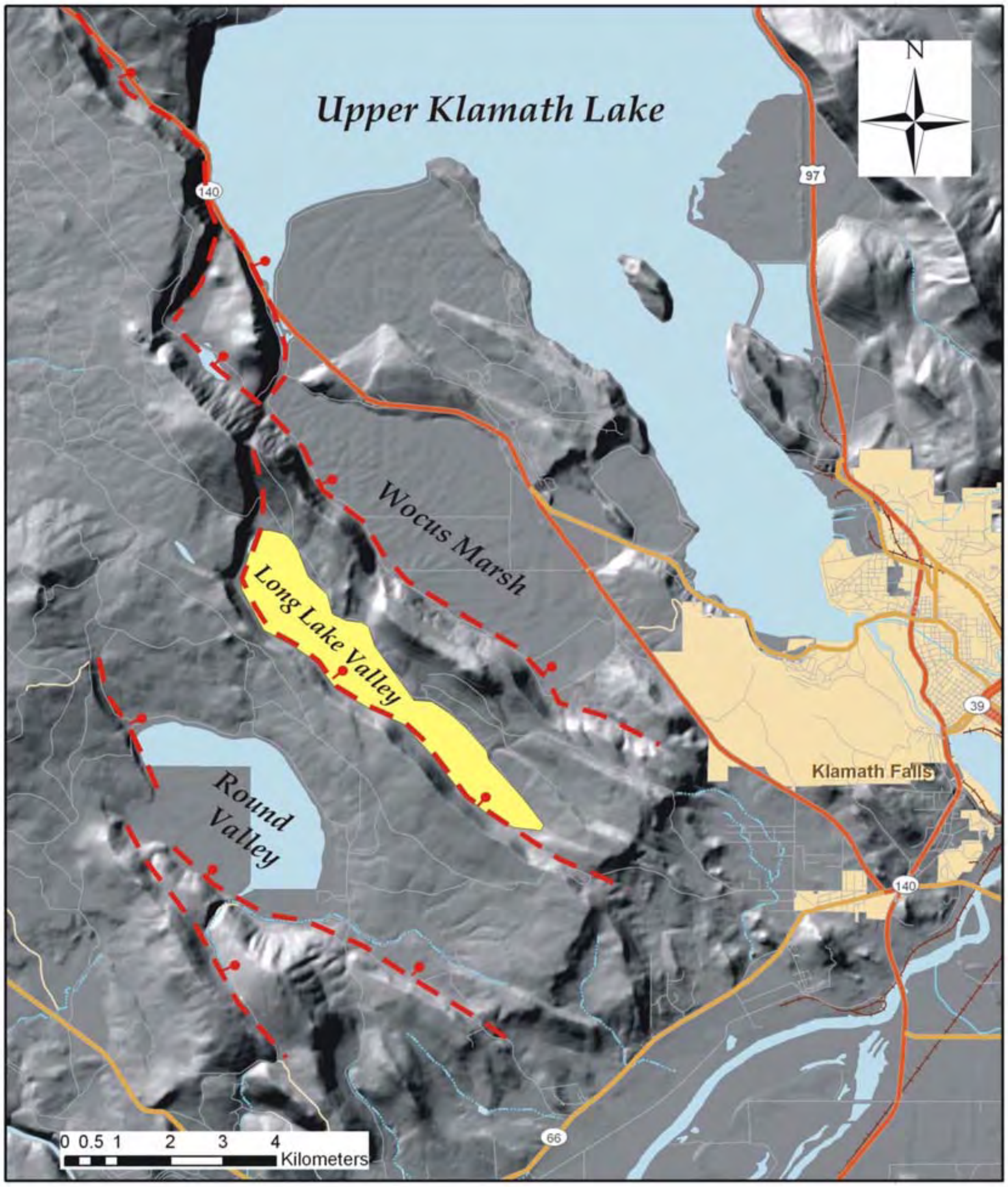

Figure 2-2 Map showing known and suspected Quaternary faults (dashed red lines) in the vicinity of Long Lake Valley. Note that all faults in and adjacent to Upper Klamath Lake have not been shown. Fault traces modified from Sherrod and Pickthorn (1992) and Hladky and Mertzman (2002), bar and ball on downthrown side.

3.0 SEISMIC SOURCES

We have identified nine fault seismic sources within approximately 50 km of Long Lake Valley area that are of potential significance to engineered facilities **(Figure 3-1)**. These sources include four fault zones associated with the Klamath graben, as well as the Sky Lakes, Klamath Hills, Stukel Mountain, Gillem, and Mahogany Mountain faults. These sources range from less than 3 km from the central part of Long Lake Valley to about 40 km from the site. Although more than 100 km to the west, the Cascadia subduction zone (considered capable of generating M~9 earthquakes), is also considered a potential source in this analysis.

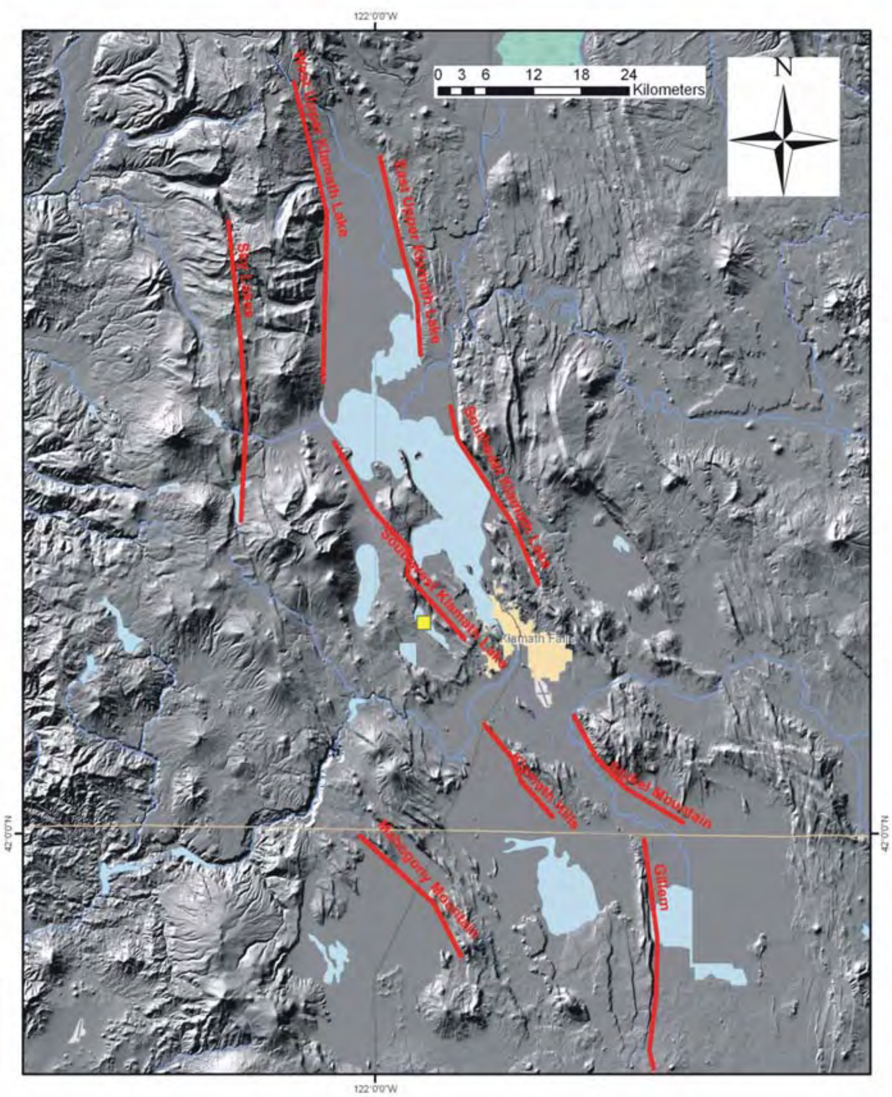

Figure 3-1 Map showing major fault zones and systems as described and modeled for the probabilistic seismic hazard analysis.

The nine fault sources identified here represent a fairly simplified analysis of all the potential sources present in the Klamath Falls area of southern Oregon and northern California. As mentioned previously, numerous known and suspected Quaternary faults are present in the region (**Figure 2-2**) suggesting that additional sources of large magnitude surface-rupturing earthquakes may be present in the region. However, based on their length, recency of movement, and high slip rates, we believe that the nine fault sources identified in this study are the most significant to the Long Lake Valley site. Additional site-specific studies may refine both the number of potential sources and the characterization of the sources used here.

3.1 Klamath Graben Faults

3.1.1 Southwest Klamath Lake Fault

The southern end of the Klamath graben is marked by a series of northwest-striking faults, typically 15 to 25 km in length, which extend from the central area of Upper Klamath Lake, southeast near both the west and east shores of the lake, then southeast to the area of Stukel Mountain and the Klamath Hills (**Figure 2-1**). For this study, we have separated this 60-km-long group of faults into four separate sources based on their lengths and opposing senses of slip. The 30-km-long, northeast-dipping Southwest Klamath Lake fault zone is discussed here; whereas the southwest-dipping Southeast Upper Klamath Lake, Klamath Hills and Stukel Mountain faults are considered separate sources and discussed in following sections.

The faults along the southwest shore of Upper Klamath Lake are obviously the most critical to a seismic hazard evaluation for Long Lake Valley in terms of both their capability of producing large earthquakes and correspondingly high ground motions, as well as their potential for surface fault displacement. However, high lake and ground water levels, high sedimentation rates, and man-made modifications make it difficult to evaluate the graben bounding faults in the immediate Wocus Marsh-Long Lake Valley area in terms of age and amount of displacement. The only study to document Holocene activity associated with any of the structural features in the southern Klamath graben is that of Colman et al. (2000). They identified numerous northwest-striking faults within the sediments of Upper Klamath Lake that displace the ~ 7 ka Mazama tephra. These graben-like features within the southern arm of the lake are the closest documented Holocene faults to Long Lake Valley, and faults associated with this system may exist within both Wocus

Marsh and Long Lake Valley itself. Colman et al. (2000) estimate a slip rate of 0.43 mm/yr for these faults based on an observed 3.1 m of displacement of the Mazama tephra layer. For this analysis, a range of slip rates between 0.15 and 0.6 appears appropriate for the Southwest Klamath Lakes fault zone. This range is based on the greater than 0.1 mm/yr estimate for the long term rate (**section 2.2**), and the estimate of 0.43 mm/yr for faults within Upper Klamath Lake. The rate of 0.43 mm/yr for intragraben faults suggests that rates for the major basin bounding faults may be even higher; thus, the upper bound of 0.6 mm/yr and a preferred estimate of 0.3 mm/yr.

For this screening-level analysis, we consider the Wocus Marsh fault (the fault bounding the southwest side of Wocus Marsh) to be the major portion of the Southwest Klamath Lake fault system in the vicinity of Long Lake Valley based on its apparently greater amount of total displacement (Hladky and Mertzman, 2002). Alternative characterizations could include the Long Lake Valley faults as part of this system as well. Depending on the location of specific facilities and the slip rate values used, this could result in significant changes to the hazard characterization.

Surface fault displacement and related deformation also is a potential hazard for facilities in the Klamath graben, particularly for structures constructed near the margins of the various basins. This could include offset on basin-bounding as well as un-mapped intragraben faults, large scale tilting of fault blocks or basin floors, and liquefaction and related deformation within basin sediments. When more specific facility locations are identified, more detailed, higher level studies may be required to better characterize earthquake related deformation in the Wocus Marsh-Long Lake Valley area.

3.1.2 West Upper Klamath Lake Fault Zone

The 40-km-long West Upper Klamath Lakes fault zone appears to be the major bounding fault for the northern portion of the Klamath graben. The entire fault system could be as much as 60-km-long if it continues north of Crater Lake; however, we have not included the north-striking Annie Spring and Red Cone Spring faults located north of Crater Lake within our 40-km-length estimate because of the significant gap (~10 km) between these faults and the northern-most faults of the main West Upper Klamath Lake fault.

Late Quaternary activity has been documented for several of the faults associated with the West Upper Klamath Lake fault system (Hawkins et al., 1989; Bacon et al., 1999). Hawkins et al. (1989) examined fault scarps near the northwest end of Upper Klamath Lake, about 25 km north of Long Lake Valley. They found evidence for up to 25 m of late Quaternary displacement and concluded that at least one Holocene event had produced 1 to 2 m of surface displacement. They further estimated the late Pleistocene (last 130 ka) slip rate for the fault zone to be 0.17 mm/yr. This indicates that if earthquakes associated with this portion of the West Klamath fault zone are characterized by 1 to 2 m of displacement, the return period for large-magnitude, surface-rupturing earthquakes could be about 10,000 years. However, this may be a low estimate as the work of Hawkins et al. (1989) was on only one limited portion of the fault.

Based in part on the earlier probabilistic studies of Schapiro et al (2002), we have adopted a range of slip rates between 0.15 and 0.6 mm/yr to characterize the West Upper Klamath Lake fault, with a preferred value of 0.35 mm/yr

3.1.3 East Upper Klamath Lake Fault

The eastern margin of the Klamath graben is marked by a 25-km-long west-dipping fault zone that we have termed the East Upper Klamath Lake fault. This fault zone appears to be antithetic to faults on the west side of the graben based in large part on the assumed lower rate of activity and west dip. The main fault is mapped along the base of a 70- to 250-m-high escarpment composed of Pliocene basalts, but no fault scarps have been mapped on late Quaternary surficial deposits suggesting the youngest displacement may be mid-Quaternary in age (Personius, 2002b). Geomatrix (1995) used estimated slip rates of 0.15 to 0.5 in their earthquake hazard analysis but Schapiro et al. (2002) used a much lower range of 0.05 to 0.3 mm/yr based on the apparent lack of evidence for young faulting. Like the other Klamath graben faults, this zone is assumed to have a fairly steep dip, on the order of 70°. Slip rates for the East Upper Klamath Lake fault are modeled as between 0.05 and 0.3 mm/yr with a preferred value of 0.1 mm/yr.

3.1.4 Southeast Klamath Lake Fault

As defined here, the 25-km-long Southeast Klamath Lake fault is a southwest-dipping structure that bounds the southeast margin of Upper Klamath Lake. This structure may include various short faults near Klamath Falls, but for this analysis we have considered only what appears to be the main fault trace based on geomorphic characteristics. Personius (2002c) includes this structure with his South Klamath Lake section of the Klamath graben. Sherrod and Pickthorn (1992) inferred Holocene activity associated with the fault but this activity has not been confirmed. Similar to the East Upper Klamath Lake fault, this zone is assumed to have a fairly steep dip, on the order of 70°, and slip rates are modeled as between 0.05 and 0.3 mm/yr with a preferred value of 0.1 mm/yr.

3.1.5 Stukel Mountain

Stukel Mountain is an approximately 20-km-long, northwest-trending mountain block located approximately 15 km southeast of Klamath Falls and about 22 km southeast of Long lake Valley (**Figure 3-1**). Sherrod and Pickthorn (1992) indicate on their map that the southwest side of the mountain is fault bounded by a down-to-the-west normal fault and that this fault may have Holocene displacement. Personius (2002c) includes this fault within the South Klamath Lakes section of the Klamath graben fault system.

Klinger et al. (1996) reported that the foot wall of the Stukel Mountain fault is exposed in a large gravel pit at the north end of Stukel Mountain. The bedrock fault plane is smooth, near-vertically striated, and strikes N45^{o}W and dips about 50^{o}SW. Steeply-dipping colluvial deposits are in contact with the fault plane. However, no clear or obvious disruption of the colluvial deposits was noted, and it is unclear if any or all of the deposits are faulted or not. Thus, an actual assessment of whether there is Holocene displacement (or even latest Pleistocene displacement) at this location is very difficult, especially without detailed study.

Southeast of the gravel pit, a large landslide is present along the west side of Stukel Mountain (Sherrod and Pickthorn, 1992). The large size (4 km^2) and generally subdued morphology of the landslide suggests it is probably late Pleistocene in age. The upper portion of the slide mass is relatively flat and vegetated only with grasses and crosses the assumed trace of the fault. Sherrod and Pickthorn (1992) show the fault trace as approximately located or inferred across the landslide and no obvious scarps were observed during an aerial reconnaissance of the area (Anderson, 1999, unpublished data). This observation suggests that no significant surface rupture has occurred associated with the Stukel Mountain fault since movement of the landslide. Thus, it is very possible that no Holocene activity has occurred on the Stukel Mountain fault. This also suggests that the late Quaternary slip rate for the fault may be relatively low, about 0.1-0.2 mm/yr. This would be comparable to that of the West Klamath Lake fault zone and to that of the Gillem fault discussed in a following section. Based on the 20-km-length of Stukel Mountain and allowing the rupture to extend slightly beyond the obvious range front, a maximum rupture length of about 25 km appears reasonable.

3.1.6 Klamath Hills

The Klamath Hills fault system consists of a series of faults along the southwest side of the Klamath Hills, about 15 km southeast of Long Lake Valley (**Figure 3-1**). These down-to-the southwest, assumed normal faults have received very limited study, and have been included with the South Klamath Lake section of the Klamath graben fault system (Personius, 2002c). Sherrod and Pickthorn (1992) show these faults as active in the Holocene but this activity has never been documented. For this study, we follow Schapiro et al. (2002) and consider a possible rupture length of nearly 15 km and assign slip rates of 0.005 to 0.1 mm/yr.

3.2 Sky Lakes

The Sky Lakes fault zone is a 70- to 80-km-long series of down-to-the-east bedrock faults and fault scarps, each of which is typically 5- to 12-km-long, located west of the West Upper Klamath Lake fault system (**Figure 3-1**). The Lake of the Woods fault, the possible source of the 1993 **M** ~ 6 earthquakes (Braunmiller et al., 1995), is included within this fault system. Compared to the West Klamath Lakes faults, the Sky Lakes faults and associated scarps are typically more subdued and hence do not appear as active as the faults along the west side of Upper Klamath Lake. Only about 40 km of the fault system is believed to have mid Quaternary or younger activity (Personius, 2002d) which is the basis for only considering a 40-km-long rupture length. Studies by Hawkins et al. (1989) indicate that the scarps cut older volcanic rocks than do the West Klamath Lake faults with geomorphic evidence of about 300 m of post-early Pleistocene displacement. However, Hawkins et al. (1989) found no evidence for latest Pleistocene or Holocene surface displacement.

For this study, we model the Sky Lakes fault as having rupture lengths of about 37 km. This follows the work of Hawkins et al. (1989) and Schapiro et al. (2002) which consider rupture lengths of 18 to over 50 km as possible. The slip rate for Sky Lakes fault is between 0.05 and 0.2 mm/yr with a preferred value of 0.1 mm/yr. This range and preferred value takes into account the lack of evidence for latest Pleistocene and Holocene surface faulting associated with this fault system.

3.3 Mahogany Mountain

The 20-km-long northwest-striking Mahogany Mountain fault is present approximately 28 km south of Long Lake Valley (**Figure 3-1**). It may be part of a more extensive system of faults in the Butte Valley area of northernmost California that includes the Cedar Mountain fault system of Bryant (2000). However, only the Mahogany Mountain portion is considered in this analysis because it is the closest part of the fault system to Long Lake Valley and it is the only portion of the fault system believed to have latest Pleistocene to Holocene activity. Based on the earlier studies of Schapiro et al. (2002), we assign a range of slip rates between 0.1 and 0.4 mm/yr with a preferred rate 0.2 mm/yr.

3.4 Gillem

The Gillem fault is a north-striking, east-side down normal fault that bounds the west side of the Tule Lake basin (**Figures 2-1 and 3-1**). The fault is approximately 40 km southeast of Long Lake Valley, and it has been considered a seismic source in all of the previous Reclamation seismotectonic studies in the area.

The northern-most surface trace of the Gillem fault is about 25 km in length, extending from the north end of Gillem Bluff south into Lava Beds National Monument (**Figure 2-1**). Geophysical data suggest that the subsurface trace of the fault may extend another 15 km south beneath the east flank of Medicine Lake volcano (Evans and Zucca; 1988; Donnelly-Nolan, 1988). The Gillem fault clearly displaces late Tertiary and Pleistocene volcanic rocks. Near the northern end of Gillem Bluff, flows near the rim of the bluff have K-Ar ages of 3.6 and 5.3 Ma (Hart, 1982). Based on the height of Gillem Bluff, total displacement across the Gillem fault could approach 600 m.

In Lava Beds National Monument, the late Pleistocene basalt of Mammoth Crater is displaced approximately 15 m by the Gillem fault (Donnelly-Nolan and Champion, 1987). The age of the basalt of Mammoth Crater is currently unknown with any certainty except that it is apparently less than 100 ka (Donnelly-Nolan and Champion, 1987). The mid (?) Holocene flow of Devil's Homestead overlies the fault without apparent displacement (Donnelly-Nolan and Champion, 1987), although the flows originated from vents at Fleener Chimneys that are located essentially on top (hanging wall) of the Gillem fault trace. Thus, there appears to be good geologic evidence for significant late Pleistocene activity but no mid- to late Holocene surface rupture on the southern end of the Gillem fault.

Reconnaissance studies conducted as part of studies for Clear Lake Dam (Anderson, 1999, unpublished data) also suggest that no mid-to late Holocene displacement has occurred on the Gillem fault. Petersen et al. (1996) in their compilation of seismic sources for the state of California list the Gillem fault and assign a poorly constrained slip rate of 1 mm/yr to it. They cite the work of Donnelly-Nolan and Champion (1987) and say that the slip rate is based on vertical separation of the late Pleistocene (about 40 ka) Mammoth Crater basalt. It is unclear where or how this assessment was made. In order to get a slip rate of 1 mm/yr, the Mammoth Crater basalt would have to be 40 ka and have to be displaced 40 m. Review of the mapping of Donnelly-Nolan and Champion (1987) as part of studies for Clear Lake Dam (Anderson, 1999, unpublished data) indicates that the Mammoth Crater basalt is displaced no more than 15 m (T.46 N., R.4 E., sec. 30). Thus, even if the Mammoth Crater basalt is only 40 ka, the slip rate for the Gillem fault at that location is no more than about 0.4 mm/yr. If the basalt is closer to 100 ka as suggested by Donnelly-Nolan and Champion (1987), the slip rate would be 0.15 mm/yr. For this study, we will assume that the basalt of Mammoth Crater could be as young as 40 ka. Thus, the slip rate for the Gillem fault is probably between 0.15 and 0.75 mm/yr, with a preferred value of 0.4 mm/yr. A maximum surface rupture length of about 28 km is considered likely based on the mapped surface length of the fault and comparisons to other faults in the area.

3.5 Cascadia Subduction Zone

The Cascadia Subduction Zone, a source for potentially great earthquakes (M ~ 9), extends from northern California to southern British Columbia. The subduction zone represents the location where two oceanic plates, the Juan de Fuca and Gorda, are being subducted beneath the North American plate at the rate of 38 to 45 mm/yr (Wells et al. 1998). The subduction zone is located approximately 150 km west of Long Lake Valley. Recent studies indicate that the most recent great earthquake associated with the zone was an event of M ~ 9 that occurred in January 1700 which probably ruptured the entire zone of nearly 1000 km (Satake et al. 1996). Most workers also consider the possibility that the subduction zone may be segmented and rupture in smaller events as well as great earthquakes.

3.6 Related Seismic Hazards

Besides the obvious hazards of strong ground shaking accompanying a large earthquake, a potential hazard to structures or facilities that may be constructed as part of the Long Lake Valley storage project is the possibility of surface fault displacement. Numerous recurrently active Quaternary faults are present in the site vicinity (**Figures 2-1 and 2-2**), any of which, based on the current level of study, may be the site of surface faulting that would accompany a major earthquake. At the present time, we do not have adequate information to delineate either the exact location or the amount of potential displacement associated with any of these faults. An additional hazard is the possibility of a volcanic eruption in the area of Long Lake Valley. Such an eruption could be associated with either the Crater Lake area or any one of numerous vents in the region. A major eruption could be accompanied by strong earthquake shaking as well as the eruption of lava and associated lahars or mudflows.

It also is fairly well known that the impoundment of deep (> 100 m), large reservoirs and injection of fluids deep within the earth can induce seismic activity. Reclamation has first hand knowledge of injection-induced seismicity due to Reclamation's activities within the Paradox Valley of southwestern Colorado, where it is injecting brine over 4 km below the surface (Ake et al., 2005). One of several options being considered for additional water storage in the Upper Klamath Lake area is the injection or pumping of water into shallow aquifers within Wocus Marsh. At the present time, we have no information on the depth of possible injection. However, unless the pumping and/or injection takes place at depths greater than one or two kilometers (3000 to 5000 feet), it is extremely unlikely that such injection or pumping would result in induced seismic activity.

4.0 PROBABILISTIC SEISMIC HAZARD ANALYSIS

A probabilistic seismic hazard analysis (PSHA) was performed for the Long Lake site, using the basic precepts of Cornell (1968). This study was designed to be used in scoping and feasibility level analyses, and as such no new investigations or data collection activities were employed. The results of this study consist of hazard curves for peak horizontal acceleration (PHA) and 1.0 second acceleration spectral response (at 5% damping), and a source deaggregation showing relative contributions for the complete range of ground motions for the two response periods. Ground motion amplitudes for return periods of 10,000 and 50,000 years are tabulated, but results for any shorter return period can be derived from the hazard curves.

The seismic source model for this study consists of nine crustal faults, the Cascadia shallow interface, and three areal zones of randomly occurring “background” seismicity.

4.1 Crustal Faults and the 1993 Earthquake Sequence

The fault sources used in this study were described in detail in Section 3.0. For the purposes of the PSHA the fault traces and their down-dip widths as modeled and characterized are shown in **Figure 4-1**.

Two earthquakes with magnitudes of M_W 5.9 and 6.0 occurred within a few km of the Long Lake site on September 20, 1993, within about 2 hours of each other. The ensuing aftershock sequence covered a northwest-trending area roughly 20 by 30 km (**Figure 4-1** and **Figure 4-4**). Effects of the sequence included two fatalities, about $7.5 million in damage, ground cracking, and landslides (Wiley et al., 1993). The earthquakes were the strongest in recorded Oregon history, and the area had been relatively quiescent in the previous 100 years (Sherrod, 1993). Although initial seismograph coverage was sparse (the nearest stations were about 70 km away), the deployment of a portable network 2 days after the mainshocks allowed for greatly improved location accuracy of the entire sequence (Qamar and Meagher, 1993).

Of importance to this study is the possible correlation of the sequence to mapped faults in the vicinity, and the depth distribution of the earthquakes. Braunmiller et al. (1995) present an analysis of the sequence based on waveform modeling of broadband seismograms. The results

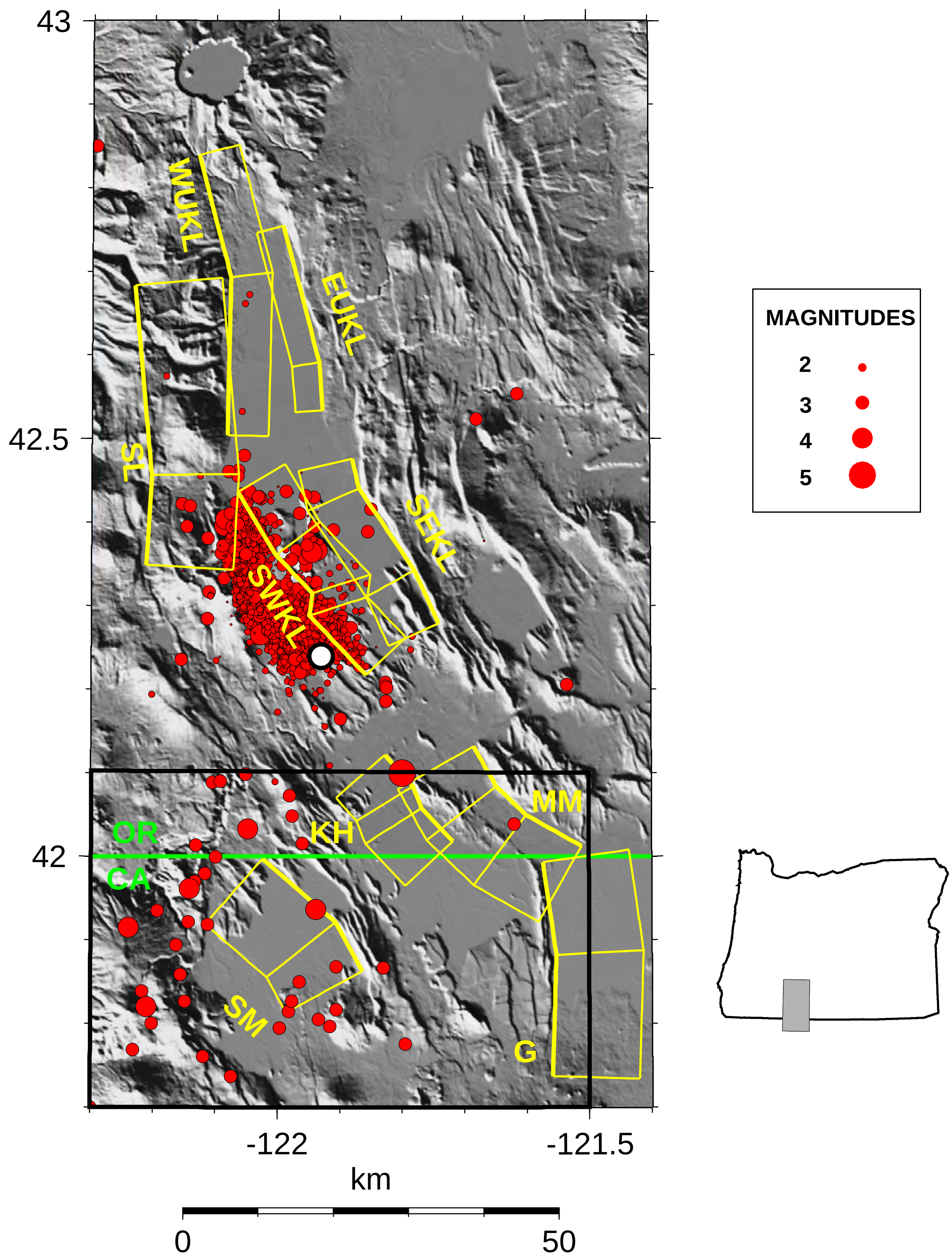

Figure 4-1 Fault sources used in PSHA shown in yellow; thicker line is surface trace: G, Gillem; KH, Klamath Hills; SEKL, Southeast Klamath Lake; SWKL, Southwest Klamath Lake; MM, Mahogany Mountain; SL, Sky Lakes; SM, Stukel Mountain; WUKL, West Upper Klamath Lake; EUKL, East Upper Klamath Lake. Seismicity in black rectangle, magnitude >= 2, from ANSS catalog, 1900-October, 2006. Seismicity above 42.1N is 1993 Klamath Lake earthquake sequence, from U. of Washington. White dot is Long Lake "*site*".

indicate east-dipping normal faulting, with the trend following the regional pattern of mapped faults; i.e., NW trending planes in the southern part of the cluster, and NNW trending planes to the north. Braunmiller et al. postulate a correlation with the “Lake of the Woods” fault of Hawkins et al. (1989), which is included with the Sky Lakes fault in this study. However, they emphasize that the sequence appears to have occurred on a number of faults of varying orientation, some or all of which may not be mapped on the surface.

An important issue for the characterization of these faults is the maximum depth of seismicity in the region, which affects the potential rupture areas of the faults, the magnitudes the faults are capable of producing, and the rates of earthquakes occurring on them. Two groups of seismicity were examined: the 1993 Klamath Lake earthquake sequence, and seismicity occurring to the south of the site (below 42.2N; the black rectangle in **Figure 4-1**). Hypocenters for the 1993 earthquake sequence were obtained from the University of Washington (ftp://ftp.geophys.washington.edu/pub/kfalls); those below 42.2N were obtained from the ANSS catalog (http://www.ncedc.org/ncedc). This data set consists of earthquakes from 1900 through October, 2006, and due to the lack of nearby seismograph stations in this region, are much more poorly located than those of the 1993 sequence, which were located with the benefit of local stations emplaced during the aftershock sequence.

A cross-section of the 1993 sequence is shown in **Figure 4-2**. It is apparent that the main cluster of activity reached depths of about 20 km. A similar cross-section for the rectangle to the south (**Figure 4-3**), though drawn from earthquakes whose focal depths are much less reliable, shows a similar pattern, with most hypocenters in the upper 20 km. Based on this evidence, the effective maximum seismogenic depth was judged to be 20 km.

Fault dips were assumed to be 60^{o} (**Table 4-1**), as a default estimate due to the lack of independent observations. Exceptions to this are the faults which bound the Klamath graben on the east and west sides. These were increased to 70^{o} to assure that the fault planes did not intersect at shallow depth. The depth of the East Upper Klamath Lake fault was also reduced to 15 km to avoid intersection with the West Upper Klamath Lake fault. The depth of the Klamath Hills fault was reduced to 15 km, to increase the fault aspect ratio (length/width) from 0.6 to a more seismologically plausible value of 1.0.

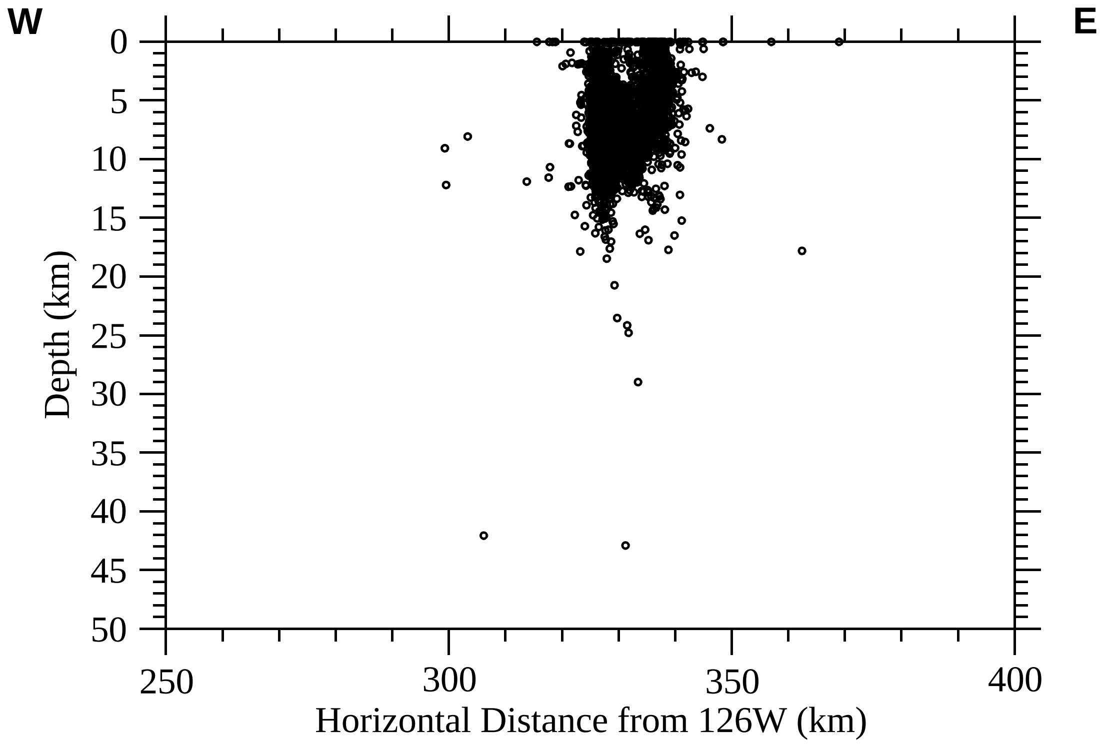

Figure 4-2 East-West cross-section of Klamath Lakes sequence; seismicity north of 42.1N in Figure 4-1. From University of Washington website (see text).

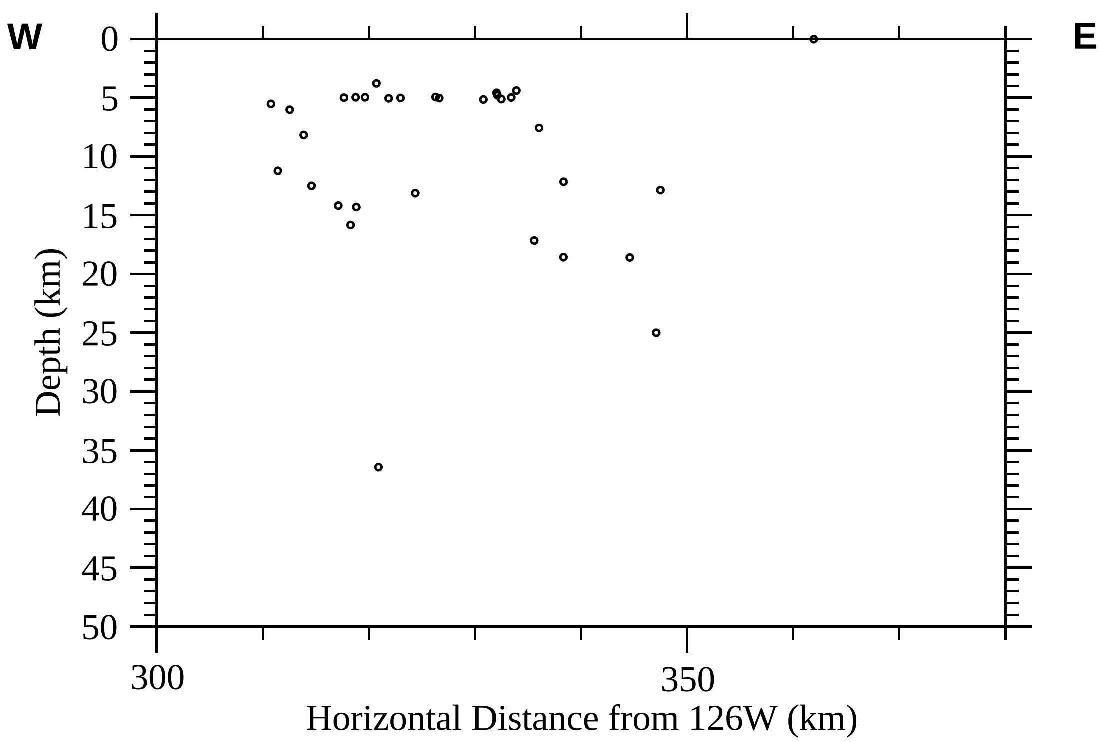

Figure 4-3 East-West cross-section of seismicity from ANSS catalog, 41.7N - 42.1N, 122.3W - 121.5W (black rectangle in Figure 4-1).

Table 4-1 Long Lake Site Geometric Fault Parameters

Fault	Length (km)	Area (km^2)	Depth Range	Dip	Mag from Length	Mag from Area	Closest Distance (km)	Farthest Distance (km)	Mean Distance (km)
Gillem	28.7	684	0.0 to 20.0	60.0	6.8	6.8	40.2	73.1	56.6
Klamath Hills	14.8	258	0.0 to 15.0	60.0	6.4	6.4	15.6	35.8	25.6
Southeast Klamath Lake	25.0	547	0.0 to 20.0	70.0	6.7	6.7	13.3	31.9	20.4
Southwest Klamath Lake	30.7	636	0.0 to 20.0	70.0	6.8	6.8	2.6	32.9	17.1
Mahogany Mountain	20.3	421	0.0 to 20.0	60.0	6.6	6.6	28.1	51.7	39.7
Sky Lakes	37.3	882	0.0 to 20.0	60.0	6.9	6.9	23.3	55.8	38.0
Stukel Mountain	20.0	536	0.0 to 20.0	60.0	6.6	6.7	22.7	49.8	34.8
West Upper Klamath Lake	37.8	616	0.0 to 20.0	70.0	6.9	6.8	31.6	70.5	50.4
East Upper Klamath Lake	25.2	265	0.0 to 15.0	70.0	6.7	6.4	32.7	57.9	45.3
Cascadia Interface	489	74,000	5.0 to 30.0	9.5	N/A	N/A	131	416	252

All geometric fault parameters, including surface lengths, areas, depth ranges, dips, and distances to the site are shown in **Table 4-1**. The magnitude based on fault area is based on the Wells and Coppersmith (1994) empirical relations for normal faults.

Slip rate distributions for the faults, their means, and the maximum magnitudes used in the PSHA are listed in **Table 4-2**.

Table 4-2 Magnitudes and Slip Rate Distribution for Fault Sources

Fault	Magnitude (M_w)	Slip Rate (mm/yr)	Mean	Distribution Type
Gillem	6.8	0.150 to 0.750 (0.40)	0.433	triangle,asym
Klamath Hills	6.4	0.005 to 0.100 (0.01)	0.038	triangle,asym
Southeast Klamath Lake	6.7	0.050 to 0.300 (0.10)	0.150	triangle,asym
Southwest Klamath Lake	6.8	0.150 to 0.600 (0.30)	0.350	triangle,asym
Mahogany Mountain	6.6	0.100 to 0.400 (0.20)	0.233	triangle,asym
Sky Lakes	6.9	0.050 to 0.200 (0.10)	0.117	triangle,asym
Stukel Mountain	6.7	0.010 to 0.100 (0.03)	0.047	triangle,asym
West Upper Klamath Lake	6.8	0.150 to 0.600 (0.30)	0.350	triangle,asym
East Upper Klamath Lake	6.5	0.050 to 0.300 (0.10)	0.150	triangle,asym

4.2 Cascadia Interface

The Cascadia subduction zone, which exists because of the collision of the Juan de Fuca plate with the North America plate, poses a major seismic hazard in the Pacific Northwest. Earthquakes in the M_W 8-9 range apparently occur at intervals on the order of 500 years, the most recent a M_W 9 event that occurred in 1700 (Satake et al., 1996). Seismic hazards from subduction zones are generally of two types, from earthquakes occurring on the plate interface (such as the 1700 event), and from those caused by deformation of the downgoing plate as it sinks into the upper mantle. Damaging earthquakes of this type (termed “intraslab” earthquakes) occurred in the Puget Sound in 1949, 1965, and 2001. However, Wong (2005) argues that due to the geometry and thermal structure of the plate interface, the hazard from this type of earthquake is practically nonexistent in central and southern Oregon. We therefore do not consider intraslab earthquakes to pose a threat to the Long Lake site.

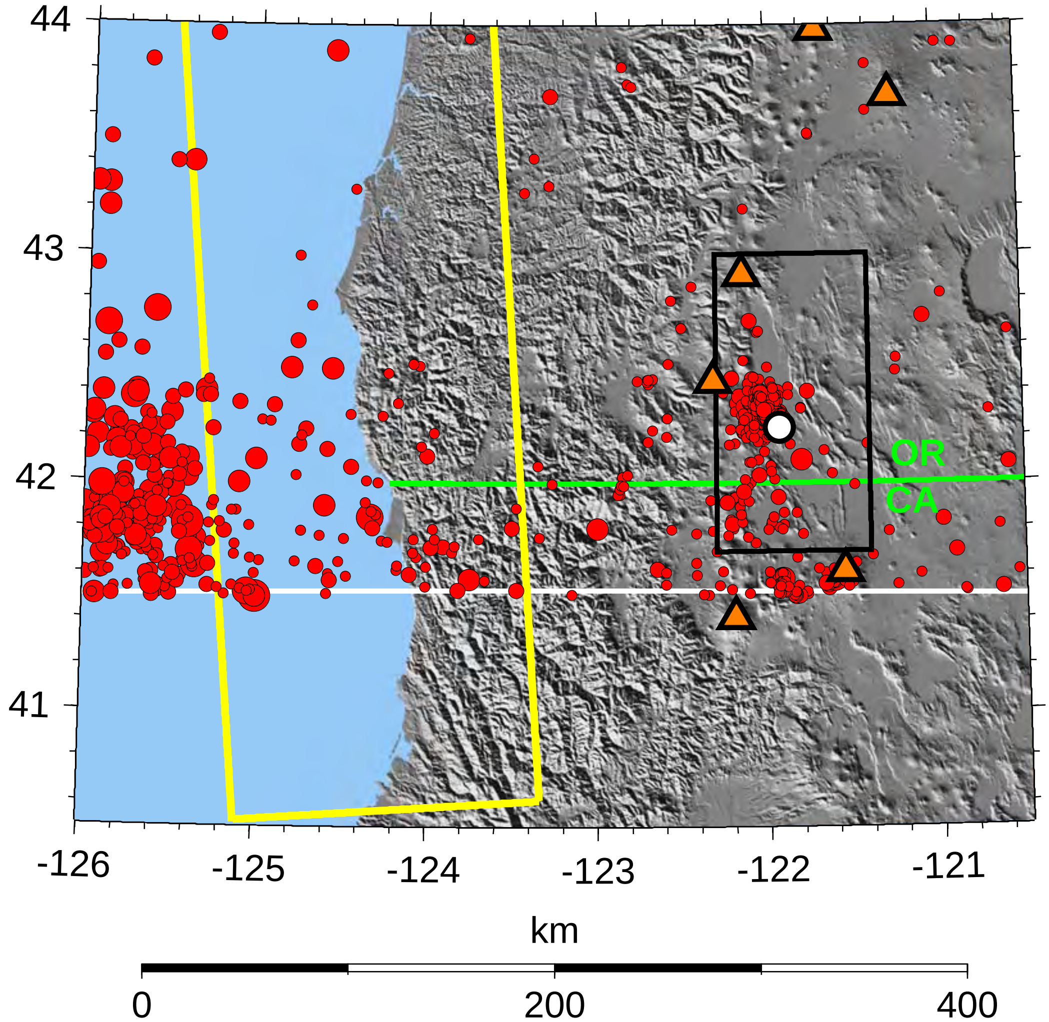

Figure 4-4 Geometry of Cascadia interface (yellow outline). Potential rupture surface dips 9.5 deg to the east, from 5 to 30 km depth (Table 4-1). Seismicity from ANSS catalog (1900 - October, 2006), magnitude >= 2 shown north of 41.5N. Orange triangles are volcanoes. White dot is Long Lake "*site*". Black rectangle is area of Figure 4-1.

The source characterization for earthquakes occurring on the subduction interface is taken directly from Ostenaa and LaForge (2006), which was a similar study for Scoggins Dam in northwest Oregon. The reader is referred to that report for details regarding fault geometry, magnitude distributions, and activity rates. Maximum magnitudes were assumed to be either 8.5

or 9.0, based on information in Nelson et al. (2006). The activity rates for the M_W 8.5 scenario is characterized by a lognormal return period distribution with a mean of 200 years; the M_W 9 scenario with the same type of distribution but with a mean return period of 560 years. In Ostenaa and LaForge (2006), these two magnitude scenarios were weighted 0.3 and 0.7, based on the observations of Nelson et al. that the larger magnitude events have predominantly occurred in the northern part of the subduction zone. Because the Long Lake site is in the southern part of the subduction zone, the weights were changed to 0.5 and 0.5.

4.3 Areal Seismicity

Seismic hazards are also posed by randomly occurring "background" earthquakes of limited magnitude that are not associated with known faults. For the characterization of this type of seismic hazard, in this preliminary study we have relied on the areal zones and activity rates presented in Schapiro et al. (2002). The zones as adapted from Schapiro et al. are shown in **Figure 4-5** and their *a* and *b* values in the Gutenberg-Richter recurrence relation are shown in **Table 4-3**. Random events were assumed to occur in the magnitude range 5.0 to 6.5. Because no occurrence tables were shown in Schapiro et al., no rate variations were incorporated into the PSHA from these sources.

Table 4-3 Recurrence Parameters for Areal Source Zones

Areal Zone	a - value*	b - value
Basin and Range	-3.25	0.64
Southern Cascades	-1.36	1.00
Rotating Block	-2.10	0.90
* Normalized to km^2/yr from Schapiro et al. (2002)		

4.4 PSHA Procedure

Two attenuation functions, Pankow and Pechmann (2004), and Spudich et al. (1999), equally weighted, were used for the crustal faults and random seismicity. These relations, designed for use in extensional environments and in particular for normal faults (Pankow and Pechmann) were judged the most currently suitable for the tectonic environment surrounding the Long Lake site.

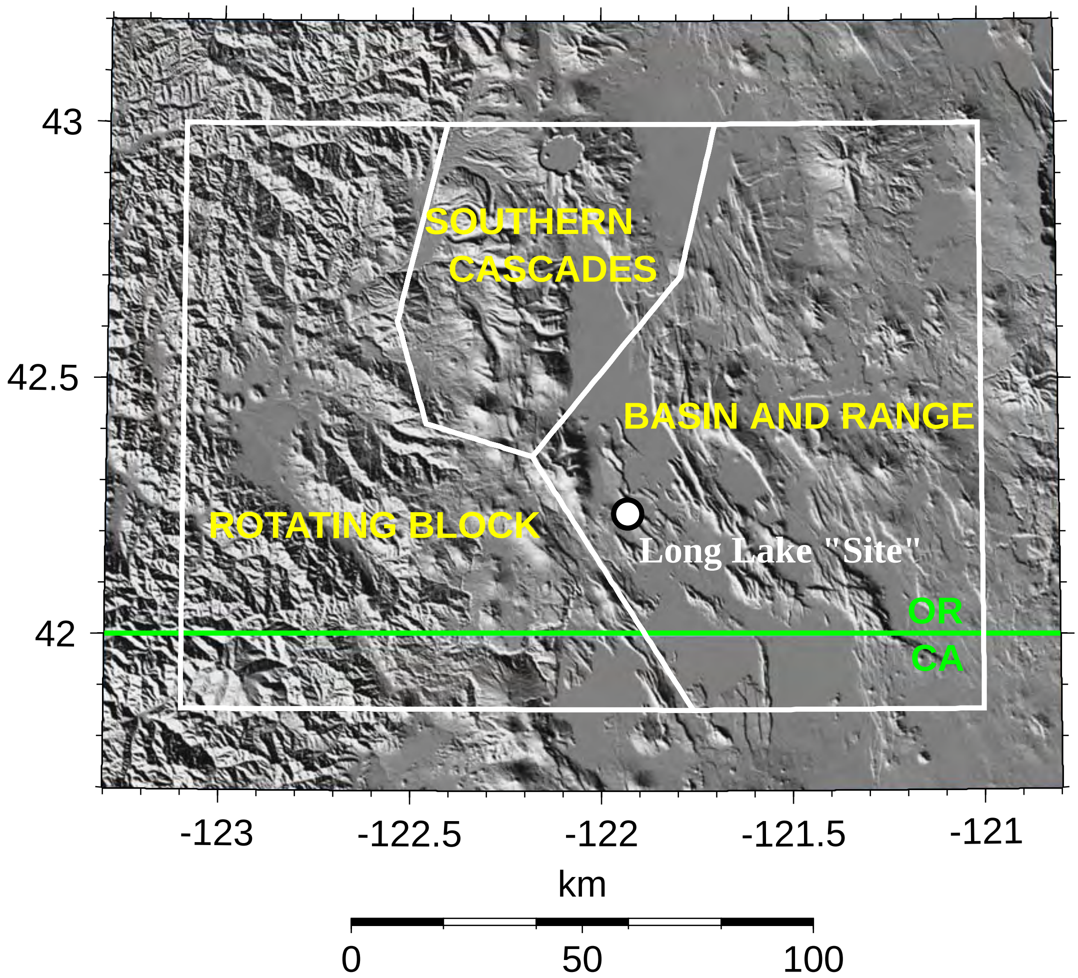

Figure 4-5 Areal source zones, adapted from Schapiro et al. (2002).

For the Cascadia interface source, three attenuation functions were used (Gregor et al., 2002; Youngs et al., 1997; Atkinson and Boore, 2003). As in Ostenaa and LaForge (2006) these were weighted 0.15, 0.15, and 0.7, respectively. The "rock" site classification for each relation was used.

The maximum moment recurrence distribution was used, which assumes that all earthquakes on a fault occur within a limited range of the maximum magnitude allowed by the fault area (e.g., Wesnousky, 1986). The magnitude characterization for the crustal faults consisted of a Gaussian distribution with the median value shown in **Table 4-2**, and a standard deviation of 0.2.

Reclamation in-house program *faultsource_20, rev. 2.0.203* was used for the fault sources, and *mrs5.0 rev. 1.0* was used for the areal source zones.

4.5 PSHA Results

Mean hazard curves for the individual sources and total are shown in **Figure 4-6** and **Figure 4-7**, respectively. Mean and fractile curves for the total hazard are shown in **Figure 4-8** and **Figure 4-9**. Relative contributions to the total hazard for the two response periods, along with markers for return periods of 10,000 and 50,000 years, are shown in **Figure 4-10** and **Figure 4-11**.

Figure 4-10 shows that above a return periods of about 1000 years (0.2 g) the PHA hazard is dominated by the Southwest Klamath Lake fault, whose surface trace lies less than 3 km from the site. This fault is judged capable of earthquakes of magnitude 6.8 (**Table 4-1**). For the 1.0 second response the situation is quite different, with the Cascadia interface source dominating the hazard until a return period of about 20,000 years, whereupon the Southwest Klamath Lake fault becomes the dominant contributor. The Cascadia interface source is characterized by M_w 8.5 or 9.0 events, at a distance of 130 km. This source will produce much stronger lower frequency vibrations than the local fault source, and for a much longer duration.

Table 4-4 gives ground motion amplitudes for the two response periods, for the two return periods.

Table 4-4: Summary PSHA Ground Motions

Return Period (years)	Response Frequency	
	PHA (g)	1.0 second (g)
10,000	0.50	0.67
50,000	0.76	1.08

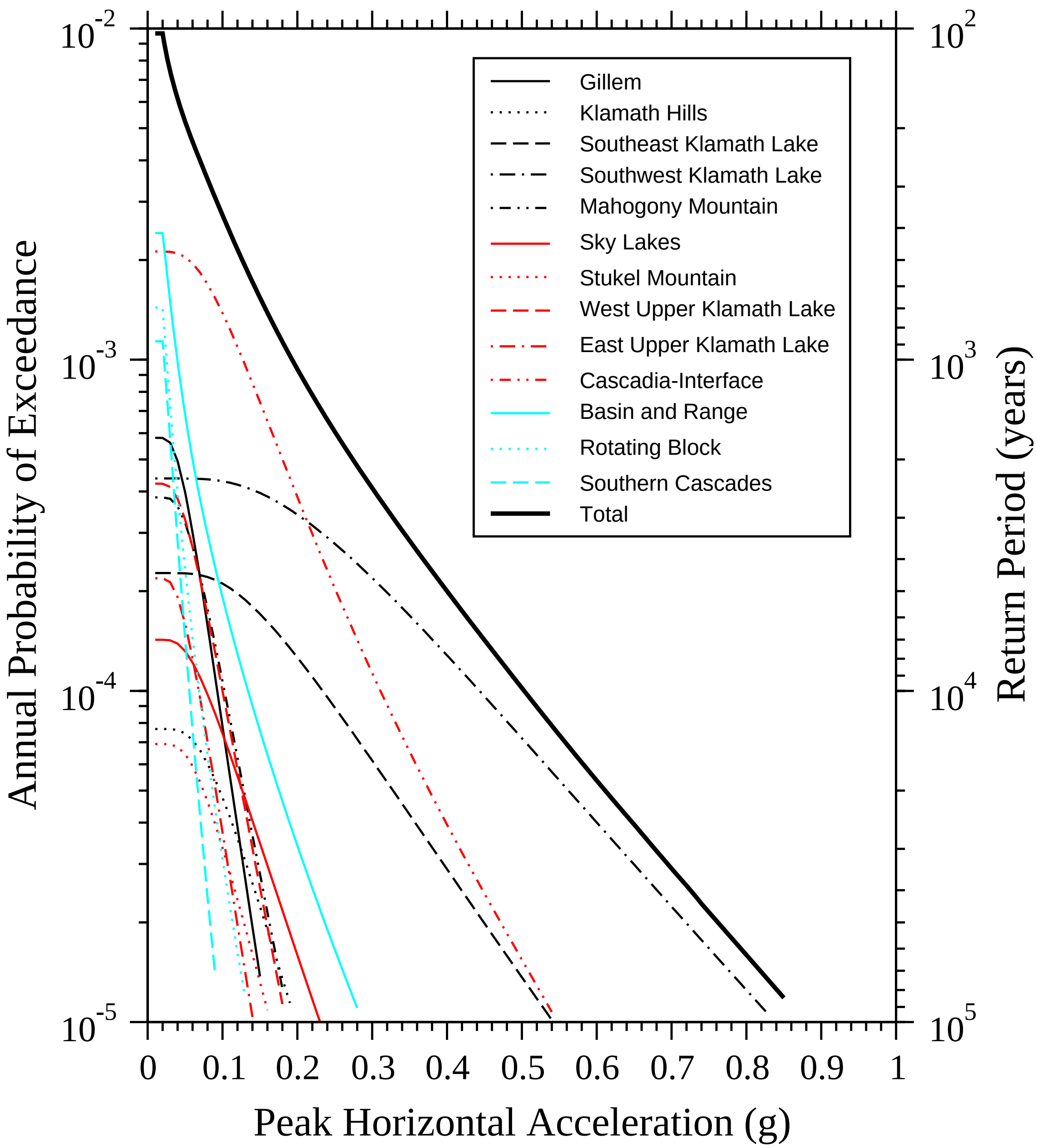

Figure 4-6 Mean hazard curves for PHA, individual sources and total.

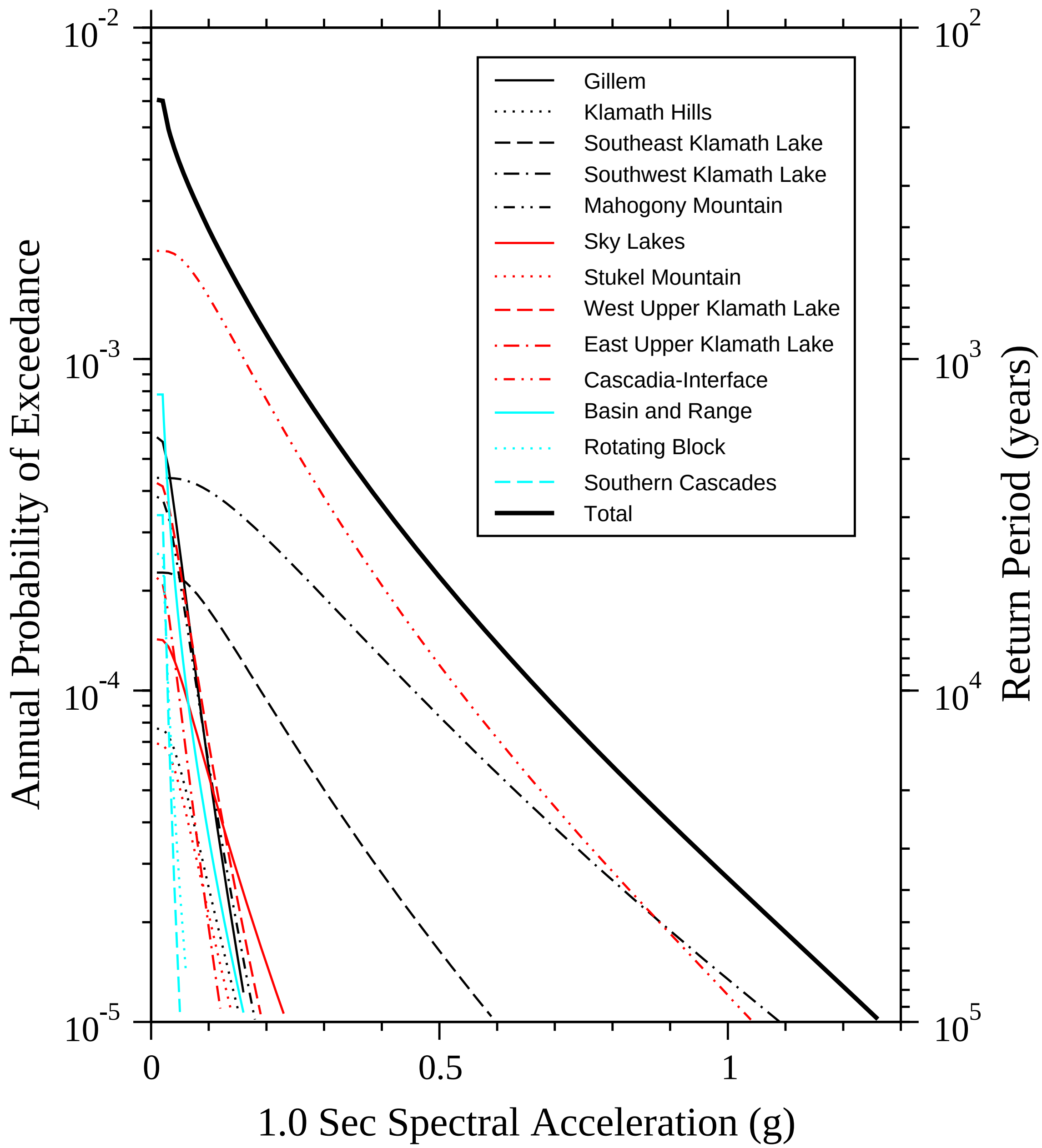

Figure 4-7 Mean hazard curves for 1.0 second spectral acceleration, individual sources and total.

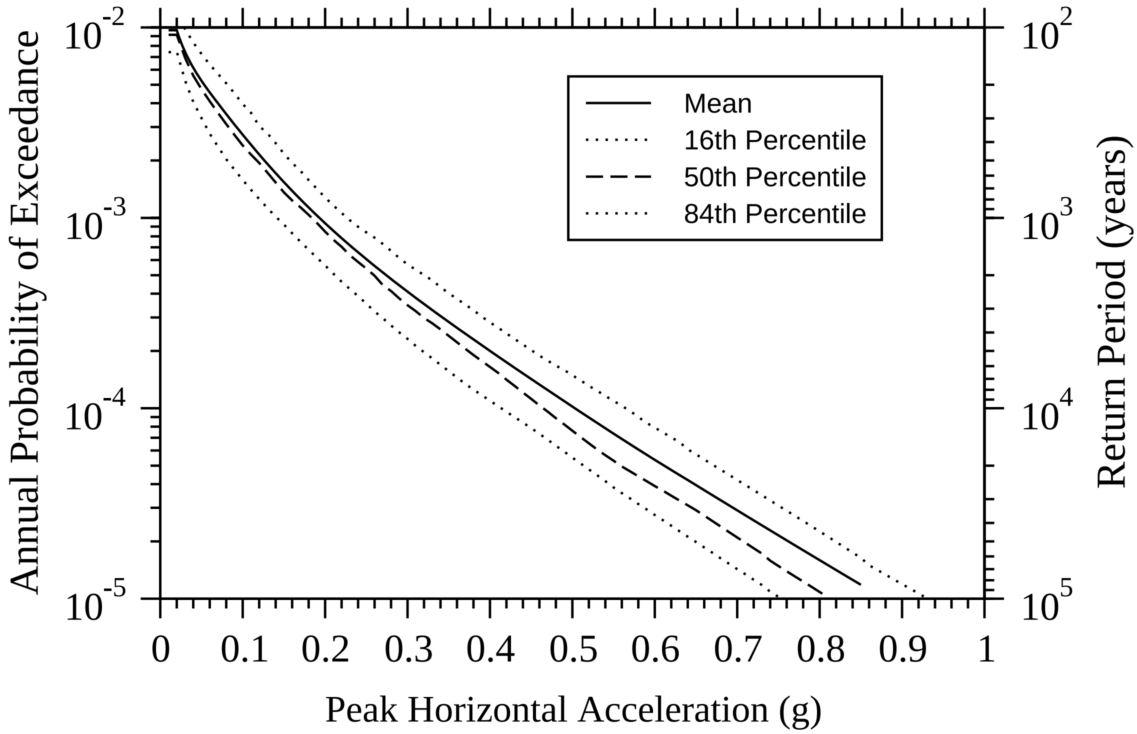

Figure 4-8 Mean and fractile hazard curves for PHA, total hazard.

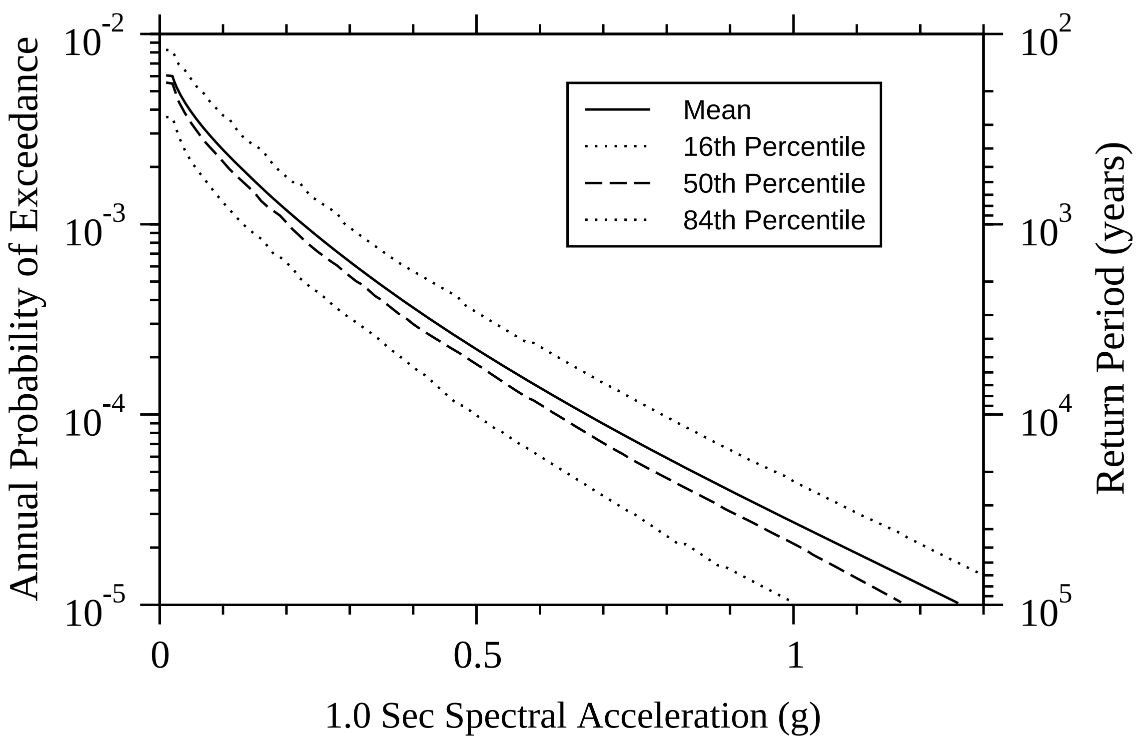

Figure 4-9 Mean and fractile hazard curves for 1.0 second spectral response, total hazard.

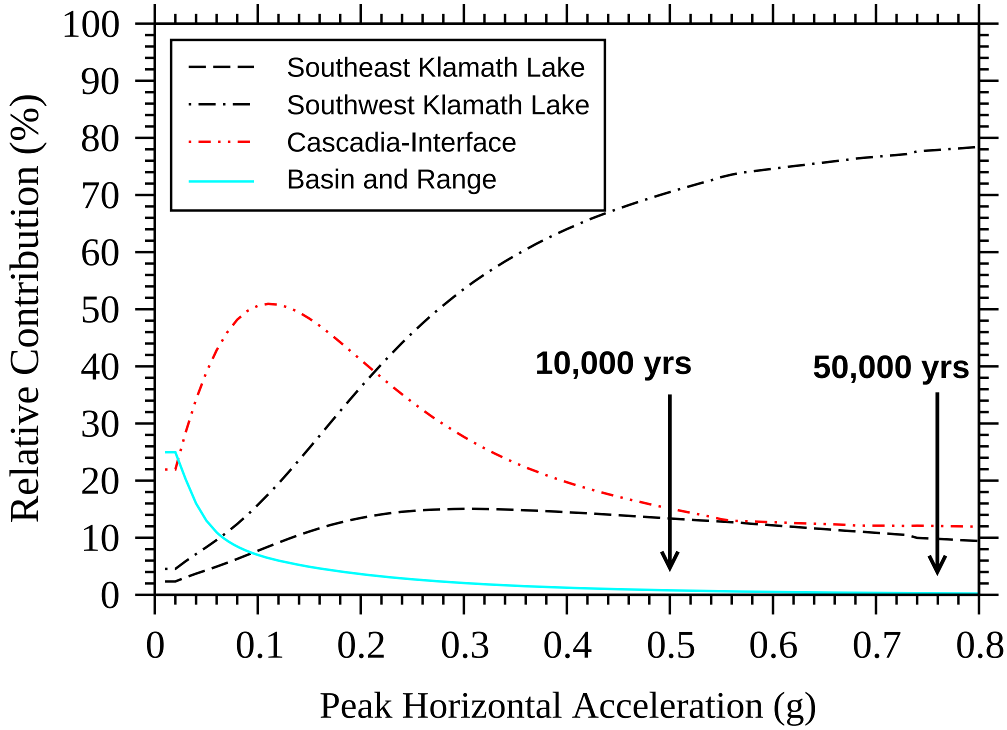

Figure 4-10 Relative contributions to total PHA hazard.

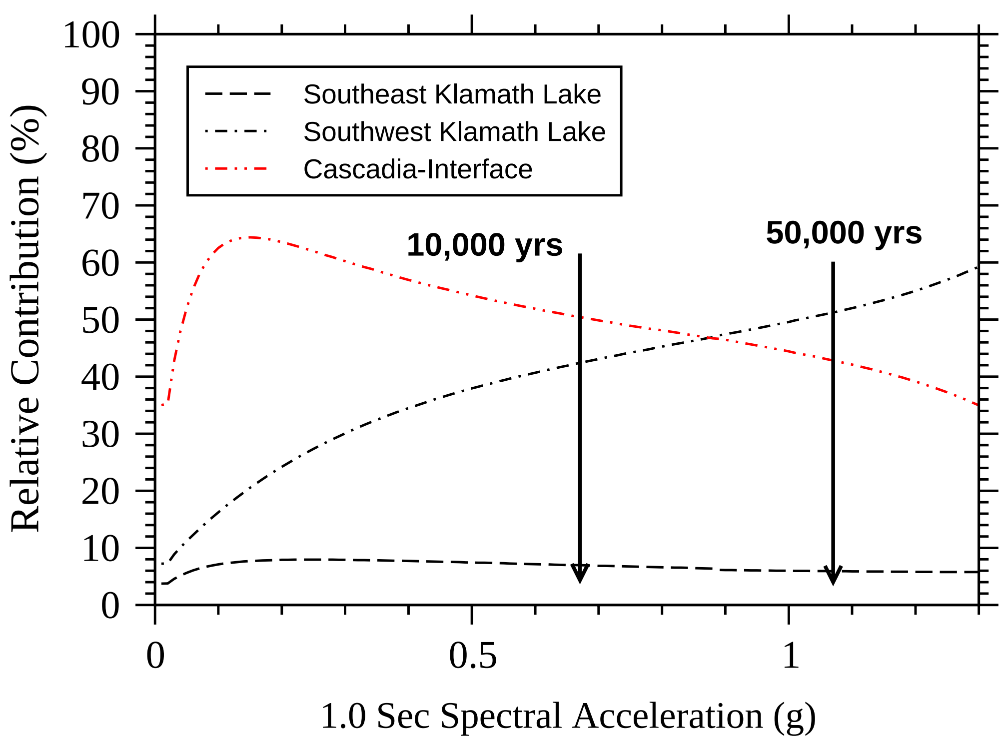

Figure 4-11 Relative contributions to total 1.0 second spectral response hazard.

5.0 CONCLUSIONS

A PSHA was conducted for use in feasibility designs for potential facilities in Long Lake Valley, southern Oregon. The results of this screening-level analysis show that for PHA for return periods greater than about 1,000 years the seismic hazard at Long Lake Valley is dominated by the faults of the Klamath graben, in particular, the nearby faults associated with the southwest margin of the graben. At shorter return periods the hazard is dominated by large events from the Cascadia plate interface. For 1.0-sec spectral response the hazard is dominated by the Cascadia interface up to a return period of 30,000 years, and the Southwest Klamath Lake fault beyond that. Surface fault rupture, as well as liquefaction and seismically-induced landsliding are potential hazards to facilities constructed within and near the margins of both Long Lake Valley and Wocus Marsh. Options that include pumping of water into shallow aquifers as a water storage mechanism, or unless a very large, deep reservoir is constructed, appear to pose a negligible risk of inducing seismicity.

The present study is a screening-level analysis for a generic site in Long Lake Valley. As such, a simplified source model and "rock" site conditions have been assumed. Depending upon the location and type of facility considered for construction, additional studies for appraisal or final designs should include a more detailed seismic source model and geologic field studies to better define slip rates and fault locations. Such investigations should refine the rather simplified seismic source model used for this analysis and better define the risks associated with potential surface fault rupture and other earthquake related hazards.

This PSHA was computed assuming generic “rock” site conditions. As potential sites and associated structures become more specifically identified, the PSHA also should be recalculated using appropriate site correction factors. Finally, the 1993 Klamath Lakes earthquake sequence is important in that it occurred near or directly below the Long Lake Valley site. Although detailed seismological analyses have been performed for the sequence, it is likely that additional analyses, including a simultaneous 3-d velocity model-hypocenter inversion and site response studies, would provide more accurate information regarding fault geometries, velocity structure, maximum depth of faulting, wave propagation, and site response characteristics than is currently available. Analyses of this type also are recommended for any further site development studies.

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Appendix C—*Wetlands Delineation Final Report—Long Lake Valley Offstream Storage Project*, July 2007

WETLAND DELINEATION

FINAL REPORT

LONG LAKE VALLEY OFFSTREAM STORAGE PROJECT KLAMATH COUNTY, OREGON

PREPARED FOR:
U.S. BUREAU OF RECLAMATION
KLAMATH BASIN AREA OFFICE

PREPARED BY:
Tetra Tech, Inc.
1020 SW Taylor Street, Suite 530
Portland, OR 97205

July 2007

1.0 INTRODUCTION

The U.S. Bureau of Reclamation (BOR) is considering the feasibility of creating approximately 350,000 acre-feet of water storage in the Long Lake Valley to supplement existing water supplies in the Klamath Basin (Figure 1). Wetlands in the Long Lake Valley and at the inflow canal corridor/intake/pumping plant could be inundated or disturbed as a result of the proposed action. In order to consider the potential effects and any potential mitigation that could be required, the BOR requires a delineation of wetlands and other Waters of the U.S. to aid in determining appropriate mitigation measures.

1.1 Landowner Information

The proposed project area is currently owned by three major private landowners and the U.S. government.

Parcel Number	Landowner	Contact Information
27933	Alice Kilham, et al.	P.O. Box 212, Klamath Falls, OR 97601
33074	Running Y, Inc.	P.O. Box 1329, Klamath Falls, OR 97601
28265	Jeld-Wen, Inc. c/o Timber Holdings	401 Harbor Isles Blvd., Klamath Falls, OR 97601
31495	James & Carol Creswell	10665 Creswell Ranch Road, Klamath Falls, OR 97601
31419	U.S. Bureau of Land Management	333 SW First Avenue, Portland, OR 97204

2.0 METHODS

This wetland and Waters of the U.S. delineation was conducted via field investigations following the Corps of Engineers Wetland Delineation Manual (Corps 1987) and subsequent implementation guidance, including the Arid West Region Interim Regional Supplement (Corps 2006). Tetra Tech P.W.S. Merri Martz, and staff biologists, David Lundgren, Darlene Siegel, and Meredith Zaccherio, conducted all wetland field investigations during the time period from May 29 through June 7, 2007.

Potential wetland areas were initially identified from aerial photographs and the National Wetland Inventory (NWI 2007). On-line soil surveys (NRCS 2007) were reviewed to determine mapped soils and their characteristics (see Appendix A).

The intermediate-level field sampling methodology described in the Corps 1989 manual (Federal Interagency Committee for Wetland Delineation 1989), was used to develop the transect and sampling plan; however, the determination of wetland/not wetland made at each plot used the 1987 Manual. Additional references utilized included the Munsell ® Soil Color Charts (2000 Edition), *Flora of the Pacific Northwest* (Hitchcock and Cronquist 1973), *The Jepson Manual: Higher Plants of California* (Hickman 1993), *Weeds of the West* (Whitson, *et al*. 1992), Sagebrush Country, a Wildflower Sanctuary (Taylor 1992), Northwest Weeds (Taylor 1990), *National List of Plant Species that Occur in Wetlands: Northwest (Region 9)* (Reed 1988) and the 1993 Supplement (Reed 1993).

The project area is shown in Figures 2 (Long Lake Valley) and 3 (Canal area). In order to identify wetlands in the Long Lake Valley, transects were set up approximately every 3,000 feet perpendicular to the access road along the eastern edge of the valley. At the inflow canal/intake/pumping station site, transects were set up approximately every 1,500 feet perpendicular to the canal levee access road. Supplemental boundary sites were also sampled in between transects as necessary. In addition, the upland areas up to an elevation of 4,430 feet, the proposed maximum surface elevation of the storage lake, were walked to document the presence of streams or wetlands in this area.

Along each transect, vegetation communities were identified and a sample plot was taken in each community at least once (vegetation communities extended across multiple transects and were not sampled at every transect if they had been adequately described in a previous transect). Upland sites were sampled to characterize the distinctions between upland and wetland sites. At each sample plot, indicators of vegetation, hydrology and soils were documented. Vegetation plots were circular and approximately 11 feet in diameter for herbaceous dominated sites, and 33 feet in diameter for shrub or tree dominated sites; or a reasonable dimension to fit within the vegetation community being sampled. Percent cover was estimated visually for plant species present in each cover layer. Typically, all species were documented at each site and then dominants were calculated based on the percent cover in each stratum (herbaceous, shrub/sapling, tree). Second, soil pits were dug to a standard depth of 14-16 inches for determination of both wetland hydrology and hydric soil indicators. Depths to standing water or saturated soil were measured, if present. Soil horizons and texture were identified at each plot and soil matrix and mottle colors, if present, were determined using the Munsell ® Soil Color Charts. The mapped soil survey units were not confirmed in the field; however, if the soil texture and color appeared to match the mapped soil, it was so noted.

Wetland boundaries were documented via a GPS point or line segment using a Trimble GeoXT hand held survey grade GPS unit. The field accuracy of the Trimble units varied from less than 3 feet the majority of the time to approximately 20 feet in areas of tree cover. The accuracy of the wetland boundaries is estimated to be within an average of 5 feet. The boundary line was walked in between the transect lines to obtain a more accurate boundary line, using the line segment function of the Trimble Geo XT, than would be obtained by simply drawing a straight line between transect points in GIS.

Figure 1. Vicinity Map.

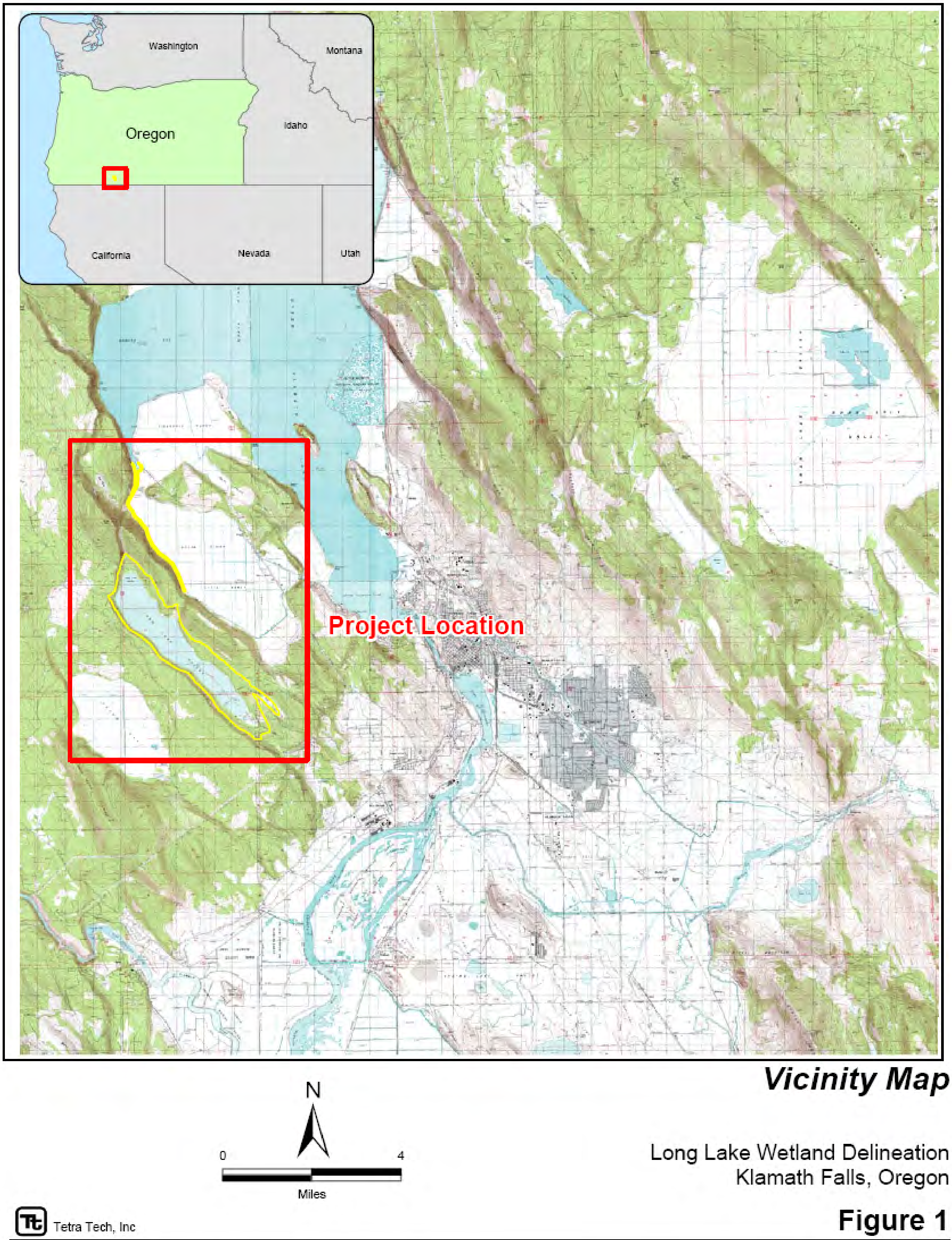
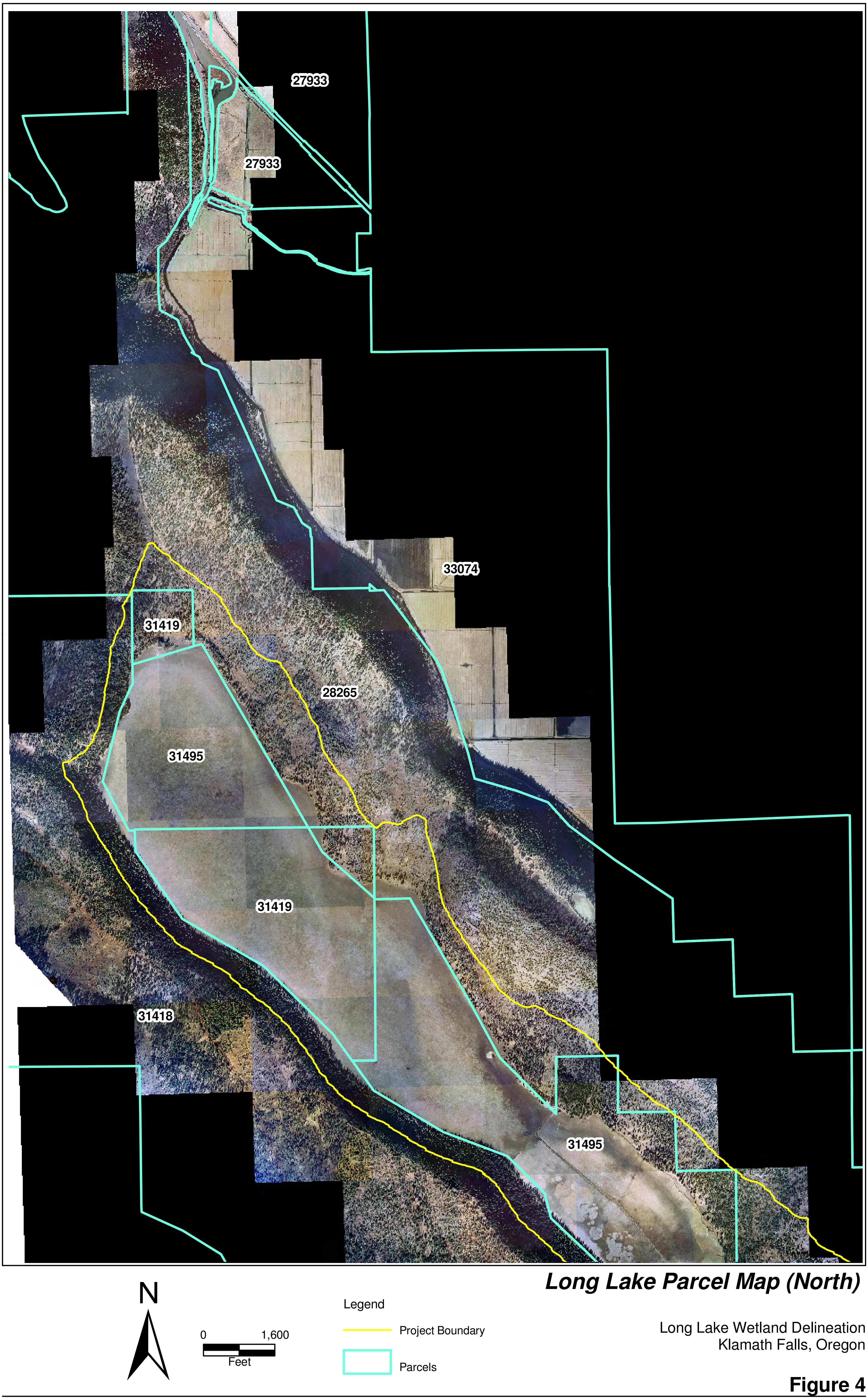


Figure 2. Project site aerial view for Long Lake Valley with project boundary at elevation 4430 feet.

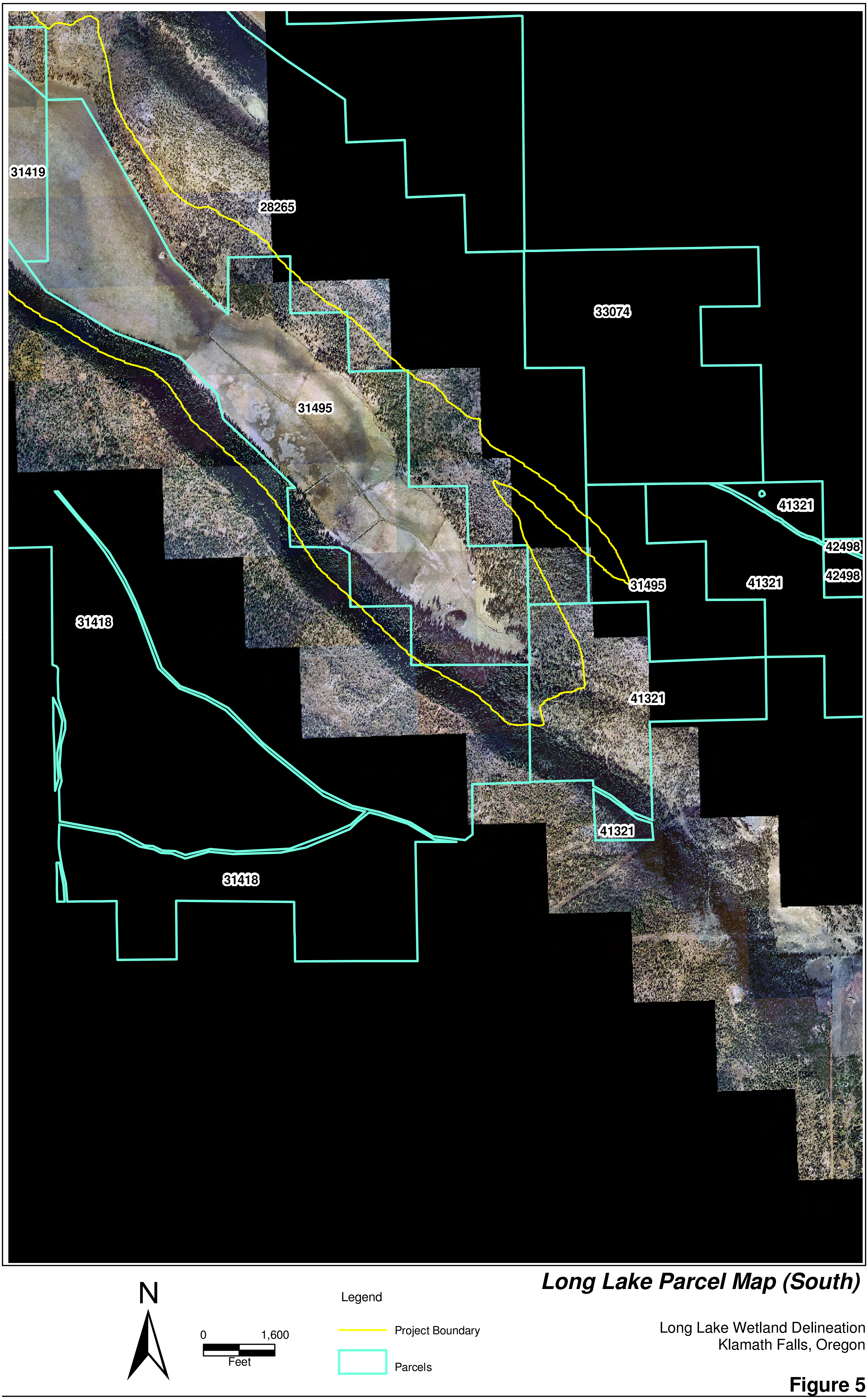
Figure 3. Project site aerial view for the inflow canal area showing 300 foot project boundary.



Long Lake Parcel Map (North)

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 4



Long Lake Parcel Map (South)

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 5

3.0 SITE CONDITIONS

Long Lake Valley is located immediately west of the southern end of Upper Klamath Lake in an enclosed valley that has no outlet drainage. The valley and the surrounding ridges were formed from volcanic activity. The area delineated is approximately 5 miles long and varies in width to a maximum of approximately 4,000 feet (approximately 2,000 acres). Long Lake Valley is predominantly privately owned ranchland (with a portion of the valley operated under a long term lease from the Bureau of Land Management) and is subject to grazing by cattle. The valley is also irrigated via ditches and a small area is irrigated via sprinklers. The landowner had just started irrigation via the ditch system during the time that the field surveys occurred. The stream drainages that flow from the ridges into the valley are all ephemeral. Some of these ephemeral streams have been modified to serve the irrigation function and have been diverted into the irrigation ditches in the valley. Two ponds have been constructed to impound water during the snowmelt season.

The area proposed for the intake canal is located to the east of Long Lake Valley (immediately over the ridge to the east on the southwest corner of Upper Klamath Lake in an area known as Wocus Marsh. The canal project area is approximately 3 miles long and is 300 feet wide (109 acres). The canal area currently has an existing irrigation ditch in the southern 2/3 of the site that is approximately 60 feet wide with an access road/levee that runs along the east side of the canal for most of its length. This ditch outlets into a wider canal that joins with Upper Klamath Lake (Howard Bay). The area to the east of the irrigation ditch and levee is periodically farmed with a cultivated crop such as wheat or corn, or is in pastureland. All areas not in a cultivated crop are grazed by cattle. The area is also irrigated via a dense ditch system. Portions of the site were being irrigated during the field survey.

3.1 Soils

The Soil Survey of Klamath County, Southern Part (SCS 1985) indicates that the study area contains numerous soil types, including Bly loam, Deter clay loam, Harriman loam, Lather muck, Lobert loam, Lorella very stony loam, Pit silty clay, Royst stony loam, Woodcock association, and Woodcock-Rock outcrop. The Long Lake valley floor is dominated by Pit silty clay and Wocus Marsh is dominated by the histosol, Lather muck (see Appendix A maps). Pit silty clay is a poorly drained level soil formed from clayey sediment weathered from tuff and basalt. The surface layer is black silty clay about 6 inches thick and the lower part is black clay about 27 inches thick. Permeability and runoff is very slow. The soil survey identified the Long Lake Valley (closed basin) as having a water table that fluctuates from 0 to 4 feet and is subject to frequent flooding. Pit soil is on the National List of Hydric Soils (SCS 1991) and Klamath County List of Hydric Soils (NRCS 2007). Pit soil is subject to shrinking and swelling. The two major soils surrounding the valley floor are Deter clay loam, and Lobert loam. Deter clay loam is a well drained soil on terraces formed in clayey sediment weathered from tuff, diatomite, and basalt. 1% of the mapped unit is hydric soils on lake terraces. The surface layer is typically very dark brown or very dark grayish brown and can form deep cracks from shrinking and swelling. Lobert loam is a well drained soil on low terraces formed in alluvial and lacustrine sediment weathered from tuffaceous sandstone. The surface layer is a very dark grayish brown loam, and the lower part is a dark brown fine sandy loam. It may contain brittle nodules as much as 3 inches in diameter.

Lather muck is a very poorly drained muck found on diked or drained marshes adjacent to Upper Klamath Lake, and was formed from deep deposits of partially decomposed fibrous organic matter and has one or more layers of diatomaceous silt. It is listed on the National and Klamath County Lists of Hydric Soils (SCS 1991; NRCS 2007). The surface layer is black mucky peat about 6 inches thick, and the lower part is dark brown, fibrous mucky peat. Permeability is moderate and runoff is very slow. If the Lather muck dries out completely it may become hydrophobic.

Long Lake Valley and Wocus Marsh are both potential problem areas[1] because the soils are either of volcanic origin and thus may not show diagnostic hydric soil colors (redoximorphic features), or are organic soils in the canal area and also do not show diagnostic colors (organic soils are typically very dark with a chroma of 1 or less or are very light peaty soils that cannot be reduced). The volcanic soils in some parts of the project area are bright red and thus would not show a chroma of 2 or less even when reduced (Figure 6). Organic soils that have been effectively drained still appear dark and meet hydric soil criteria.

Figure 6. Quarry adjacent to Wocus Marsh showing iron rich volcanic parent material.

3.2 Hydrology

The Long Lake Valley has several potential sources of hydrology, including snowmelt runoff from the surrounding ridges, on-site precipitation, and irrigation. At the time of the delineation, it had been several weeks at a minimum since the snowmelt had occurred. All drainages from the ridgelines were dry. The

[1] Problem areas are defined as areas that may be lacking indicators for one or more of the three wetland parameters due to natural seasonal or annual variations in environmental conditions that result from causes other than human activities or catastrophic natural events (Corps 1987).

valley bottom is a sink for all runoff and fine sediments and appeared to have had higher water earlier in the growing season that had since dried up. The landowner had started irrigating a portion of the site using the ditch along the eastern edge of the valley (fed by private groundwater pumping), adjacent to the access roadway (upslope of the delineation area). The southern end of the valley adjacent to the barns is also seasonally irrigated using sprinklers.

Wocus Marsh has several potential sources of hydrology, including snowmelt runoff, on-site precipitation, irrigation, and flooding from Upper Klamath Lake. The landowner had started irrigating a portion of the site during the field surveys using surface flows from the main canals into smaller ditches running both parallel to and perpendicular to the levee access roadway. All portions of the Wocus Marsh inlet canal area were considered to be directly affected by irrigation.

The winter of 2006-2007 was slightly less than average precipitation for the Klamath Falls area (NOAA NWS 2007). The average annual precipitation for Klamath Falls is 12.44 inches (WRCC 2007). For water year 2007, approximately 10.03 inches of precipitation had fallen through May 2007. This is 85% of the average to date (NOAA NWS 2007). During the site visit, it showered occasionally.

Both the Long Lake Valley and Wocus Marsh are potential problem areas for hydrology, because of the prolonged summer and fall drought and due to the highly manipulated irrigation regime. Wetland areas would not likely be saturated or inundated after the early part of the growing season due to natural precipitation and runoff, but, due to irrigation, some areas are likely to be wetter than would occur naturally.

3.3 Vegetation

The project area has several distinct plant communities including emergent marsh, pastureland, cultivated crops, Ponderosa pine woodland, Douglas fir woodland, and sagebrush dominated scrubland. The entire project area is subject to grazing by cattle, and was being grazed during the field surveys. In some cases, this affected our ability to identify plant species.

4.0 RESULTS

A total of 200 plots were sampled between the two project areas, along 24 transects, plus the drainages and upland areas were also characterized (Figures 15-19). Copies of all completed Wetland Determination Data Forms are provided as Appendix B. A complete list of vegetation species identified on the sites is provided as Appendix C.

Six wetlands and nine other waters of the U.S. (intermittent streams and canal deepwater habitat) were delineated within the two project areas. There are multiple irrigation ditches also present, which were generally not delineated. A description of the hydrologic, hydrophytic vegetation, and hydric soils characteristics are presented for each of the wetland and water sites and representative upland sites, below.

4.1 Long Lake Valley Wetland 1

This wetland occupies the majority of the valley bottom within Long Lake Valley and is identified on the NWI map as a freshwater emergent wetland with a fringe around the northern end of freshwater shrub wetland. The boundaries of this wetland generally follow subtle topographic swales that are a foot or two in elevation above the valley bottom. In some locations, the tree line is approximately the boundary and in other locations, due to management for pastureland, the boundary is more defined by topography than a vegetation break.

Transects T-1, T-2, T-5, T-7, T-11, T-a, T-b, T-c, and three boundary transects b-6 were completed in this wetland, along with additional boundary points as necessary and points along the levees and ditches in the interior of the wetland. In general, the center of the valley was inundated with standing water up to 3-4 feet in depth. The transects were thus not completed as one complete unit, but completed by two separate teams working on the opposite side of the valley. Sample plots were taken from the uplands towards the wetland until the water became too deep to cross.

The southern third of the valley has a system of irrigation ditches and side-cast “levees” that encircle various sections and can be seen on the aerial photograph in Figure 2. In general, these “levees” appear to be uplands but are a small part of the overall acreage, would have been very time consuming to delineate each one, and were thus lumped in with the rest of the wetland. At the south end of the valley, the wetland is surrounded by slightly higher elevation irrigated pasture/grassland in the vicinity of the landowner’s barns and house. The dominant species were *Agrostis alba* (redtop), *Alopecurus pratensis* (meadow foxtail), *Alopecurus aequalis* (little meadow foxtail), *Poa bulbosa* (bulbous bluegrass), a non-blooming *Poa* species (believed to be *Poa pratensis*, Kentucky bluegrass), *Phalaris arundinacea* (reed canary grass), and a variety of Brassicates. These grass species varied in dominance near the wetland boundary. Along the eastern and western margins of the valley and at the northern end, the hillslopes come down to meet the valley floor and there is typically a fairly abrupt topographic transition from Ponderosa pine or Douglas fir woodland onto the emergent valley floor. Table 1 identifies the wetland boundary points and basis for boundary determination for each transect.

Table 1. Boundary plots and basis for boundaries at transects in Long Lake Wetland 1.

Transect	East Upland Plot	East Wetland Plot	Basis for Boundary	West Upland Plot	West Wetland Plot	Basis for Boundary
T-1	T-1-2	T-1-3	End of surface soil cracking and slight vegetation change from FAC dominant to FACW or wetter dominant species	T-1-14	T-1-13	Change in vegetation from Alopecurus/Juncus dominated to Pinus/Poa dominated and soil texture change
T-2	T-2-10	T-2-9	End of surface soil cracking and soil texture change	T-2-1	T-2-2	End of surface soil cracking and soil texture change
T-5	T-5-4	T-5-5	End of surface soil cracking and soil texture change	T-10a-2	T-10a-1	Soil texture change and vegetation community change
T-7a	T-7a-5	T-7a-6	End of surface soil cracking and soil texture change	b1-6	b1-5	Edge of forested vegetation and soil texture change (b1-5 was on boundary)
T-11	T-11-2	T-11-3	End of surface soil cracking and soil texture change		T-5a-1	End of surface soil cracking and soil texture change
T-a	Ta-2	Ta-3	Soil texture and color change and where Eleocharis ends	b1b-1	b1b-2	End of surface soil cracking and soil texture change
T-b	Tb-2	Tb-1	Change in soil texture, topographic break, and vegetation dominance	b2b-4	b2b-5	End of surface soil cracking and soil texture change and vegetation dominance
T-c	Tc-1	Tc-2	End of surface soil cracking and soil texture change	T6_5-1	T6_5-2	T6_5-1 is boundary where soil cracking ends and soil texture changes
b-6(1)	B6-7	B6-8	End of surface soil cracking and soil texture change	B5-5	B5-6	End of surface soil cracking and soil texture change
b-6(2)	B6-4	B6-5	End of surface soil cracking and soil texture change	B5-3	B5-4	End of surface soil cracking and soil texture change
b-6(3)	B6-1	B6-2	End of surface soil cracking and soil texture change	B5-2	B5-1	Soil texture change and saturated soils

At transect T-1, plot 1 was identified as definitely upland on the eastern side of the valley, and was dominated by *Agrostis alba* (FAC), the likely *Poa pratensis* (FAC), and *Phalaris arundinacea* (FACW). While this community meets the hydrophytic vegetation indicator of greater than 50% of the dominant species are FAC or wetter, there were no indicators of hydrology and the soil was very dry and hard silty loam with a color of 10YR2/2, but no mottles. At transect T-1, plot 8, the definite wetland was dominated by *Eleocharis palustris* (common spikerush, OBL), *Phalaris arundinacea* (FACW), and an unidentified *Festuca* species (*Festuca rubra* or *Festuca idahoensis*; FAC+ or FACU). Thus, 67% of the dominant species were FAC or wetter, and there was standing water at the surface, and the soil was clay with a color of 10YR3/1, thus also meeting the hydrology and hydric soil criteria. Further into the wetland, the community had no grass species other than *Phalaris arundinacea*, and also included *Alisma plantago-aquatica* (water plantain, OBL). Multiple sample points were taken in between plots 1 and 8 to define the wetland boundary. The boundary was determined to be at plot 4 between plots 2 and 3. Plot 2 was dominated by *Alopecurus pratensis* (FACW), *Alopecurus aequalis* (OBL), and *Trifolium repens* (white clover, FAC) and thus met the hydrophytic vegetation criteria, but there were no hydrology indicators and the soil was the same dry and hard silty loam with a color of 10YR2/2. Plot 3 was dominated by the same three species, *A. pratensis, A. aequalis*, and *T. repens*, but was in a swale with very cracked soil, and the soil texture had transitioned to clay with a color of 10YR2/2. While Plot 3 clearly meets the hydrophytic vegetation and hydrology criteria, the hydric soil is somewhat tenuous because there were no oxidation or depletion mottles in the soil matrix. However, based on the strong hydrophytic vegetation and hydrology indicators, the preponderance of evidence points to Plot 3 being wetland (Figure 7). The boundary at Plot

4 was determined based on the change in soil texture from clay to loam, the loss of soil surface cracking, and a slight change in dominant species to include more dominance from *Agrostis alba*, a FAC species.

On the western side of the valley, the definite upland was Plot 14, dominated by *Pinus ponderosa* (ponderosa pine, FACU-), *Achillea millefolium* (yarrow, FACU), *Rosa woodsii* (FACU), and the probable *Poa pratensis* (FAC). There were no indicators of hydrology, and the soil was loam of color 10YR2/2. The definite wetland was Plot 13, dominated by *Alopecurus aequalis* (OBL) and *Alopecurus pratensis* (FACW) with saturated soils and clay soils of matrix color 10YR2/2 and mottles of 2.5YR4/8. The boundary was determined between these two close plots by the change in vegetation. In general, on the west side of the valley, there was a much more significant topographic break or vegetation change at the wetland boundary that was far more straightforward to identify.

There are a number of irrigation ditches and side-cast "levees" that occur throughout the southern third of the valley (Figure 8). The levees were sampled versus the inundated wetland areas adjacent to them at Transect T-4. The levee soil was obviously excavated and comprised of the same soil as was present in the wetland, thus having the same color (10YR2/1). At Plot 1, the dominant species were *Phalaris arundinacea* (FACW) and *Populus tremula* (aspen, FAC+) which was not rooted on the levee, but was immediately adjacent. The soil was cracked and had a color of 10YR2/1. This meets all wetland criteria. For the purposes of this delineation, these levees have been included in the total wetland acreage because in many sample plots they did meet wetland criteria, although there may be small patches that would not qualify as wetlands. The majority of the interior portion of the wetland was inundated with more than 2 feet of water during the delineation and numerous waterfowl were observed in this area (Figure 9).

Moving north from transect T-1, the boundary was determined by the presence of cracked soil. Plots B2-1 and B2-2 were taken to identify upland and wetland. Plot B2-1 was dominated by *Agrostis alba* (FAC) and *Trifolium repens* (FAC), had no hydrology indicators and had silty hard dry soil of 10YR2/2. Plot B2-2 was dominated by *Trifolium repens* (FAC), *Alopecurus aequalis* (OBL), and an unidentified non-blooming forb, and had surface soil cracking, and moist clay soil of color 10YR2/2. Plots B2-7 and B2-8 identified where the wetland swung closer to the eastern access roadway, and it appears that the irrigation ditch in this area leaked water out into the field. Plot B2-7 was dominated by *Juncus balticus* (Baltic rush, FACW+), *Carex athrostachya* (slenderbeak sedge, FACW), *Alopecurus pratensis* (FACW), and *Phalaris arundinacea* (FACW), and had clayey loam or loamy clay soils with a matrix color of 10YR2/1 and mottles of 2.5YR4/8. There was no surface soil cracking, but the preponderance of hydrophytic vegetation and redoximorphic features indicates that this area is wetland. Plot B2-8 was on the slope of the ditch and dominated by *Cardaria draba* (hoary cress, N.L.) and *Bromus tectorum* (cheatgrass, N.L.) and had silty loam soils of color 10YR2/2 and no indicators of hydrology. The boundary was determined at the vegetation and topographic change.

North of transects T-4 and T-5, the eastern edge of the valley becomes more topographically distinct, similar to the western edge (Figure 10), and the boundary comes closer to the eastern access road and the tree line. For example, at transect T-11, the definite upland was dominated at Plot 1 by *Pinus ponderosa* (FACU-), *Juniperus occidentalis* (western juniper, N.L.), and *Poa bulbosa* (N.L.), with dry loamy soil of 10YR2/2 and no hydrology indicators. The definite wetland at Plot 6 was dominated by *Phalaris* *arundinacea* (FACW), *Juncus drummondii* (Drummond's rush, FACW-), and *Eleocharis palustris* (OBL), with standing water. The boundary was determined between Plots 2 and 3. Plot 2 is dominated by *Agrostis alba* (FAC), *Festuca rubra* (red fescue, FAC+) and the probable *Poa pratensis* (FAC), with no hydrology indicators and loamy soil of color 10YR2/2. Plot 3 is dominated by the same species, but has surface soil cracking and heavy clay soil with a color of 10YR2/2. The boundary was determined where the soil texture changed and surface soil cracking ended.

At transect T-A, the definite upland at Plot 1 was similarly dominated by Pinus ponderosa woodland with a wide variety of shrub and herbaceous species; none of the dominants were FAC or wetter, and the soils were loamy with a color of 10YR2/2 and no hydrology indicators. However, at this transect, the boundary was primarily determined by the vegetation community. Plot 2 was dominated by *Artemisia cana* (sagebrush, FACU), *Poa bulbosa* (N.L.), and *Juniperus occidentalis* (N.L.) with a shallow clay surface layer that was cracked, but below 4 inches, the soil became sandier and loamy with a color of 10YR2/2. Plot 3 was dominated by *Artemisia cana* (FACU), *Eleocharis palustris* (OBL), and *Silene noctiflora* (N.L.) and the soil texture changes to heavy clay with significant surface soil cracking and a color of 10YR3/1. The boundary was determined where the *Eleocharis* was no longer a dominant species. On the western side of this transect, the boundary was determined between Plots B1-b-1 and B1-b-2. Plot B1-b-2 was dominated by *Populus tremula* (FAC+), *Pinus ponderosa* (FACU-), *Fragaria virginiana* (strawberry, FACU), and *Agrostis alba* (FAC) with loamy soil of color 10YR2/2 and no hydrology indicators. Plot B1-b-2 was dominated by *Eleocharis palustris* (OBL), *Juncus drummondii* (FACW-), and *Eleocharis bella* (FACW) with heavy clay soil of color 10YR2/1 and significant surface cracking. The boundary was determined where the soil cracking ended and the soil texture changed from clay to loam.

The remainder of the boundary around the north end of the valley was determined primarily by the presence of cracked soils and the soil texture change from clay to loam. The clay soils where the wetland boundary was typically determined appear to match the description of Pit clay soils from the soil survey, and are hydric.

Figure 7. Soil cracking and *Alopecurus* dominance typical of Wetland 1 near wetland boundary.

Figure 8. Interior "levees" in Wetland 1 formed from side-cast material from ditches.

Figure 9. Sandhill cranes in the interior inundated area of Wetland 1.

Figure 10. View from Wetland 1 towards western ridgeline showing abrupt change in vegetation.

4.2 Long Lake Valley Wetland 2

This wetland is an obvious isolated and bermed pond located approximately 1000 feet south of Wetland 1 and nearer the landowner's house and is shown in Figure 11 and identified as Wetland 2 on Figure 17. The boundary was determined such as between Plots Lake 1 and Lake 2. Plot Lake 2 was the obvious upland and was dominated by *Agrostis alba* (FAC) and the probable *Poa pratensis* (FAC), and had loamy soil of color 10YR2/2 and no hydrology indicators. Plot Lake 1 was in the obvious wetland and was dominated by *Eleocharis palustris* and had saturation to the surface and loamy soil with a color of 10YR3/1. The boundary was determined at the obvious topographic break where soil saturation was well below 12 inches and where the vegetation changed from FAC dominated to FACW or wetter dominated.

Figure 11. Looking northwest across Wetland 2 towards western ridgeline.

4.3 Long Lake Valley Wetland 3

This wetland is located in the alignment of two ephemeral creek channels, identified on USGS quads as Home Creek, which flow north from the southern ridge line and includes a small pond that has been created to store water during the snowmelt runoff (Figure 12). This wetland is shown as a linear line on Figure 17 labeled Wetland 3. The landowner indicated that in the 1940s, these channels were deep scour channels (similar to arroyos) and the southern end of the valley was an unvegetated alluvial fan. This may have been a result of historic logging and a high level of sediment transport. The landowner and his father recontoured the channels to direct the flow towards the valley and create a flatter area for the house and pastureland. The creek channel/swale is dominated primarily by *Alopecurus pratensis* (FACW) and includes *Juncus balticus* in many areas, and has either clay or clayey loam soils with a color of 10YR3/1 with cracking in the flatter areas. Only the actual creek channel was considered wetland. Upland vegetation begins approximately 12 inches upslope of the creek channel. The ponded reservoir had standing water in a portion of the site and was saturated to the surface in the remainder of the pond. Dominant plant species included *Eleocharis palustris* (OBL) and *Oenothera tanacetifolia* (N.L.). The soil was loamy clay with a color of 10YR2/1 in the surface layer, but became very rocky loam at depth with a matrix color of 10YR4/4 and mottles of 2.5YR 4/8.

Figure 12. Pond portion of Wetland 3.

4.4 Long Lake Valley Wetland 4

This wetland is a small wetland apparently created as a result of excavation of a large deep hole that may have been used as a burn site or a small landfill. It is shown on Figure 17 as Wetland 4. There was standing water in the hole at the time of the survey and the wetland area was dominated by *Carex athrostachya* (FACW) and *Rosa gymnocarpa* (FAC). Pinus ponderosa was overhanging the site, but was rooted in the upland. The soil was loamy clay with a color of 10YR2/1. There were buried iron pieces that had decomposed. The adjacent upland was dominated by *Pinus ponderosa* (FACU-), *Poa bulbosa* (N.L.), *Rosa gymnocarpa* (FAC), *Agrostis alba* (FAC), and *Lonicera utahensis* (honeysuckle, FAC). The soil was dry clay loam with a color of 10YR2/1 and no hydrology indicators. While this hole meets wetland criteria, it appears to be an artifact of human excavation and is also isolated.

4.5 Long Lake Valley Drainages

All other drainages that appear on the USGS quads for the area were investigated to document if they had wetland characteristics and are shown on the map as Drainages A through J. Drainages A through F and H and I are rocky intermittent channels that have little to no vegetation in the channel. The riparian or surrounding vegetation is dominated by *Pinus ponderosa* (FACU-), *Pseudotsuga menziesii* (Douglas' fir, FACU), and shrubs such as *Ceanothus velutinus* (mountain balm, N.L.), *Rhamnus purshiana* (cascara, FAC-), *Arctostaphyllus patula* (manzanita, N.L.), *Artemisia tridentata* (Great basin sage, N.L.), and *Purshia tridentata* (antelope brush, N.L.). These drainages do not meet wetland criteria, but are intermittent streams.

Drainage G had saturated soils and a small area of standing water toward its lower end. Dominant species in the channel included *Poa bulbosa* (N.L.), *Eleocharis palustris* (OBL), *Alopecurus aequalis* (OBL), and *Alopecurus pratensis* (FACW). This channel seasonally meets wetland criteria, and is also an intermittent stream channel.

Drainage J in the upper end had *Alopecurus aequalis* (OBL) and *Juncus bufonius* (FACW) in the channel with loamy soil with matrix color 10YR2/2 and mottles of 2.5YR4/6. This channel seasonally meets wetland criteria, and is also an intermittent stream channel.

4.6 Irrigation Ditches

There are several irrigation ditches on the Long Lake Valley site and the irrigated portion of the valley is shown in Figures 17-19. These ditches were not separately evaluated in the determination of wetlands, although the ditch to the lake meets wetland criteria. These are human-created and would not have water but for deliberate import of water for irrigation.

4.7 Wocus Marsh Canal Area Wetlands

The majority of the proposed intake canal area in Wocus Marsh was determined to be wetlands, except for the toe of the hillslope on the west side and the levee access roadway immediately adjacent to the irrigation ditch/canal on the east side. Twelve transects were sampled in this area. The western side of the canal has loamy or clayey soils derived from the hillslope; the eastern side of the canal has entirely organic soils that are relict from the Wocus Marsh soil formation. Transects included points on both sides of the canal, with a definite wetland point at the canal on each side and then in the upland on the west side and on the upland levee and then in the typically wet lower ground on the east side. Lateral levees and drainage/irrigation ditches were not delineated, but were lumped in with the upland and wetland acreages, respectively.

Transect C1 had Plots A and 2 in the canal area. Dominant species included *Alopecurus pratensis* (FACW), *Polygonum aviculare* (prostrate knotweed, FACW-), *Typha latifolia* (cattails, OBL), and *Phalaris arundinacea* (FACW). The soil was saturated or inundated and comprised of muck or mucky clay with soil color of 10YR2/1. The upland on the west side at Plot 1 was dominated by *Alopecurus* *pratensis* (FACW) and *Phalaris arundinacea* (FACW), but had no hydrology indicators and the soil was loam with a color of 10YR2/2. Typically the soil was very rocky on the western slope of the ridge. The levee adjacent to the canal was dominated by *Elymus canadensis* (FAC), but was drained organic soil with no indicators of hydrology (Figure 13). The levee was constructed likely of material excavated for the canal as well as imported crushed rock. Diatomaceous earth layers were encountered while digging soil pits in the levee. To the east of the levee, the ground surface is at least 2 feet lower in elevation as is grazed pasture that was being irrigated via ditches at the time of the field delineation. Dominant species at Plot C included *Elymus canadensis* (FAC), *Alopecurus pratensis* (FACW), and *Agrostis alba* (FAC). The soil was saturated in the upper twelve inches and was entirely organic (mucky peat). The pastureland continued beyond the edge of the project area. Transects C2 and C3 were in the same community, although at Transect C2, the levee fill extended directly east.

Table 2. Boundary plots and basis for boundary at transects in canal area.

Transect	East Upland Plot	East Wetland Plot	Basis for Boundary	West Upland Plot	West Wetland Plot	Basis for Boundary	Farmed Wetland
C-1	C1-B	C1-A	Lack of hydrology indicator	C1-1	C1-2	Lack of hydrology indicator	East of the levee, the grazed pastureland meets wetland criteria to edge of project boundary
C-2	C2-C	C2-A	Lack of hydrology indicator	C2-2	C2-1	Lack of hydrology indicator	Levee and side-cast material continues east at this transect
C-3	C3-C	C3-A	Lack of hydrology indicator	C3-1	C3-2	Lack of hydrology indicator	East of the levee, the grazed pastureland meets wetland criteria to edge of project boundary
C-4	C4-A	N/A	Lack of hydrology indicator	C4-1	C4-2	Lack of hydrology indicator	Farmed field effectively drained at time of survey; not being irrigated.
C-5	N/A	C5-A	Lack of hydrology indicator	C5-1	C5-2	Lack of hydrology indicator	East of the levee, the grazed pastureland meets wetland criteria to edge of project boundary
C-6	C6-B	C6-A	Lack of hydrology indicator	C6-1	C6-2	Lack of hydrology indicator	Levee and side-cast material continues east at this transect; C6-C is in grazed pastureland that meets wetland criteria to edge of project boundary
C-7	N/A	C7-A	Lack of hydrology indicator	C7-2	C7-1	Lack of hydrology indicator	East of the levee, the grazed pastureland meets wetland criteria to edge of project boundary
C-8	C8-B	C8-A	Lack of hydrology indicator	C8-1	C8-2	Lack of hydrology indicator	East of the levee, the grazed pastureland meets vegetation and hydric soil criteria to edge of project boundary. However, this cell is not currently being irrigated and is not saturated. When irrigation is turned on, it would meet all 3 criteria.
C-9	N/A	C9-A	Lack of hydrology indicator	N/A	C9-1	Lack of hydrology indicator	East of the levee, the grazed pastureland meets vegetation and hydric soil criteria to edge of project boundary. However, this cell is not currently being irrigated and is not saturated. When irrigation is turned on, it would meet all 3 criteria.
C-10	N/A	N/A		C10-2	N/A	Lack of hydrology indicator	Wetland continues from Transect C-9 to parking area and major cross-canal
C-11	N/A	N/A		C11-1	N/A	Lack of hydrology indicator	From boundary to east edge of project boundary is all open water, but for road fill.
C-12	N/A	N/A		C12-1 and 2	N/A	Road fill of rocks/boulders	From boundary to east edge of project boundary is all open water, but for road fill.

Transect C4 had a vertical bank on the east side of the canal, so no wetland plot was taken on that side. Plot 1 was upland on the west side dominated by *Ribes* sp. and grazed *Phalaris arundinaceae* with no hydrology indicators. Plot 2 was wetland dominated by *Typha latifolia* and *Alopecurus pratensis* and saturated soils. East of the levee was a plowed and planted field (corn or wheat) that was dry and not being irrigated (Figure 14). When this field is flood irrigated it would meet wetland criteria.

Transects C5 – C7 were similar to Transects C1-3 in that the pastureland east of the levee was wet and currently being irrigated and was dominated by *Phalaris arundinacea* (FACW) on wet organic soils (Figure 15).

Transects C8 and C9 had wetland plots at C8-A, C8-2, C9-A, and C9-1 along the canal. The basis for the boundary was the loss of hydrologic indicators. East of the levee, the grazed pastureland was dominated by *P. arundinacea* (FACW) and had organic soils, but was not currently being irrigated and thus did not have hydrologic indicators. However, it would have hydrologic indicators when the irrigation was turned on. This area was also considered wetland.

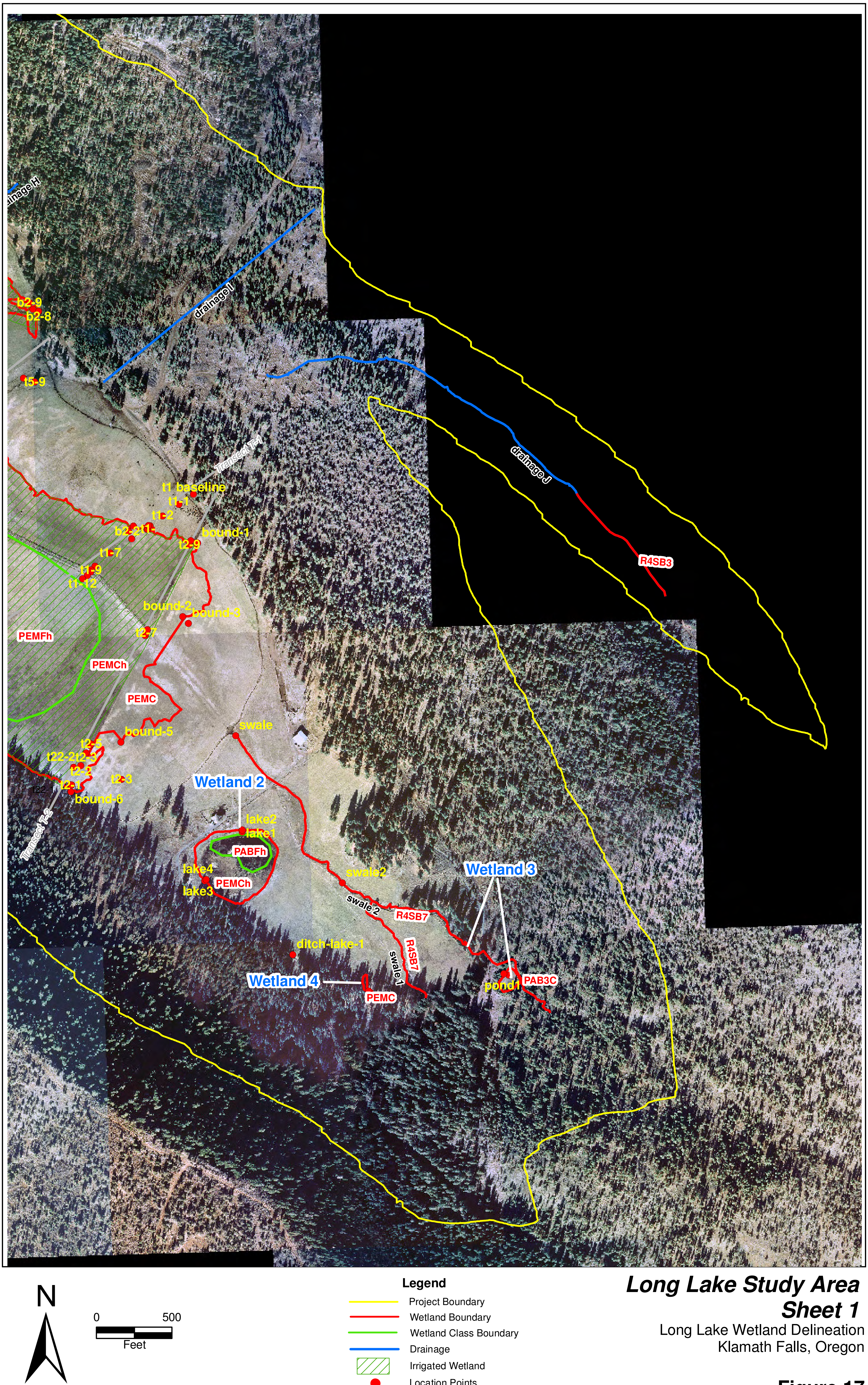
From the parking area to the north, the wetland boundary along the west shore of the canal identifies the western boundary. However, from that point east, the rest of the project area is open water, but for the levee road comprised of rock fill (Figure 16).

Figure 13. Canal and levee along east side of proposed intake canal area.

Figure 14. Levee/roadway along east bank of canal, showing farmed field to east.

Figure 15. Saturated organic soil in irrigated pastureland, Transects C6 and C7.

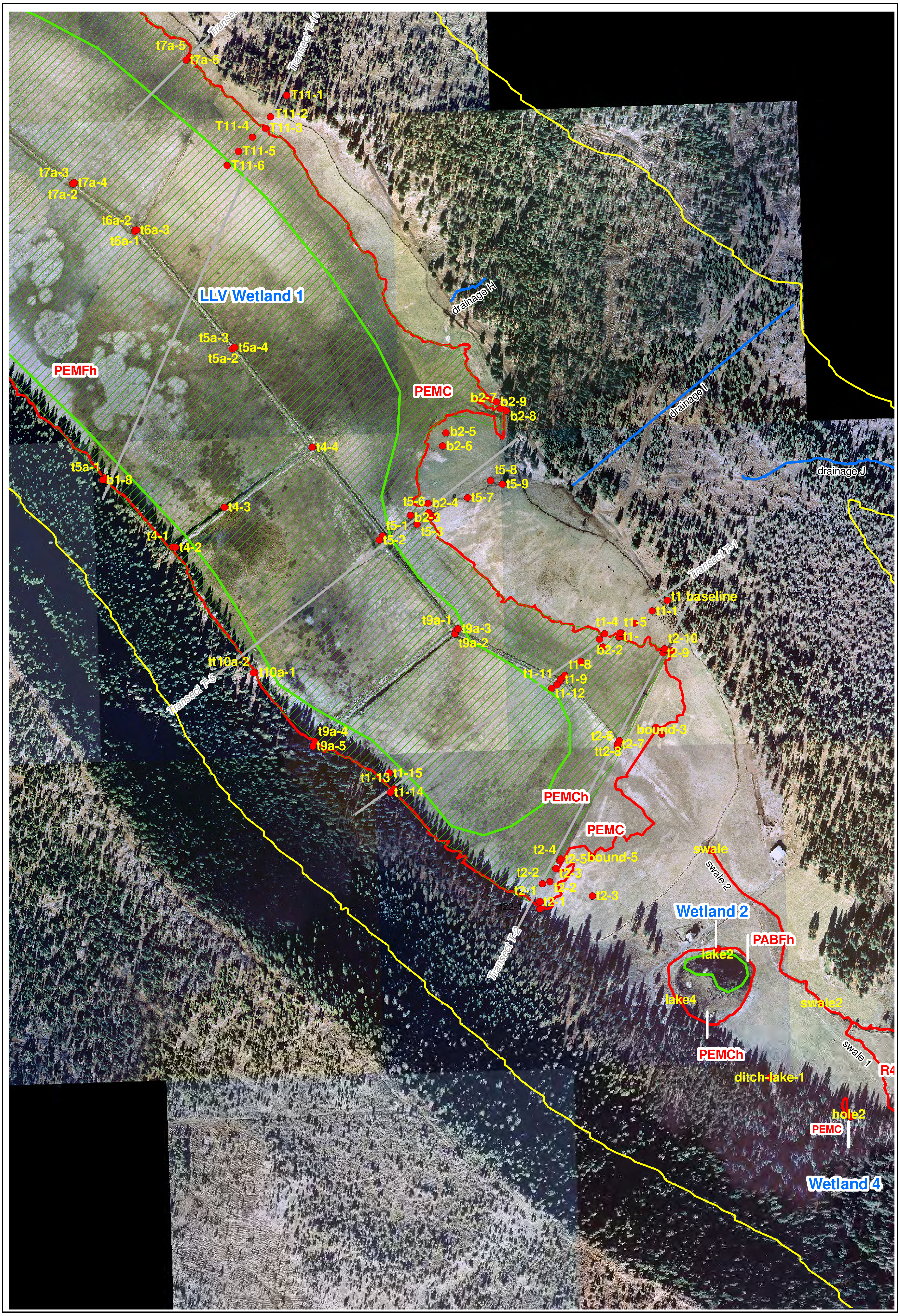
Figure 16. Open water north of parking area.



Long Lake Study Area
Sheet 1

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 17



N

0 510
Feet

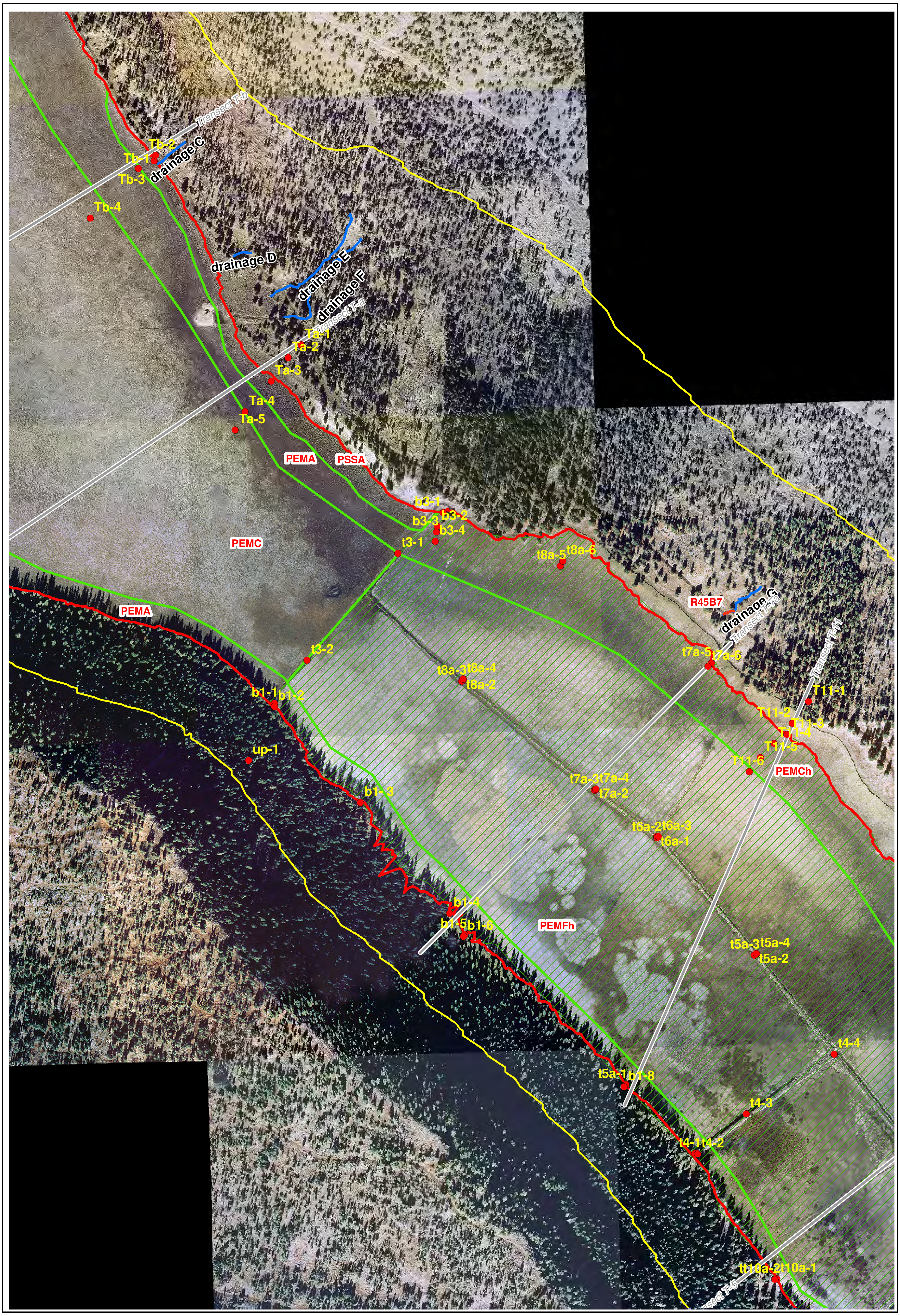
Legend

- Project Boundary
- Wetland Boundary
- Wetland Class Boundary
- Drainage
- Irrigated Wetland
- Location Points

Long Lake Study Area Sheet 2

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 18



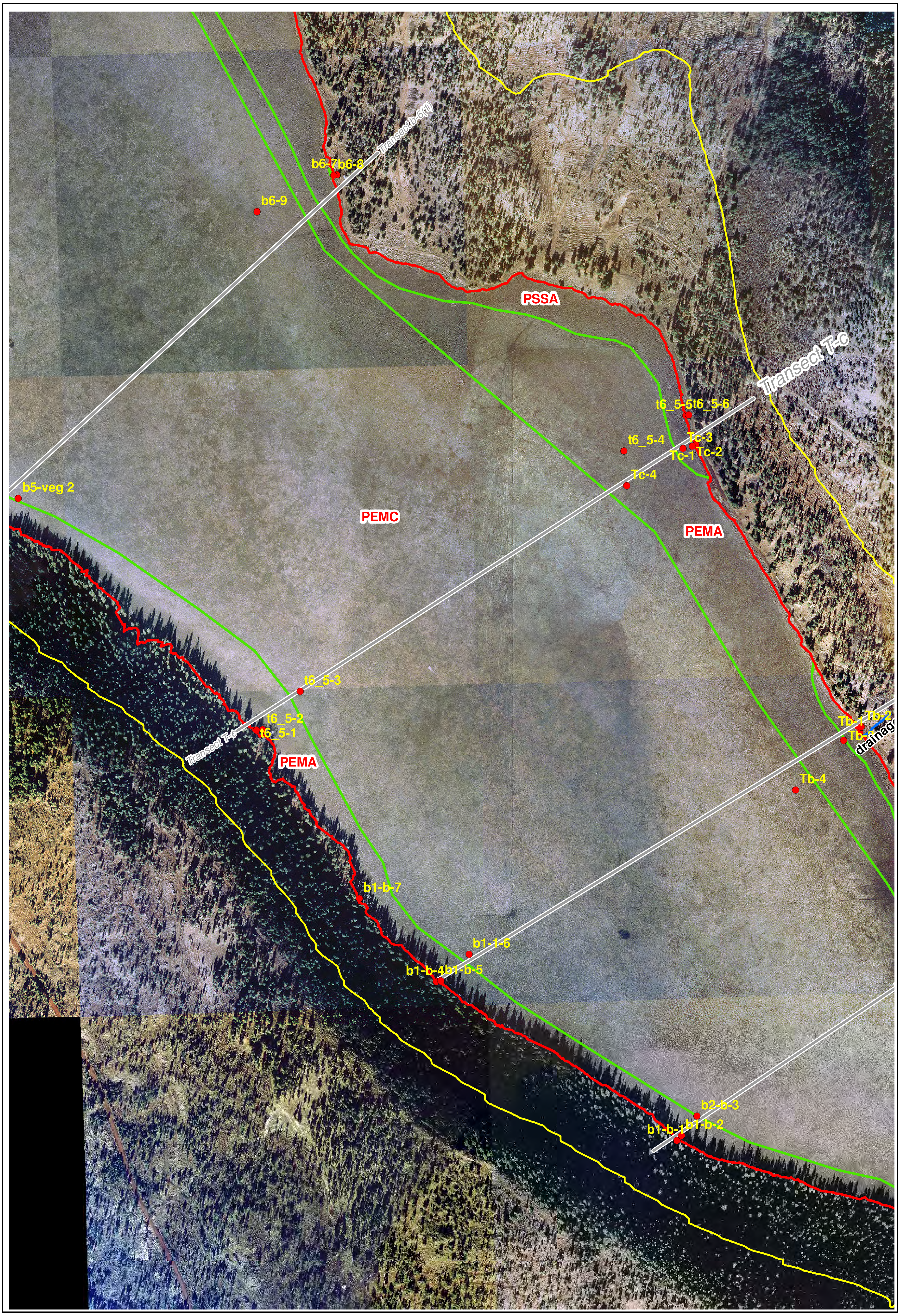
Legend

- Project Boundary
- Wetland Boundary
- Wetland Class Boundary
- Drainage
- Irrigated Wetland
- Location Points

Long Lake Study Area
Sheet 3

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 19



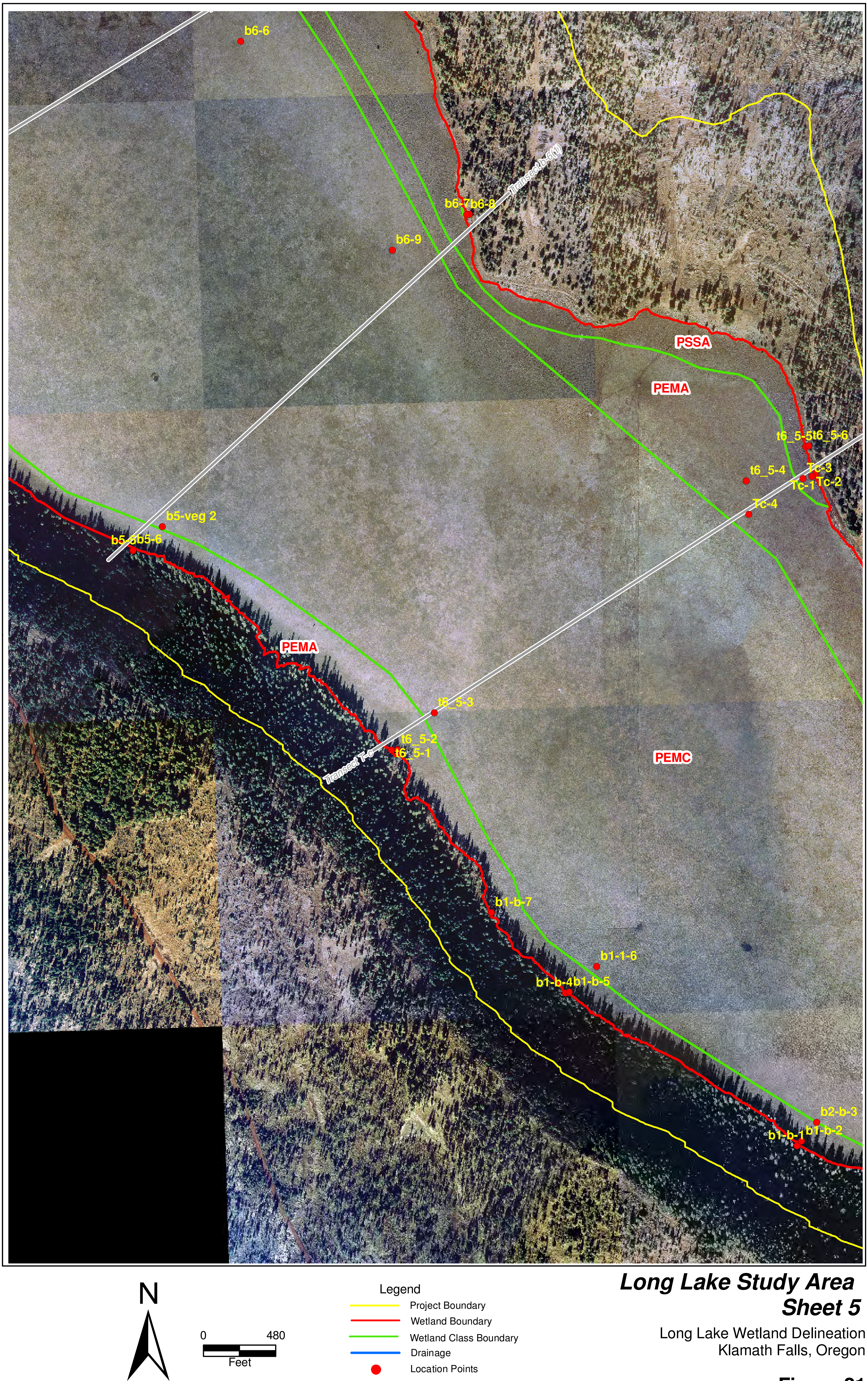
Legend

- Project Boundary
- Wetland Boundary
- Wetland Class Boundary
- Drainage
- Location Points

Long Lake Study Area
Sheet 4

Long Lake Wetland Delineation
Klamath Falls, Oregon

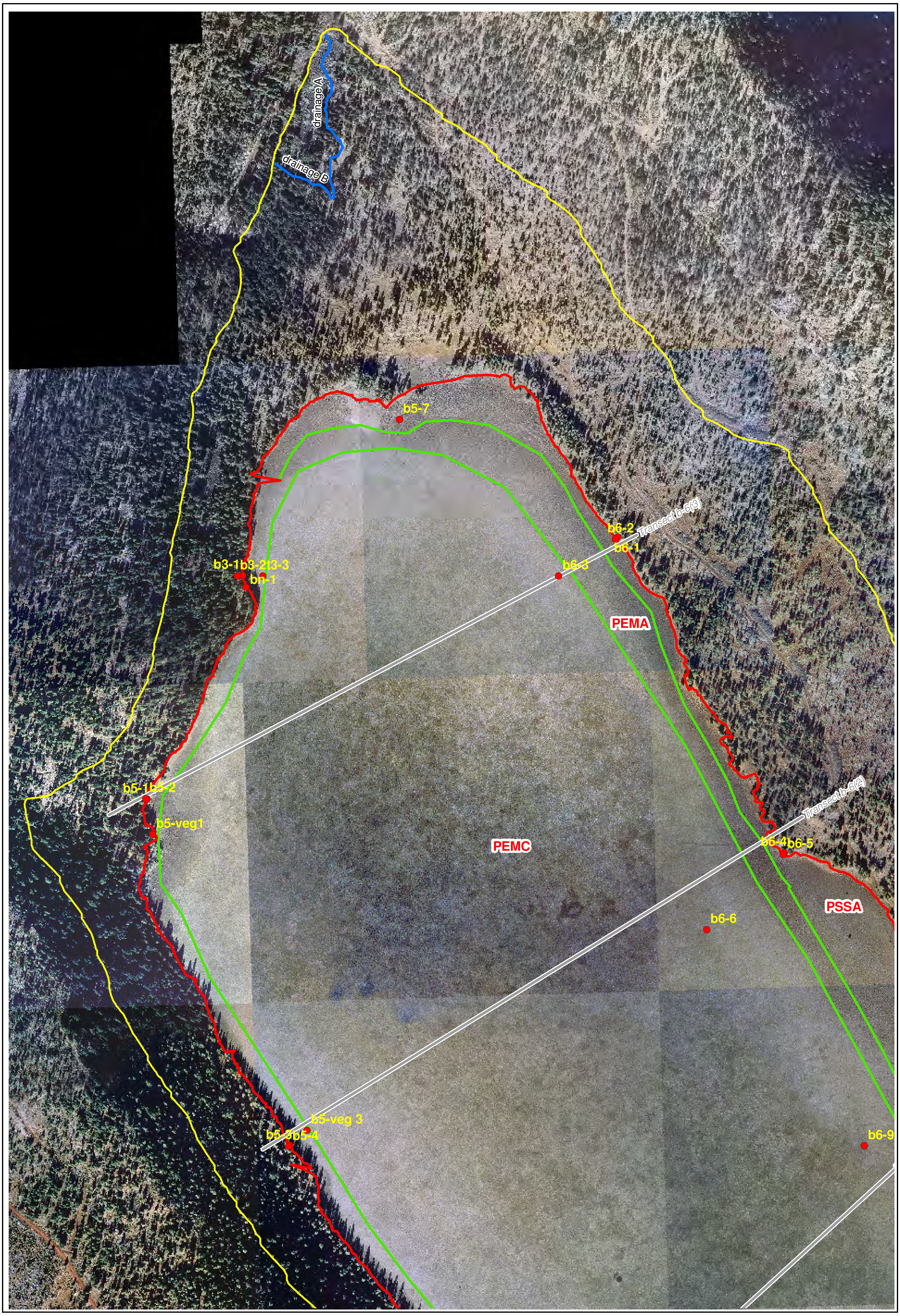
Figure 20



Long Lake Study Area
Sheet 5

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 21



N

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Feet

Legend
- Project Boundary
- Wetland Boundary
- Wetland Class Boundary
- Drainage
- Location Points

Long Lake Study Area
Sheet 6

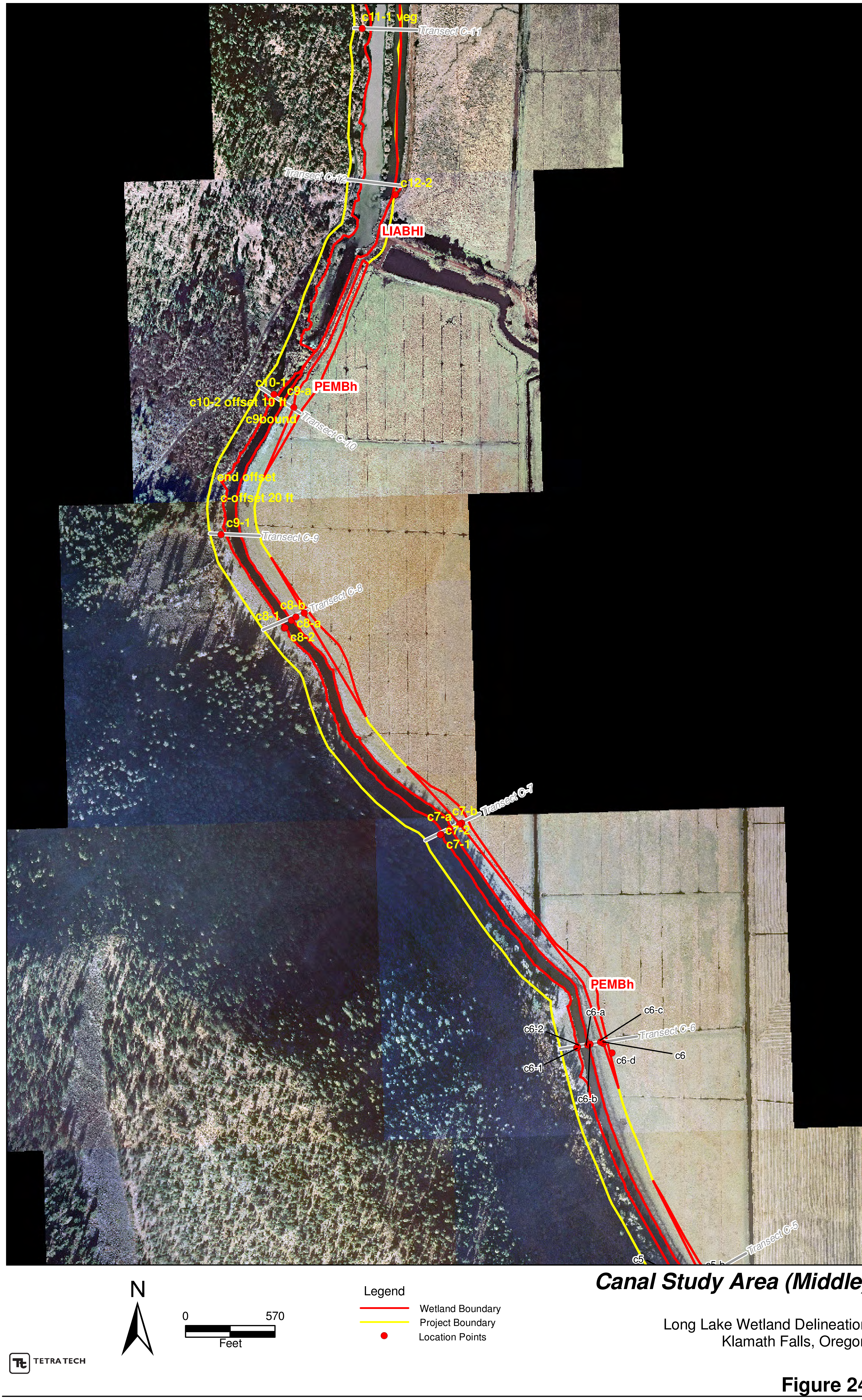
Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 22

Canal Study Area (South)

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 23

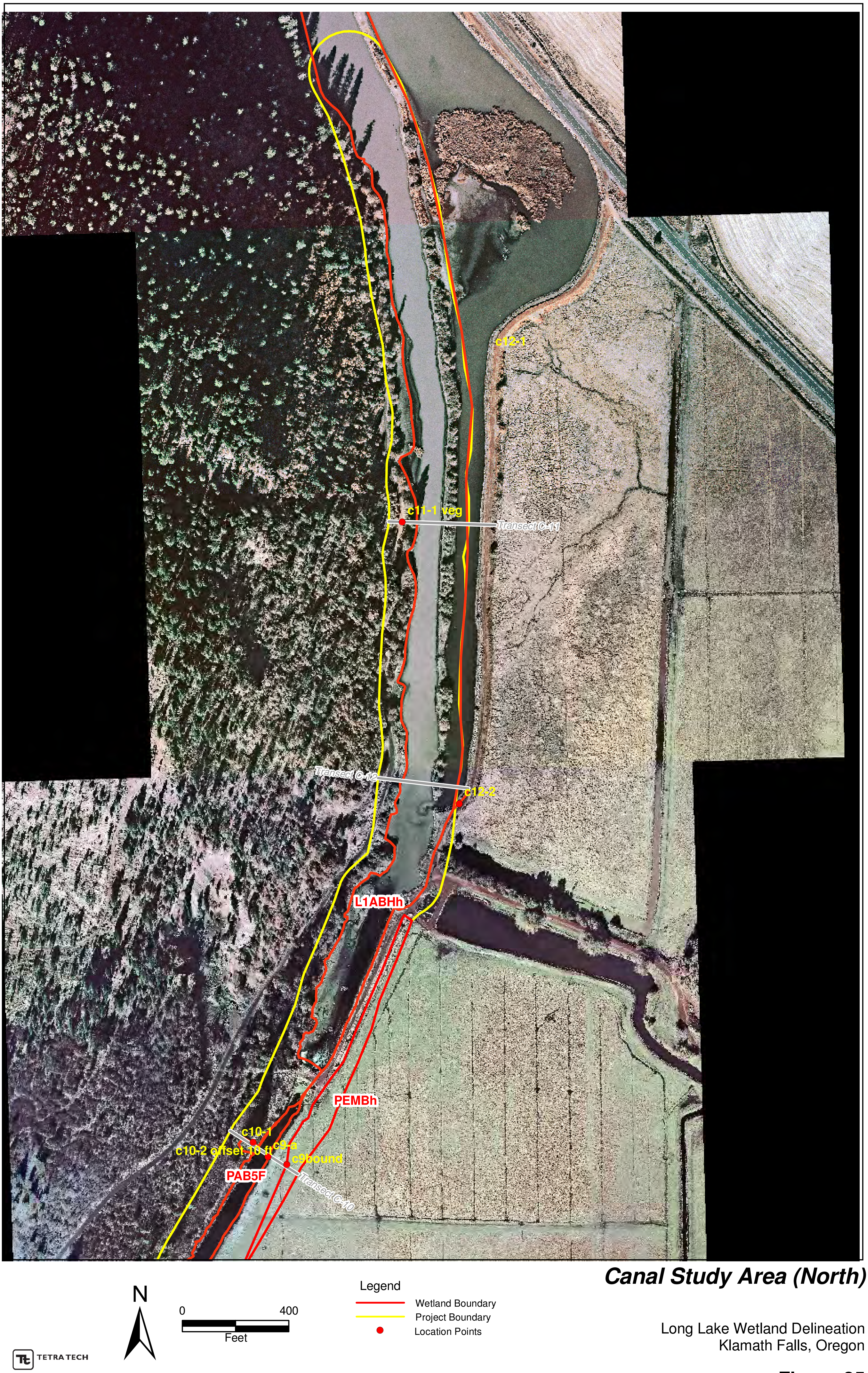


TETRA TECH

Canal Study Area (Middle)

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 24



Canal Study Area (North)

Long Lake Wetland Delineation
Klamath Falls, Oregon

Figure 25

5.0 DISCUSSION

According to the 1987 Manual and implementing guidance, there must be positive indicators of each parameter (hydrophytic vegetation, hydrology and hydric soils) present to make a wetland determination. The Arid West Regional Supplement was used to provide additional indicators for each of the parameters. However, because this site is a potential problem area due to grazing, volcanic soils, pronounced summer/fall drought, and hydrologic manipulation via irrigation and drainage ditches, indicators for one of the parameters, hydric soils, hydrology, or hydrophytic vegetation were missing in a few sample locations. Positive indicators for all three parameters were found at the vast majority of the 114 wetland sample plots. Hydric soil indicators were lacking at some sample sites within Long Lake Valley Wetland 1. However, at these sites, the hydrophytic vegetation and hydrology indicators were very strong. The dominant species at both plots were greater than 50% FAC or wetter (typically FACW or wetter) and there were distinct surface soil cracks and/or drainage patterns. The preponderance of evidence indicates that these communities are seasonally inundated, most likely in the spring following snow melt (April-May). The landowner indicated that during winter, the entire valley typically becomes inundated.

Approximately 1381 acres are either wetlands or Waters of the U.S. Wetland 1 consists of five different wetland habitat classifications (Cowardin, *et al*. 1979) including palustrine emergent semipermanently flooded diked/impounded (PEMFh), palustrine emergent seasonally flooded (PEMC), palustrine emergent seasonally flooded diked/impounded (PEMCh), palustrine emergent temporarily flooded (PEMA), and palustrine scrub/shrub temporarily flooded (PSSA), and totals 1316 acres for the entire wetland. The HGM classifications for these habitats are depressional closed permanent or nonpermanent (depending on the duration of inundation).

Wetland 2 consists of two different wetland habitat classifications (Cowardin, *et al*. 1979) including palustrine aquatic bed semipermanently flooded diked/impounded (PABFh) and palustrine emergent seasonally flooded diked/impounded (PEMCh) and totals 4.60 acres. The HGM classifications for these habitats are depressional closed permanent or nonpermanent (depending on the duration of inundation).

Wetland 3 consists of two different wetland habitat classifications (Cowardin, *et al*. 1979) including riverine intermittent streambed vegetated (R4SB7) and palustrine aquatic bed rooted vascular seasonally flooded (PAB3C) and totals 0.32 acres. The HGM classifications for these habitats are riverine flow-through and riverine impounding.

Wetland 4 has one wetland habitat classification (Cowardin, *et al*. 1979) of palustrine emergent seasonally flooded (PEMC) and is 0.06 acres. The HGM classification is depressional closed nonpermanent.

The ephemeral drainage channels are classified as riverine intermittent streambed cobble-gravel (R4SB3) except drainage G (lower) is riverine intermittent streambed vegetated (R4SB7). The ephemeral drainage channels in the Long Lake Valley total 10.04 acres. The HGM classification is riverine flow-through.

The southern canal wetland has two wetland habitat classifications (Cowardin, *et al*. 1979) of palustrine aquatic bed unknown submergent semipermanently flooded (PAB5F) with a fringe of palustrine emergent seasonally flooded (PEMC) that cannot be identified on the aerial photos due to the wetland boundary line being as wide as the fringe (typically fringe is only 10 feet in width). The farmed or pastured fields are one habitat classification (Cowardin) of palustrine emergent saturated diked/impounded (PEMBh), and the north canal area that is essentially part of Upper Klamath Lake is lacustrine limnetic aquatic bed permanently flooded diked impounded (L1ABHh). The total acreage of wetlands is 51 acres.

Wetland/Water ID	Cowardin Classification	HGM Classification	Acreage	Preliminary Jurisdictional Determination[1]
Long Lake Valley				
Wetland 1	PEMFh	Depressional Closed Permanent	230	Isolated
	PEMC	Depressional Closed Nonpermanent	780	Isolated
	PEMCh	Depressional Closed Nonpermanent	100	Isolated
	PEMA	Depressional Closed Nonpermanent	152	Isolated
	PSSA	Depressional Closed Nonpermanent	54	Isolated
Wetland 2	PABFh	Depressional Closed Permanent	1.4	Isolated
	PEMCh	Depressional Closed Nonpermanent	3.2	Isolated
Wetland 3	R4SB7	Riverine Flow-through	0.4	Isolated
	PAB3C	Riverine Impounding	0.32	Isolated
Wetland 4	PEMC	Depressional Closed Nonpermanent	0.06	Isolated
Wocus Marsh/Canal				
Canal	PAB5F	Lacustrine Fringe Valley	14.5	Jurisdictional
	PEMC	Lacustrine Fringe Valley	4.8	Jurisdictional
Fields	PEMBh	Lacustrine Fringe Valley	11.7	Jurisdictional
Northern Canal/Lake	L1ABHh	Lacustrine Fringe Valley	20	Jurisdictional

1 – Long Lake Valley is not connected to any other waterbodies, all runoff flows into the valley as a “sink”. The Corps has preliminarily determined that this valley is isolated (Pers. comm. Benny Dean, US Army Corps of Engineers, July 2007).

The quality of the Long Lake Valley Wetland 1 is moderate to high quality, in that the plant communities are very diverse and provide significant nesting habitat for a variety of waterfowl and migratory birds, but the whole site has been subject to significant disturbance such as grazing, leveling, and irrigation and drainage. The canal area has been significantly disturbed from its historic wetland state and is now entirely manipulated by the irrigation system. It is of relatively low quality with very few native species present.

Numerous bird species were observed at Long Lake including yellow-headed blackbird, red-winged blackbird, black tern, greater sandhill crane, western meadowlark, American goldfinch, bald eagle, red-tailed hawk and other unidentified songbirds. An unidentified small rail was also observed, potentially a yellow rail. At the Wocus Marsh canal area, waterfowl including western grebe, wigeon, Canada geese, and pelicans were observed.

The upland areas up to elevation 4430 feet are also quite diverse. *Pinus ponderosa/Purshia tridentata* woodland dominates the west facing slopes, whereas Douglas fir/grand fir/Western red cedar forest dominates the east facing slopes. No endangered, threatened, or otherwise rare plant species were encountered, but over 60 species were identified in the uplands. The landowner indicated that the uplands are only submitted to light and infrequent grazing, thus maintaining a largely native species dominated ecosystem.

7.0 CONCLUSIONS

In conclusion, six wetlands and nine other Waters of the U.S., totaling 1381.43 acres, are present on the project site. Vegetation communities within the wetlands include: *Scirpus acutus* marsh (PEMFh and PEMF), *Eleocharis/Juncus* marsh (PEMFh and PEMF), *Typha* marsh (PEMFh and PEMF), and *Alopecurus* seasonal wetlands (PEMC), *Artemisia cana* seasonal wetland (PSSA), and farmed/grazed pasture wetlands (PEMBh).

A wetland functional assessment was not conducted. However, functions that both sites likely perform include bird and mammal habitat, amphibian habitat, storage of runoff from adjacent slopes, groundwater recharge, and filtration of runoff from adjacent slopes.

The Long Lake Valley is a sink that collects runoff from the adjacent hillslopes, but there is no outlet. This potentially isolated wetland still provides a significant area of habitat for waterfowl, songbirds, raptors, small mammals and amphibians.

The Wocus Marsh canal area is highly modified to be farmed and the majority of the delineated area consists of drainage and irrigation canals (Wocus Drainage Canal) and lateral irrigation ditches. However, this area was a former marshland connected to Upper Klamath Lake. This area still provides habitat for waterfowl, but is primarily dominated by non-native species that are grazed or farmed.

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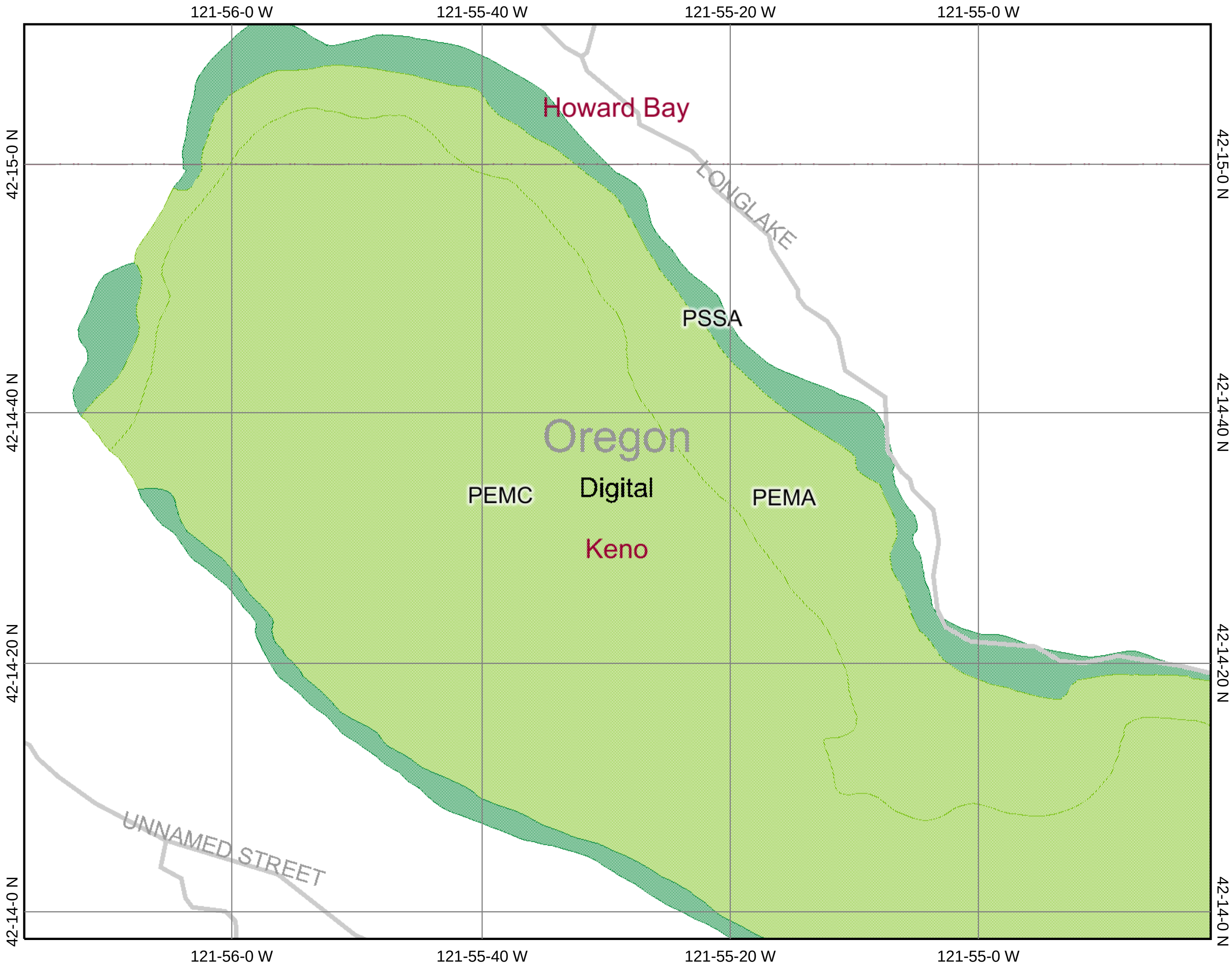
APPENDIX A: NWI AND SOILS MAPS

LLV North



Map center: 42° 14' 35" N, 121° 55' 29" W

Legend

CONUS_wet_scan

- 0
- 1
- Out of range

Interstate

Major Roads

- Other Road
- Interstate
- State highway
- US highway

Roads

Cities

USGS Quad Index 24K

Lower 48 Wetland Polygons

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Lower 48 Available Wetland Data

- Non-Digital
- Digital
- No Data
- Scan

NHD Streams

Counties 100K

States 100K

South America

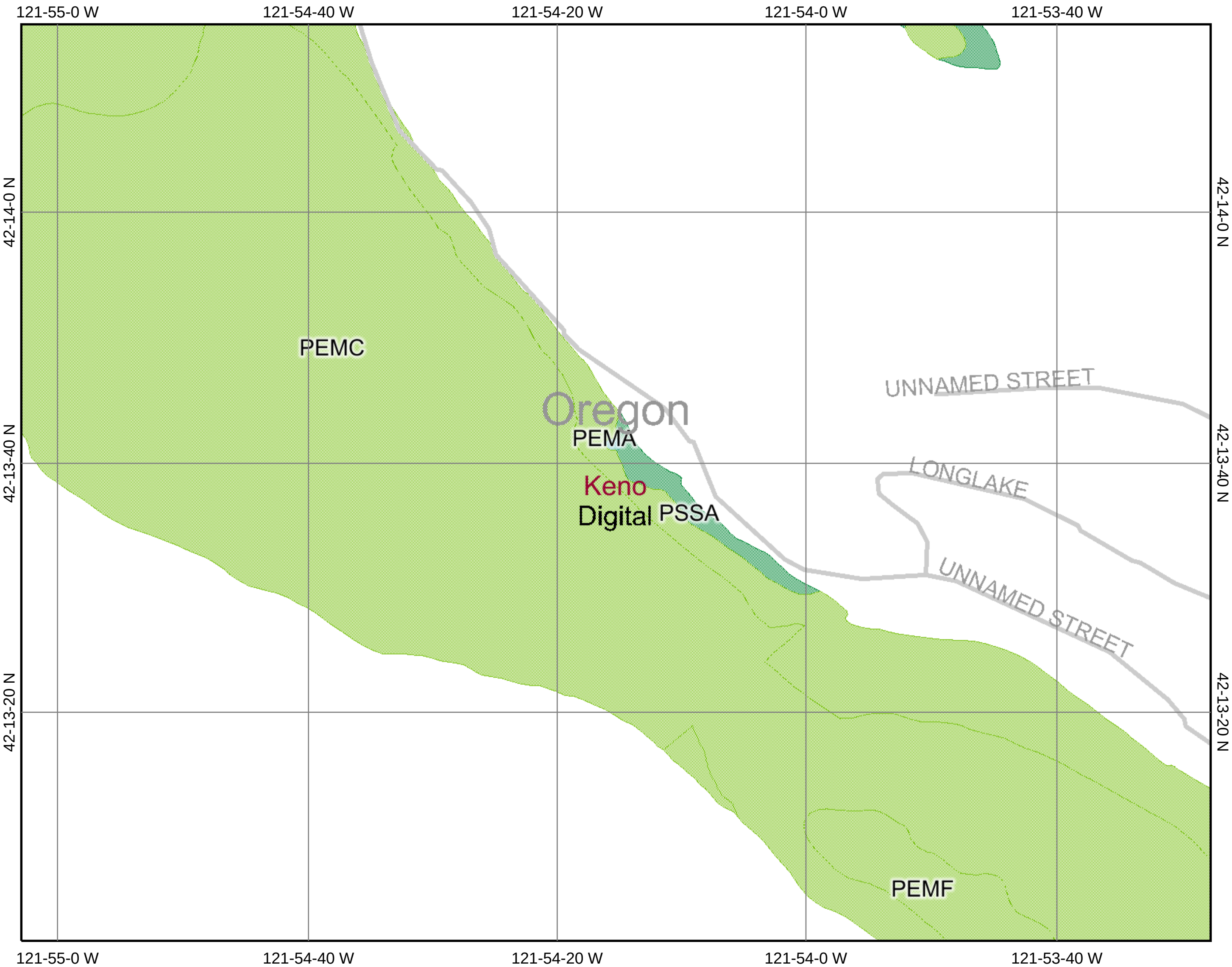
North America

N

Scale: 1:21,155

This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

LLV South



Legend

CONUS_wet_scan

- 0
- 1
- Out of range

Interstate

Major Roads

- Other Road
- Interstate
- State highway
- US highway

Roads

Cities

USGS Quad Index 24K

Lower 48 Wetland Polygons

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Lower 48 Available Wetland Data

- Non-Digital
- Digital
- No Data
- Scan

NHD Streams

Counties 100K

States 100K

South America

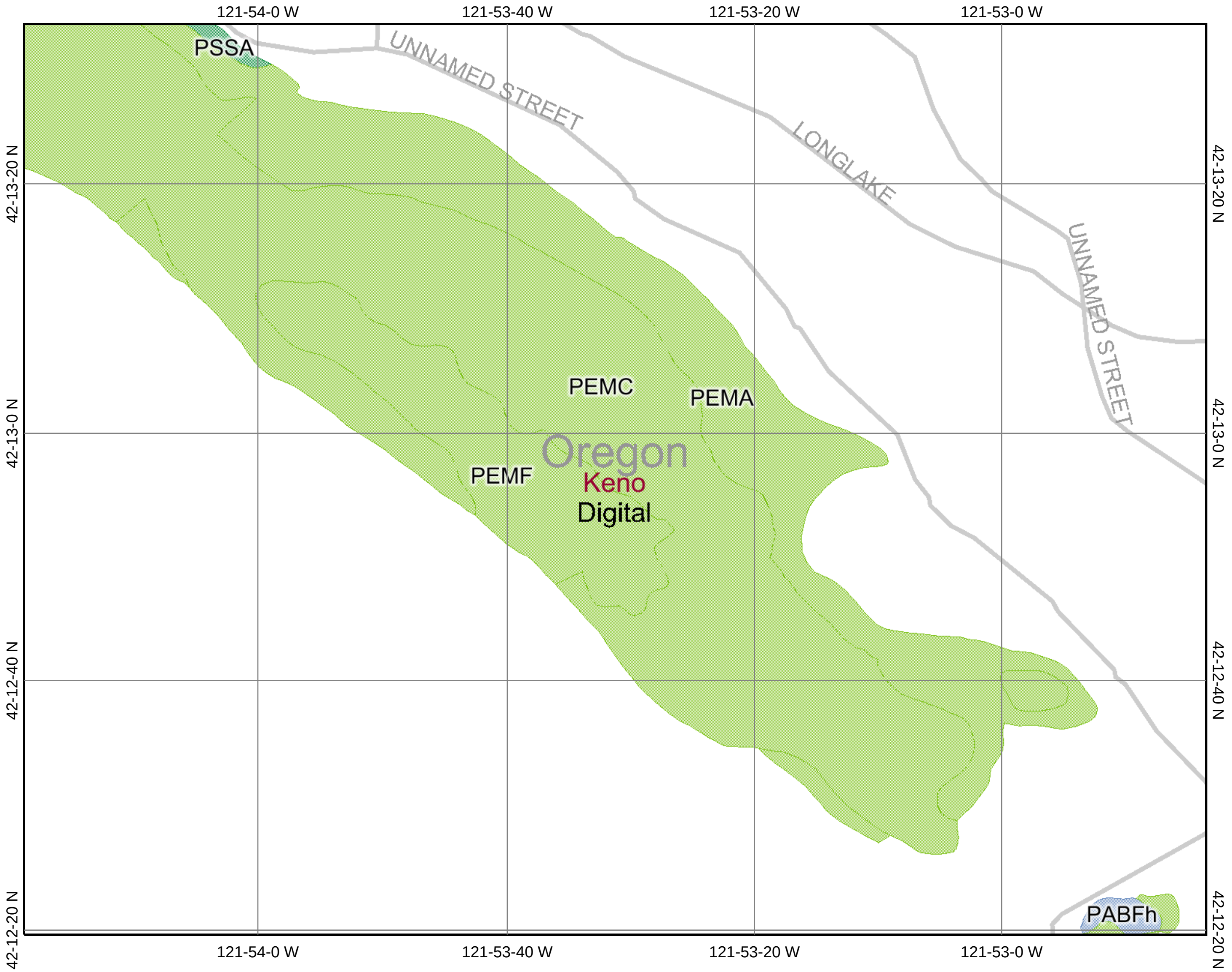
North America

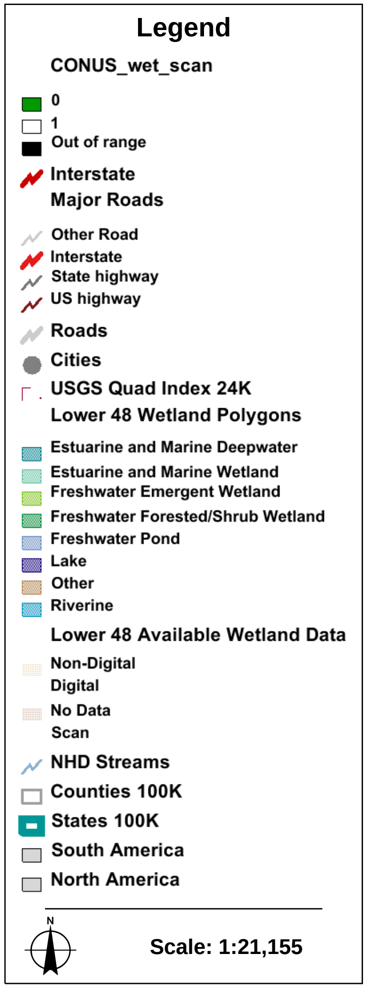
N

Scale: 1:21,155

Map center: 42° 13' 38" N, 121° 54' 15" W

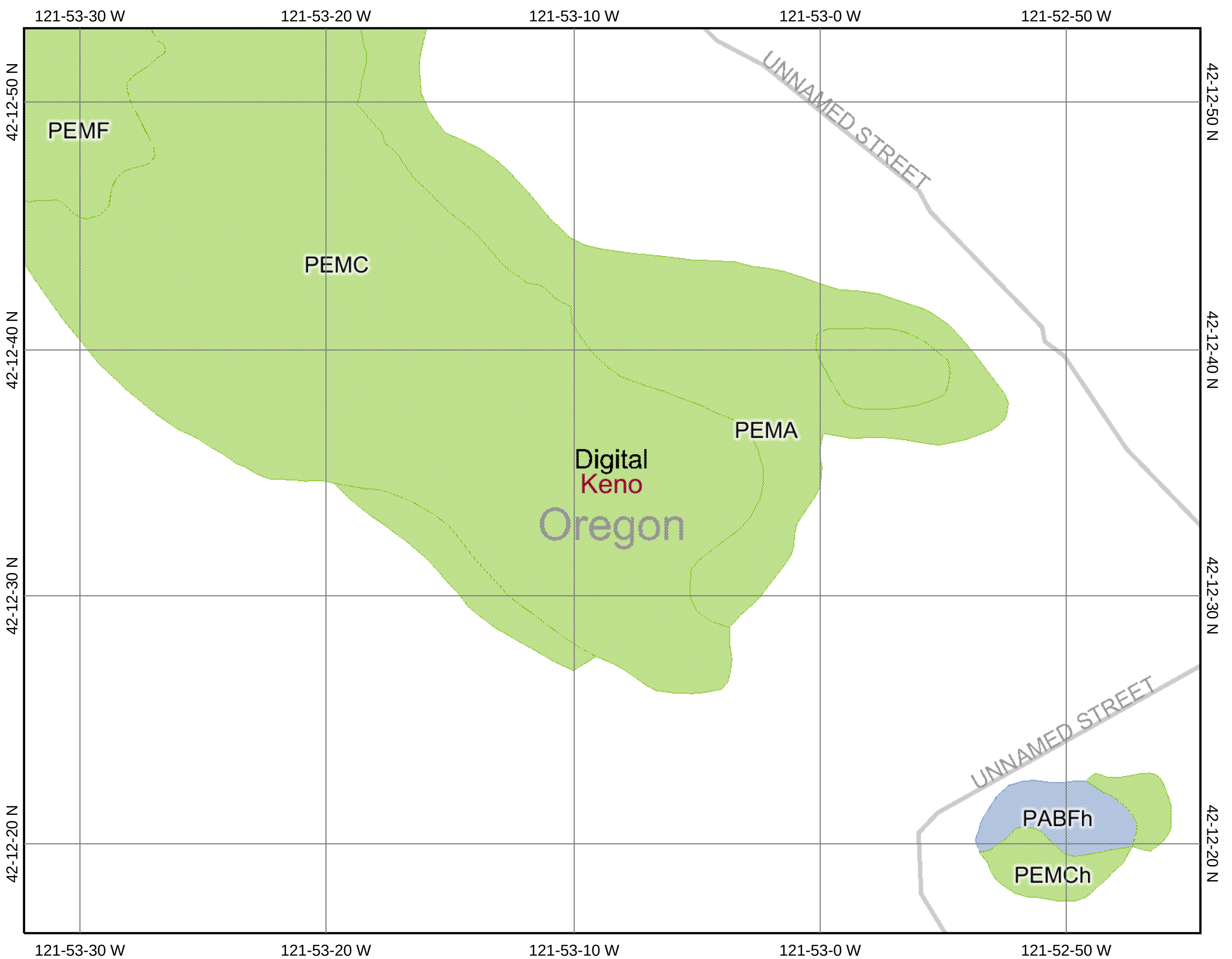
LLV South 2





Map center: 42° 12' 56" N, 121° 53' 31" W

LLV South 3



Legend

CONUS_wet_scan
- 0
- 1
- Out of range

Interstate
Major Roads
- Other Road
- Interstate
- State highway
- US highway

Roads

Cities

USGS Quad Index 24K

Lower 48 Wetland Polygons
- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Lower 48 Available Wetland Data
- Non-Digital
- Digital
- No Data
- Scan

NHD Streams

Counties 100K

States 100K

South America

North America

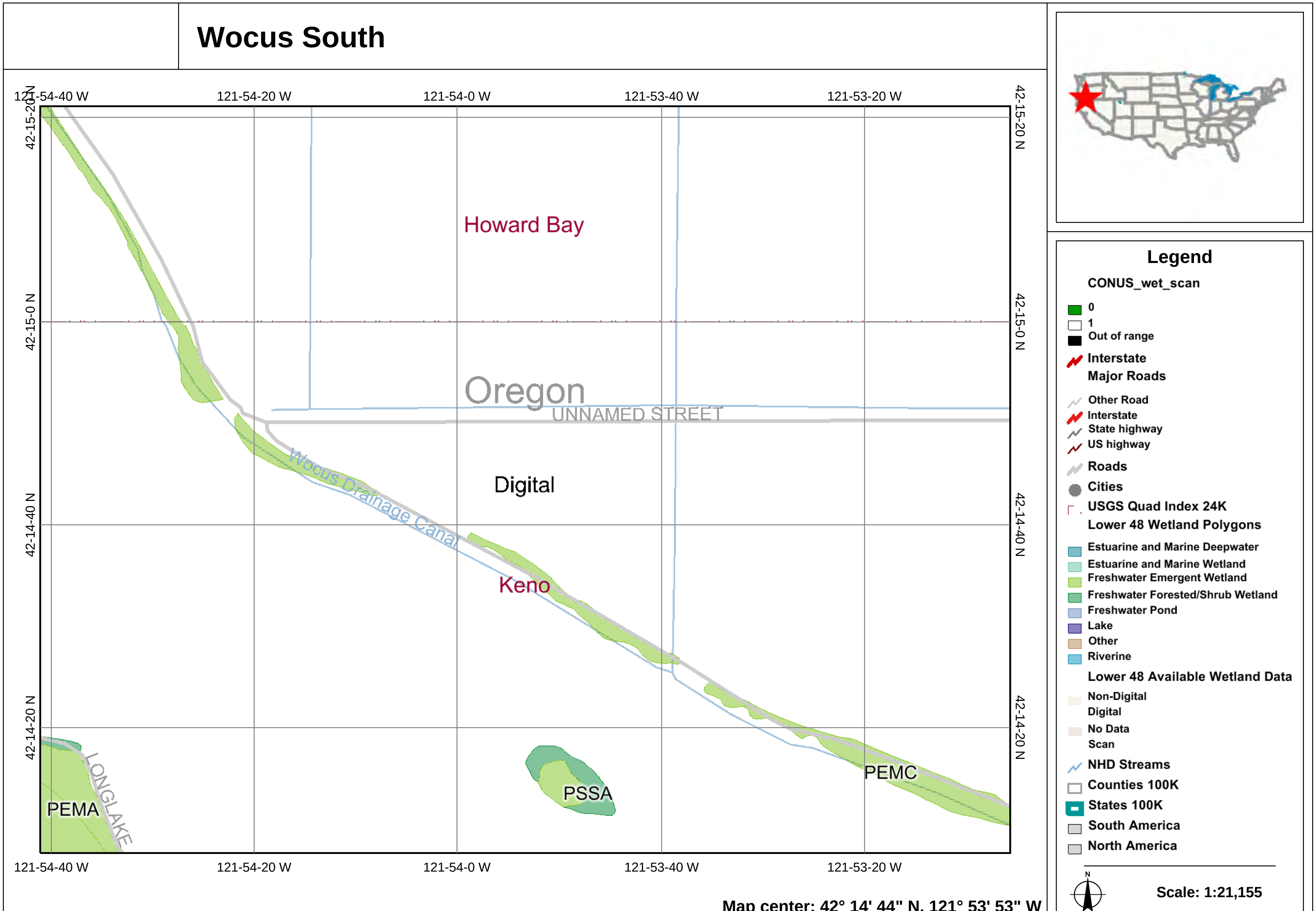
N

Scale: 1:10,577

Map center: 42° 12' 34.6" N, 121° 53' 8.4" W

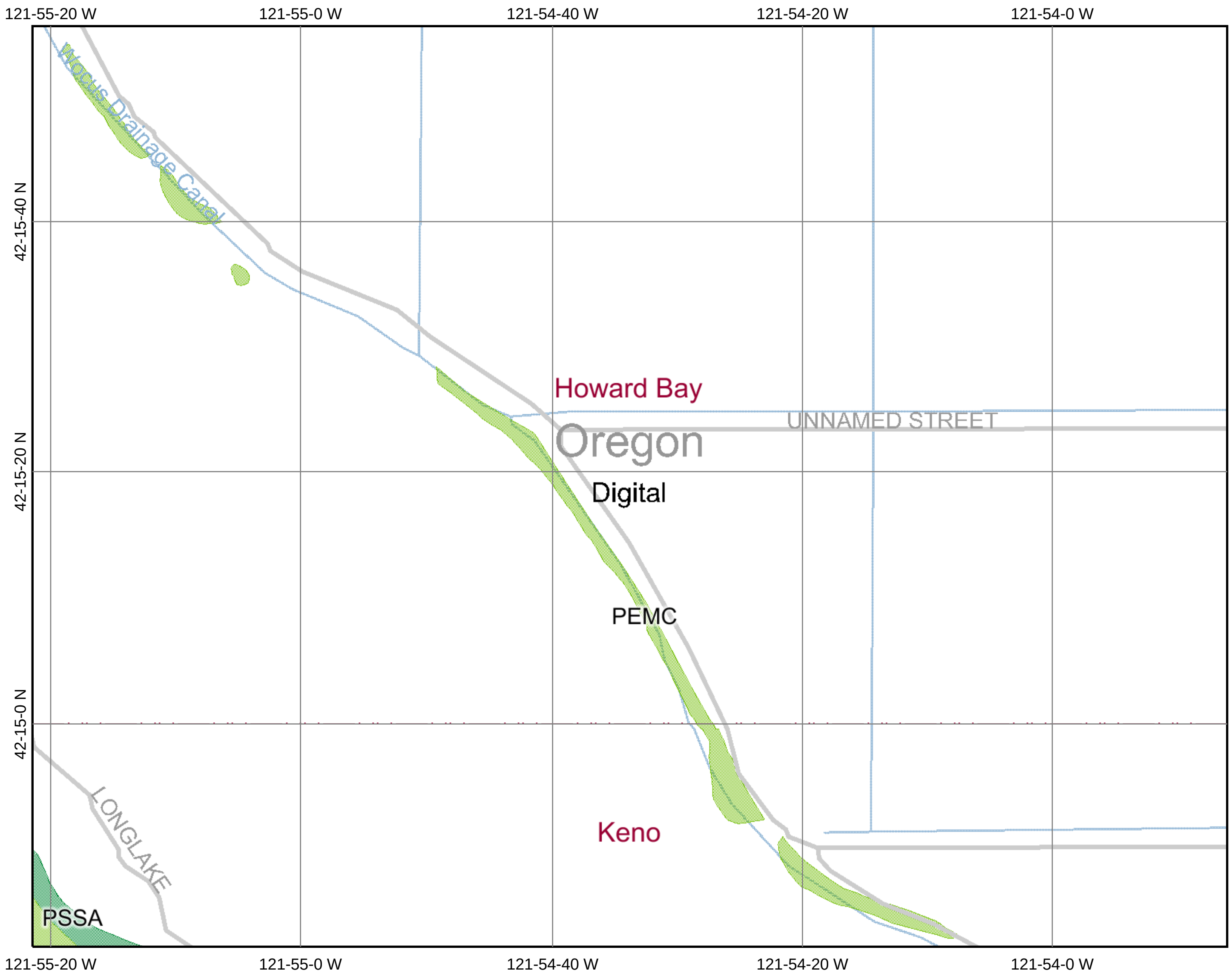
This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

Wocus South



This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

Wocus Central



Map center: 42° 15' 19" N, 121° 54' 34" W

Legend

CONUS_wet_scan

- 0
- 1
- Out of range

Interstate

Major Roads

- Other Road
- Interstate
- State highway
- US highway

Roads

Cities

USGS Quad Index 24K

Lower 48 Wetland Polygons

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Lower 48 Available Wetland Data

- Non-Digital
- Digital
- No Data
- Scan

NHD Streams

Counties 100K

States 100K

South America

North America

N

Scale: 1:21,155

Wocus North

Legend

CONUS_wet_scan
- 0
- 1
- Out of range

Interstate
Major Roads
- Other Road
- Interstate
- State highway
- US highway

Roads
Cities
USGS Quad Index 24K
Lower 48 Wetland Polygons
- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

Lower 48 Available Wetland Data
- Non-Digital
- Digital
- No Data
- Scan

NHD Streams
Counties 100K
States 100K
South America
North America

N

Scale: 1:21,155

Map center: 42° 16' 8" N, 121° 55' 17" W

Wocus North 2

Legend

CONUS_wet_scan
- 0
- 1
- Out of range

Interstate
Major Roads
- Other Road
- Interstate
- State highway
- US highway

Roads
Cities
USGS Quad Index 24K
Lower 48 Wetland Polygons
- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

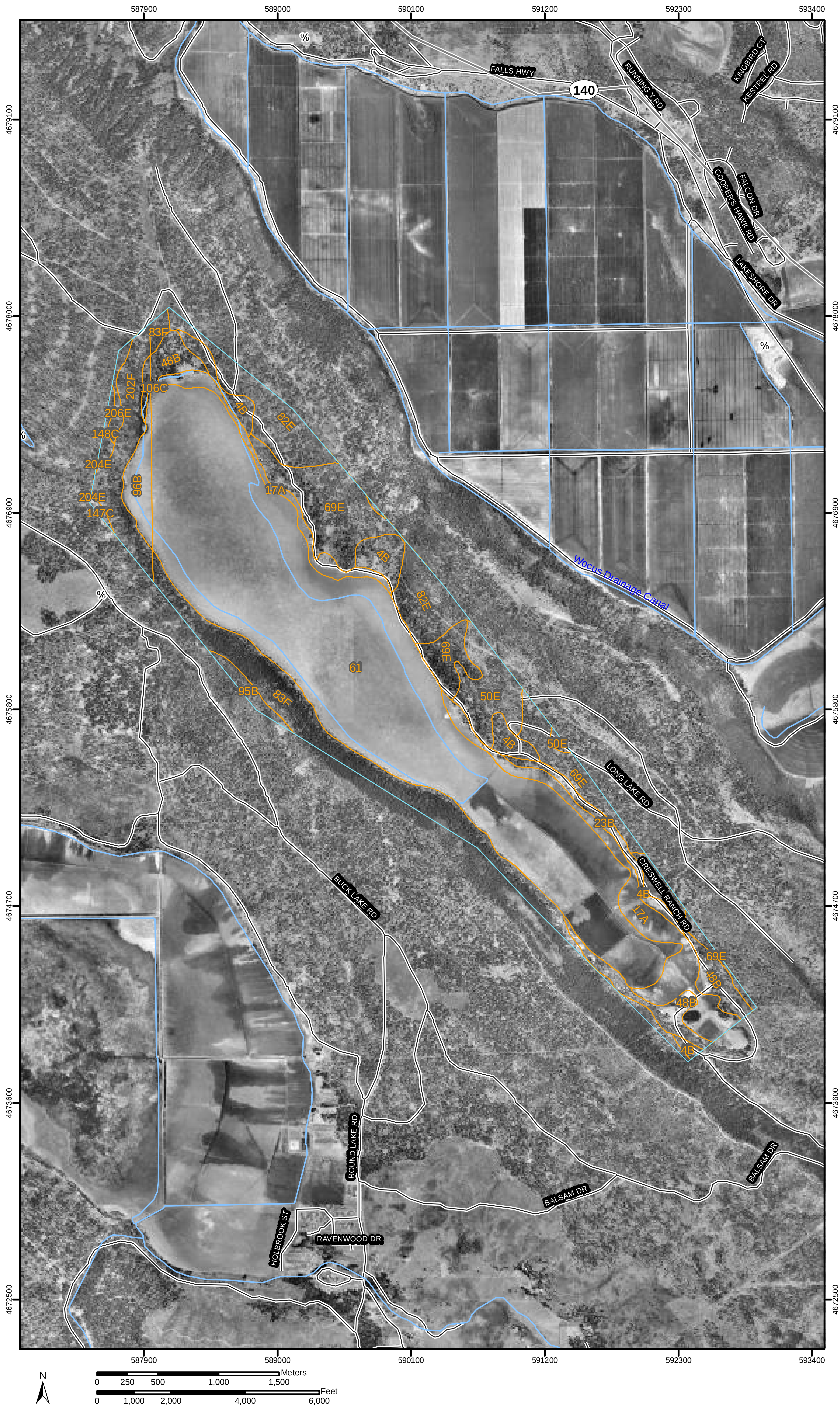
Lower 48 Available Wetland Data
- Non-Digital
- Digital
- No Data
- Scan

NHD Streams
Counties 100K
States 100K
South America
North America

N

Scale: 1:21,155

Map center: 42° 17' 13" N, 121° 55' 26" W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FALLS HWY
140
RUNNING Y RD
KINGBIRD CT
KESTREL RD
FALCON DR
COOPER'S HAWK RD
LAKESHORE DR
Wocus Drainage Canal
LONG LAKE RD
CRESWELL RANCH RD
BUCK LAKE RD
ROUND LAKE RD
BALSAM DR
HOLBROOK ST
RAVENWOOD DR
83F
48B
202F
106C
206E
148C
204E
96B
147C
4B
82E
17A
69E
61
95B
50E
23B
N
0
250
500
1,000
1,500
Meters
2,000
4,000
6,000
Feet

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

Municipalities

- Cities
- Urban Areas

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails

Roads

- Interstate Highways
- US Routes
- State Highways
- Local Roads
- Other Roads

MAP INFORMATION

Original soil survey map sheets were prepared at publication scale. Viewing scale and printing scale, however, may vary from the original. Please rely on the bar scale on each map sheet for proper map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 10N

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Jackson County Area, Oregon, Parts of Jackson and Klamath Counties
Survey Area Data: Version 4, Dec 22, 2006

Soil Survey Area: Klamath County, Oregon, Southern Part
Survey Area Data: Version 4, Dec 22, 2006

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 7/3/1994

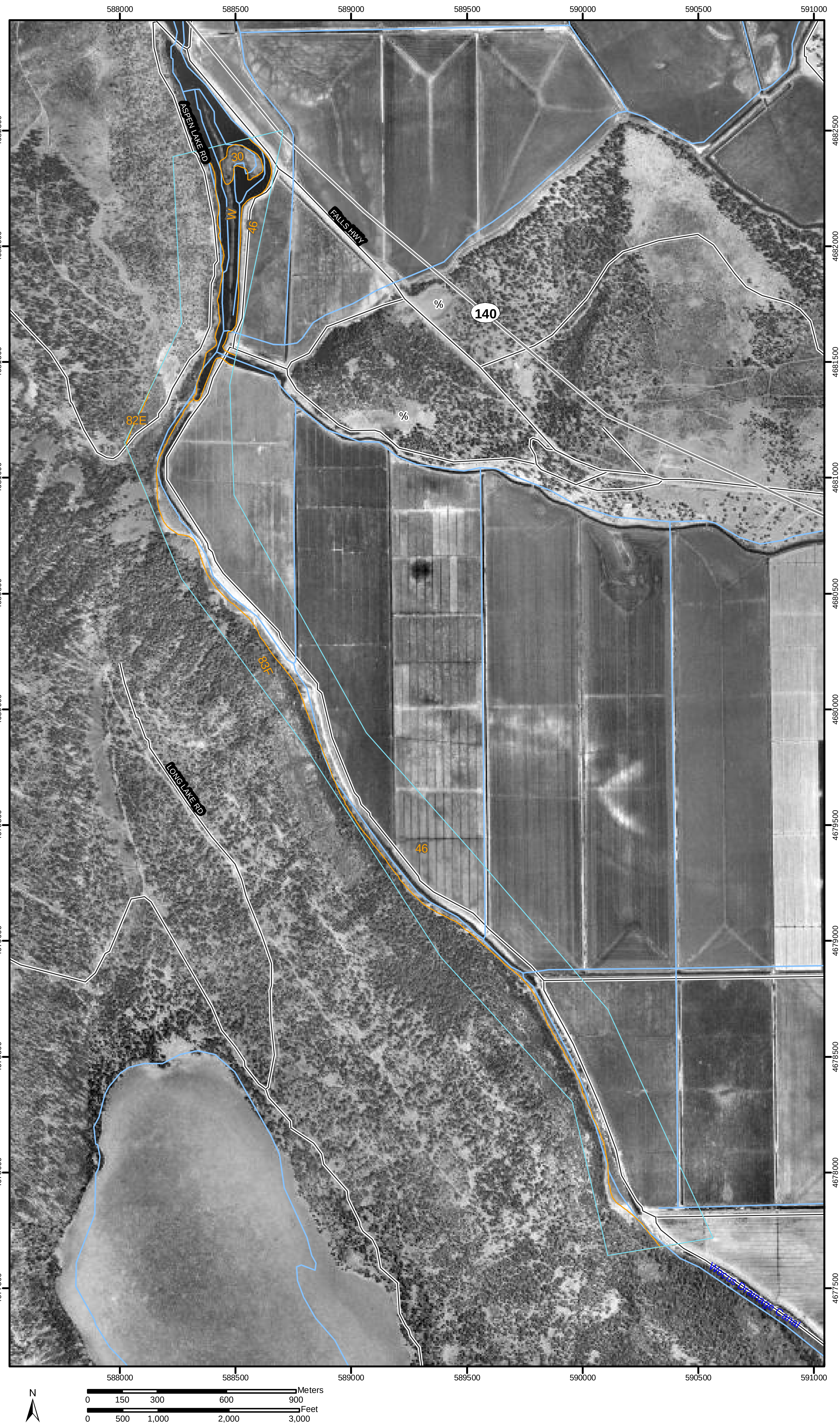
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Jackson County Area, Oregon, Parts of Jackson and Klamath Counties (OR632)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
96B	Kanutchan clay, 1 to 8 percent slopes	41.3	1.6%
106C	Lobert sandy loam, 0 to 12 percent slopes	6.5	0.3%
147C	Pokegema-Woodcock complex, 1 to 12 percent slopes	3.8	0.2%
148C	Pokegema-Woodcock complex, warm, 1 to 12 percent slopes	9.3	0.4%
202F	Woodcock stony loam, 35 to 55 percent north slopes	94.8	3.8%
204E	Woodcock-Pokegema complex, 12 to 35 percent north slopes	0.9	0.0%
206E	Woodcock-Pokegema complex, warm, 12 to 35 percent slopes	12.7	0.5%

Klamath County, Oregon, Southern Part (OR640)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
4B	Bly loam, 2 to 8 percent slopes	98.4	3.9%
17A	Deter clay loam, 0 to 2 percent slopes	182.5	7.3%
23B	Harriman loam, 2 to 5 percent slopes	33.0	1.3%
48B	Lobert loam, 2 to 5 percent slopes	102.8	4.1%
50E	Lorella very stony loam, 2 to 35 percent south slopes	81.0	3.2%
61	Pit silty clay	1,208.0	48.3%
69E	Royst stony loam, 5 to 40 percent south slopes	228.1	9.1%
82E	Woodcock association, south	162.0	6.5%
83F	Woodcock-Rock outcrop complex, 40 to 60 percent north slopes	217.9	8.7%
95B	Pokegema-Woodcock complex, 1 to 12 percent slopes	17.8	0.7%

Totals for Area of Interest (AOI)	2,500.8	100.0%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4680500
4680000
4679500
4679000
4678500
4678000
4677500
ASPEN LAKE RD
30
W
46
FALLS HWY
140
%
82E
83F
LONG LAKE RD
46
Wocus Drainage Canal
N
0 150 300 600 900 Meters
0 500 1,000 2,000 3,000 Feet

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features

Municipalities
- Cities
- Urban Areas

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails

Roads
- Interstate Highways
- US Routes
- State Highways
- Local Roads
- Other Roads

MAP INFORMATION

Original soil survey map sheets were prepared at publication scale. Viewing scale and printing scale, however, may vary from the original. Please rely on the bar scale on each map sheet for proper map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 10N

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Klamath County, Oregon, Southern Part
Survey Area Data: Version 4, Dec 22, 2006

Date(s) aerial images were photographed: 7/3/1994; 8/29/1994

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Klamath County, Oregon, Southern Part (OR640)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
30	Histosols, ponded	4.7	1.0%
46	Lather muck	283.8	60.5%
82E	Woodcock association, south	0.4	0.1%
83F	Woodcock-Rock outcrop complex, 40 to 60 percent north slopes	155.6	33.1%
W	Water	24.9	5.3%
Totals for Area of Interest (AOI)		469.3	100.0%

APPENDIX B: WETLAND DELINEATION FORMS

APPENDIX C: PLANT SPECIES LIST

List of All Species Observed
Long Lake Project Site

Species Name	Common Name	Stratum	Site	Indicator Status
Abies grandis	Grand fir	T	LL	FACU-
Achillea millefolium	Yarrow	H	LL	FACU
Agropyron spicatum	Bluebunch wheatgrass	H	LL	UPL
Agrostis alba	Redtop	H	LL	FAC
Agrostis tenuis	Colonial bentgrass	H	LL	FAC
Alisma plantago-aquatica	American water plantain	H	LL	OBL
Allium validum	Pacific onion	H	LL	OBL
Alopecurus aequalis	Little meadow foxtail	H	LL	OBL
Alopecurus pratensis	Meadow foxtail	H	LL	FACW
Amelanchier alnifolia	Serviceberry	S	LL	FACU
Amsinckia intermedia	Rancher's fiddleneck	H	LL	N.L.
Anthemis cotula	Mayweed chamomile	H	LL	FACU
Arctostaphyllus patula	Manzanita	S	LL	N.L.
Arnica chamissonis	Leafy arnica	H	LL	FACW
Artemisia cana	Sagebrush	S	LL	FACU
Artemisia tridentata	Great basin sage	S	LL	N.L.
Asclepias speciosa	Showy milkweed	H	LL	FAC+
Aster occidentalis	Northern aster	H	LL	FAC
Balsamorhiza sagittata	Arrowleaf balsamroot	H	LL	N.L.
Barbarea orthoceras	American wintercress	H	LL	FACW+
Berberis nervosa	Oregon grape	S	LL	N.L.
Brodiaea douglasii	Brodiaea	H	LL	N.L.
Bromus commutatus	Hairy brome	H	LL	N.L.
Bromus tectorum	Cheat grass	H	LL	N.L.
Bromus vulgaris	Columbia brome	H	LL	N.L.
Cardaria draba	Hoary cress	H	LL	N.L.
Carex athrostachya	Slenderbeaked sedge	H	LL	FACW
Carex utriculata	Inflated sedge	H	LL	OBL
Castilleja chromosa	Desert paintbrush	H	LL	N.L.
Castilleja exilis	Annual paintbrush	H	LL	OBL
Ceanothus prostratus	Mahala mat	S	LL	N.L.
Ceanothus velutinus	Mountain balm	S	LL	N.L.
Celtis reticulata	Netleaf hackberry	S	LL	FAC-
Centaurea solstitialis	Yellow star-thistle	H	LL	N.L.
Cerastium arvense	Chickweed	H	LL	FACU
Chrysothamnus nauseosus	Rabbit brush	S	LL	N.L.
Cirsium arvense	Canada thistle	H	LL	FACU+
Cirsium vulgare	Bull thistle	H	LL	FACU
Claytonia perfoliata	Miner's lettuce	H	LL	FAC
Cryptantha torreyana	Torrey's cryptantha	H	LL	N.L.
Danthonia californica	California oatgrass	H	LL	FACU
Delphinium bicolor	Showy larkspur	H	LL	N.L.
Delphinium occidentale	Duncecap larkspur	H	LL	FACU-
Deschampsia danthonioides	Oat hairgrass	H	LL	FACW-

Descurainia sophia	Flixweed	H	LL	N.L.
Downingia elegans	Showy downingia	H	LL	OBL
Eleagnus commutata	Silverberry	S	LL	N.I.
Eleocharis bella	Delicate spikerush	H	LL	FACW
Eleocharis palustris	Common spikerush	H	LL	OBL
Elymus canadensis	Canada wildrye	H	R	FAC
Elymus glaucous	Blue wild rye	H	LL	FACU
Eriophyllum lanatum	Eriophyllum	H	LL	N.L.
Festuca idahoensis	Idaho fescue	H	LL	FACU
Festuca megalura	Foxtail fescue	H	LL	N.L.
Festuca rubra	Red fescue	H	LL	FAC+
Fragaria virginiana	Strawberry	H	LL	FACU
Galium aparine	Cleavers	H	LL	FACU
Geum triflorum	Old man's beard	H	LL	FACU
Glyceria borealis	Northern mannagrass	H	LL	OBL
Hippuris vulgaris	Mare's tail	H	LL	OBL
Hordeum jubatum	Foxtail barley	H	LL	FAC
Juncus balticus	Baltic rush	H	LL	FACW+
Juncus bufonius	Toad rush	H	LL	FACW
Juncus drummondii	Drummond's rush	H	LL	FACW-
Juncus orthophyllus	Straight-leaved rush	H	LL	FACW
Juncus tenuis	Slender rush	H	LL	FACW-
Juniperus occidentalis	Juniper	T	LL	N.L.
Lepidium perfoliatum	Clasping pepperweed	H	LL	FACU+
Linum perenne	Wild flax	H	LL	N.L.
Lithophragma bulbifera	Prairie starflower	H	LL	N.L.
Lolium multiflorum	Italian ryegrass	H	LL	N.L.
Lomatium triternatum	Nine-leaved desert parsley	H	LL	N.L.
Lonicera utahensis	Honeysuckle	S	LL	FAC
Lupinus sericeus	Silky lupine	H	LL	N.L.
Machaerocarpus californicus	Star water plantain	H	LL	OBL
Marsilea vestita	Clover fern	H	LL	OBL
Matricaria matricarioides	Pineapple weed	H	LL	FACU
Medicago sativa	Alfalfa	H	LL	N.L.
Oenothera tanecetifolia	Tansy-leaved evening primrose	H	LL	N.L.
Orthocarpus luteus	Yellow owl's clover	H	LL	FACU-
Penstemon speciosus	Showy penstemon	H	LL	N.L.
Phalaris arundinaceae	Reed canary grass	H	LL	FACW
Pinus ponderosa	Ponderosa pine	T	LL	FACU-
Poa bulbosa	Bulbous bluegrass	H	LL	N.L.
Poa palustris	Fowl bluegrass	H	LL	FAC
Poa pratensis	Kentucky bluegrass	H	LL	FAC
Polygonum avicular	Common knotweed	H	LL	FACW-
Polygonum hydropiperoides	Waterpepper	H	R	OBL
Polygonum persicaria	Lady's thumb	H	LL	FACW
Populus tremula	Quaking aspen	T	LL	FAC+
Potentilla glandulosa	Sticky cinquefoil	H	LL	FAC-
Potentilla gracilis	Slender cinquefoil	H	LL	FAC

Prunella vulgaris	Self-heal	H	LL	FACU+
Prunus emarginata	Bitter cherry	S	LL	FACU
Prunus subcordata	Klamath plum	S	LL	N.L.
Prunus virginiana	Chokecherry	S	LL	FACU
Pseudotsuga menziesii	Douglas' fir	T	LL	FACU
Pteridium aquilinum	Bracken fern	H	R	FACU
Purshia tridentata	Antelope brush	S	LL	N.L.
Ranunculus acriformis	Sharp buttercup	H	LL	FACW-
Ranunculus acris	Tall buttercup	H	LL	FACW-
Ranunculus repens	Creeping buttercup	H	LL	FACW
Ranunculus scleratus	Celery-leaved buttercup	H	R	OBL
Rhamnus purshiana	Cascara	S	LL	FAC-
Ribes velutinum	Currant	S	LL	N.L.
Ribes viscosissimum	Sticky currant	S	LL	FAC
Rosa gymnocarpa	Little wood rose	S	LL	FAC
Rosa woodsii ultramontana	Pearhip rose	S	LL	FACU
Rubus parviflorus	Thimbleberry	S	LL	FAC-
Rumex crispus	Curly dock	H	LL	FAC+
Sagina occidentalis	Western pearlwort	H	LL	FACU+
Salix lasiandra	Pacific willow	S	R	FACW+
Salix lutea	Yellow willow	S	R	OBL
Salvia dorii	Purple sage	S	LL	N.L.
Saxifraga cernua	Nodding saxifrage	H	LL	FACW-
Scirpus acutus	Hardstem bullrush	H	LL	OBL
Sidalcea oregana	Oregon checkermallow	H	LL	N.L.
Silene noctiflora	Sticky cockle	H	LL	N.L.
Smilacina racemosa	False solomon's seal	H	LL	FAC-
Sonchus arvensis	Marsh sowthistle	H	LL	FACU+
Spergula arvensis	Corn spurry	H	LL	N.L.
Stachys palustris	Swamp hedgenettle	H	LL	FACW+
Stellaria calycantha	Northern starwort	H	LL	N.L.
Stellaria umbellata	Umbellate starwort	H	LL	FACW
Stipa richardsonii	Richardson's needlegrass	H	LL	N.I.
Symphoricarpos mollis	Creeping snowberry	S	LL	N.L.
Symphoricarpos oreophilis	Mountain snowberry	S	LL	N.L.
Taraxacum officinale	Dandelion	H	LL	FACU
Thlaspi arvense	Field pennycress	H	LL	N.I.
Thuja plicata	Western red cedar	T	LL	FAC
Tragopogon dubius	Yellow salsify	H	LL	N.L.
Trifolium repens	White clover	H	LL	FAC
Typha latifolia	Cattail	H	LL	OBL
Urtica dioica	Stinging nettle	H	R	FAC+
Verbascum thapsus	Mullein	H	LL	N.L.
Vicia americana	Purple vetch	H	LL	N.I.
Vicia sativa	Common vetch	H	LL	N.L.
Wyethia helianthoides	White-rayed wyethia	H	LL	FACW
Zigadenus venosus	Death camas	H	LL	FACU

Appendix D—*Proposed Long Lake Valley Reservoir: Operational Simulations and Water Quality Assessment*, 2008

Proposed Long Lake Valley Reservoir: Operational Simulations and Water Quality Assessment

PROJECT REPORT

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October 24, 2008

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Executive Summary

The Bureau of Reclamation Klamath Basin Area Office (Reclamation) is undertaking a series of scoping studies to identify the potential benefits and limitations of additional storage in the upper Klamath River basin in the vicinity of Upper Klamath Lake (UKL). One option is construction of an off-stream storage site in Long Lake Valley. Long Lake Valley is located southwest of UKL, approximately due west of Klamath Falls, and is a terminal watershed with minimal inflow and no surface outflow. The reservoir site consists of a relatively flat bottomed valley with steep sides, and at maximum capacity Long Lake reservoir (LLV) would hold approximately 350,000 acre-feet with a depth of approximately 180 feet. Water would be withdrawn from UKL in the vicinity of Wocus Marsh, near the southwestern edge of Howard Bay, and pumped into LLV through a combined canal and tunnel conveyance system.

To assess potential in-reservoir and release water quality from LLV, a CE-QUAL-W2 hydrodynamic and water quality model was developed. Numerous simulations were performed to explore potential reservoir water quality dynamics under differing operational criteria. Based on guidance from Reclamation staff, filling from Upper Klamath Lake (UKL) was assumed to occur from January through mid-April and releases were assumed from June through September. Inflow location was always at the north end of the reservoir near Howard Bay for all simulations described in this report; however, outflow was assumed to occur from two principal locations: discharge back to Howard Bay and discharge to the Klamath River downstream of Link River Dam. For discharges to the Klamath River, two locations were considered: Miller Island and Link River Dam. Pumped storage operations were also examined. A pumped storage system generates hydropower through reservoir discharge during periods of high electric demand and during off-peak periods water is pumped back into the reservoir to maintain storage levels. Although such a system is a net consumer of electricity, the difference in pricing schemes between peak (high) and off-peak (low) pricing yields net revenue. Pumped reservoir storage operations were simulated for selected alternatives to determine the potential effects of such operations on water quality. A total of 42 LLV simulations were completed and included sensitivity simulations. To assess potential water quality conditions on downstream Klamath River reaches, a previously developed CE-QUAL-W2 model of Lake Ewauna/Keno Reservoir was employed. Output from three LLV model simulations were used as input to the Klamath River model. Conditions below Keno Dam were not assessed in this study. The studies defined and presented herein are appraisal or pilot-level studies, intended to identify any severe (e.g., fatal flaw) water quality issues, and provide direction and insight as to what possible issues of concern warrant additional study. In defining the scope of this project, several discussions were held with Reclamation and included USGS (Portland). Of primary importance was the application of a numerical model to a system that had yet to be constructed and where prototype data were largely absent. The outcome of these discussions identified that application of a numerical model to constrain the problem would be an appropriate approach and consistent with appraisal level studies.

LLV simulations considered a range of storage conditions (e.g., low, medium, high), as well as static and dynamic fill and drawdown conditions. For purposes of this model, data were only available for low, medium, and high storage values of approximately 65 TAF, 170, TAF, and 320 TAF, respectively. For the majority of simulations, LLV initial storage was set low, filled to a approximately half capacity, and then was drawn down to approximately the initial elevation by the end of the year. Depending on maximum desired storage volume, fill rates ranged from zero (static storage with no input or output) to 1,000 cfs (for transition from low to high storage). Outlet configurations studies included a single low level outlet and multiple outlets allowing selective withdrawal of reservoir waters (selective level outlet works, SLOW).

Model results indicate that under all simulated storage conditions LLV would experience strong seasonal thermal stratification. Because imported waters are from UKL, LLV is expected to exhibit eutrophic characteristics. Operations from year-to-year will be largely dependent on hydrology and the reservoir may not fill in certain years. In fact, LLV may remain at a static level for a year or more (no significant imports or releases). Thus, hydrology and operations will govern LLV water quality and subsequent release quality to UKL and any downstream Klamath River reaches.

Major findings of this study include:

- Strong seasonal stratification results in potential nutrient depletion in surface layers and extensive anoxia in deeper waters (hypolimnion), which over the long term could lead to internal nutrient loading from LLV sediments (largely settled organic matter). Thus, LLV faces a probable long term eutrophication challenge – water treatment needs to be considered.
- Larger storage volumes tend to moderate water quality impacts, while static, low storage conditions result in notable water quality impairment. These water quality responses may play a role in managing the reservoir for water supply – extended periods of low storage would generally lead to increased seasonal water quality impairment through time. One reservoir management approach would be to evacuate poor quality water, but such operations may conflict with desired downstream water quality conditions in the Klamath River or UKL/Wocus Bay in the vicinity of LLV discharges. Another approach would be to consider water treatment.
- Any potential water quality benefits in the Klamath River in Keno reservoir or in UKL from releasing stored water in LLV would not be available in all years. During normal and wetter years, storage may be sufficient to allow active reservoir management to provide benefits in the vicinity of release locations. However, in drier years little or no available water may be present for water quality management using LLV releases.
- Limitations due to using a single low level outlet include inefficient use of cold water storage, subsaturation dissolved oxygen (DO) conditions, and larger required carryover volumes to ensure cold water supplies are not exhausted.
- SLOW is the most prudent approach to provide effective management of both temperature and water quality for in reservoir conditions as well as release waters. Even with SLOW, water quality conditions will present a management challenge requiring considerable monitoring and likely modeling of management scenarios.

- Pumped storage may have a considerable affect on water quality, and the impact will ultimately be a function of inlet and outlet works design, release volumes, and timing of operations. Pumped storage can introduce nutrients from UKL into LLV during the summer period when primary production is appreciable in both water bodies. Further, water temperature (and thus density) can have notable impacts on stratification and mixing depending on where in the water column imports from UKL enter LLV.
- Discharges to the Klamath River below Link River Dam during the discharge season (July-September) locally impact water quality, but have modest impact by the time waters reach Keno Dam. For example water temperatures near the point of discharge (Link River or Miller Island) may reduce local temperatures by 50 percent (e.g., 22^{o}C to 11^{o}C) over current July conditions, differences in water temperature at Keno Dam are reduced only moderately (e.g., 26^{o}C to 24^{o}C). LLV discharges could be used to create local thermal refugia, but once initiated full time maintenance of such refugia through the summer and early fall would be required. In addition, the refugia could attract aquatic organisms to the area of discharge. When the cool water supply is exhausted or discharges cease due to infrastructure failure or some unforeseen reason, the aquatic organisms that have been attracted to the refugia could become stranded in an area of poor water quality and/or experience rapid changes in water temperature (11C to 26C).
- Discharges to the Klamath River at Miller Island not only affect downstream reaches, but also indirectly affect upstream reaches due to reduced release from Link River Dam and increased transit time to Miller Island. This can produce variable water quality conditions, with periods of apparent improvement and periods of increased impairment.

The application of CE-QUAL-W2 to a reservoir project that has yet to be constructed has the considerable limitation of not being calibrated to field observations. However, the physically based CE-QUAL-W2 model provided a basis for constraining the analysis. The hydrodynamics of operations and wind mixing, coupled with the dynamics of stratification, algal and nutrient dynamics, and dissolved oxygen provided considerable insight into the potential response of the proposed Long Lake Valley Reservoir.

1 Introduction

The Bureau of Reclamation Klamath Basin Area Office (Reclamation) is undertaking a series of scoping studies to identify the potential benefits and limitations of additional storage in the upper Klamath River basin in the vicinity of Upper Klamath Lake (UKL). One option is construction of an off-stream storage site in Long Lake Valley. Long Lake Valley is located southwest of UKL, approximately due west of Klamath Falls, and is a terminal watershed with minimal inflow and no surface outflow. The reservoir site consists of a relatively flat bottomed valley with steep sides (Figure 1).

At maximum capacity Long Lake reservoir (LLV) would hold approximately 350,000 acre-feet. The valley floor elevation is approximately 4,250 ft msl, and with full pool at elevation is approximately 4,432 ft msl would result in a reservoir approximately 180 feet deep. Water would be withdrawn from UKL in the vicinity of Wocus Marsh, near the southwestern edge of Howard Bay, and pumped into LLV through a combined canal and tunnel conveyance system.

One option for discharge includes using the inlet works to withdrawal water from the reservoir, effectively returning LLV waters to UKL. A second option is to discharge waters through a tunnel and canal/conduit system to the Klamath River in the vicinity of Miller Island. Other options include conveying waters to Link River Dam or Keno Dam; however, the latter option was not assessed in detail herein. The studies defined and presented herein are appraisal or pilot-level studies, intended to identify any severe (e.g., fatal flaw) water quality issues, and provide direction and insight as to what possible issues of concern warrant additional study. In defining the scope of this project, several discussions were held with Reclamation and included USGS (Portland). Of primary importance was the application of a numerical model to a system that had yet to be constructed and where prototype data were largely absent. The outcome of these discussions identified that application of a numerical model to constrain the problem would be an appropriate approach and consistent with appraisal level studies.

The model application presented herein is not intended to guide design and management purposes, but rather to examine the potential water quality conditions that may occur in LLV under a future, build-out condition. This analysis is the application of a powerful numerical model to constrain the basic input assumptions and identify possible water quality conditions in LLV and potential impacts of water supply releases to the Klamath River for a limited number of simulations. A wider range of analyses and a more comprehensive review of model implementation and input assumptions would be required to refine these exploratory findings.

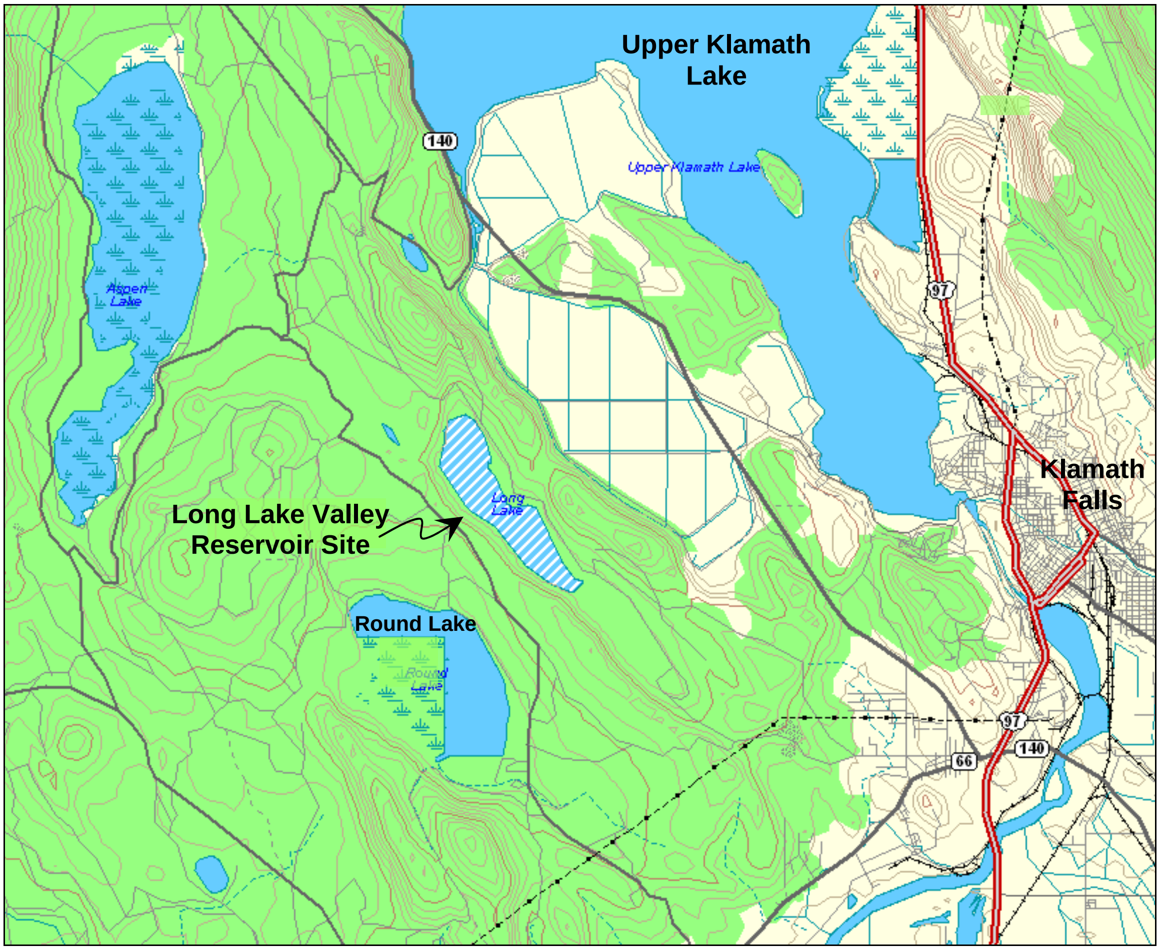


Figure 1. Proposed Long Lake Valley Reservoir Site.

1.1 Acknowledgements

We would like acknowledge PacifiCorp for the use of completed models for Lake Ewauna and Keno Reservoir. The Klamath Tribes long term data set provided critical insight into Upper Klamath Lake water quality conditions. Input on CE-QUAL-W2 parameters and sensitivity testing from USGS Portland Office was timely and resulted in a better understanding of potential water quality response from the proposed reservoir. Reclamation Klamath Basin Area Office provided water quality data for physical parameters and overall provided invaluable guidance on potential LLV configuration and operations.

2 Model Implementation

LLV was represented by the two-dimensional, longitudinal/vertical hydrodynamic and water quality model CE-QUAL-W2. This model, produced and maintained by the US Army Corps of Engineers (USACE, 2002), has also seen historic use on this river (e.g., PacifiCorp, 2004) and is used to model Lake Ewauna to Keno Dam in this project. Because the model assumes lateral homogeneity, it is suited for reservoirs that are relatively long and narrow exhibiting longitudinal and vertical, but not necessarily strong lateral, water quality gradients. The CE-QUAL-W2 model is capable of representing a wide range of physical, chemical, and biological processes affecting water quality. The model can simulate selective withdrawal, sediment nutrient release dynamics, nitrogen inhibition under anoxic conditions, internal weirs and curtains, and other options useful in assessing a wide range of existing and possible future conditions of the system.

The reservoir model CE-QUAL-W2 was implemented for LLV. The model implementation process includes constructing appropriate system geometry, flow and water quality conditions (boundary conditions, initial conditions), meteorological data, and other model parameters. Generally, modeling a reservoir includes a calibration/validation component but that was not feasible for this pre-design investigation.

- Geometry data include a description of the location, i.e., latitude and longitude, UTM, or similar coordinate system; bed slope, and cross section data. Additionally, stage-volume data; intake and outtake structure configurations, elevations; locations of diversions structures and return points are required for reservoirs.
- Flow and water quality information include system reservoir inflow in this case UKL and Link River data were utilized.
- Meteorological data include standard parameters for heat budget calculation within the numerical models, e.g., air temperature, wet bulb temperature (or dew point temperature), solar radiation, cloud cover, wind speed, and/or barometric pressure from the Pacific Northwest Cooperative Agricultural Weather Network station KFLO (4,100 ft msl), near Klamath Falls.
- Other model parameters include selection of time step, spatial resolution, identified periods of analysis, and selection of default model constants, coefficients and parameters.

Model implementation for LLV is outlined herein, with a description of geometric data, flow and water quality conditions, and meteorological conditions.

2.1 Long Lake Valley Representation

The proposed LLV reservoir site is oriented northwest to southeast, approximately 5.1 mi (8.2 km) long and 0.8 mi (1.3 km) wide, and is located about 5.0 mi (8 km) west of city of Klamath Falls, Oregon, and 2.5 mi (4 km) south of Wocus Bay of UKL, Oregon (Figure 2). Wocus Bay and the more common name of Howard Bay described the same bay of UKL. Wocus Bay will be used throughout this report.

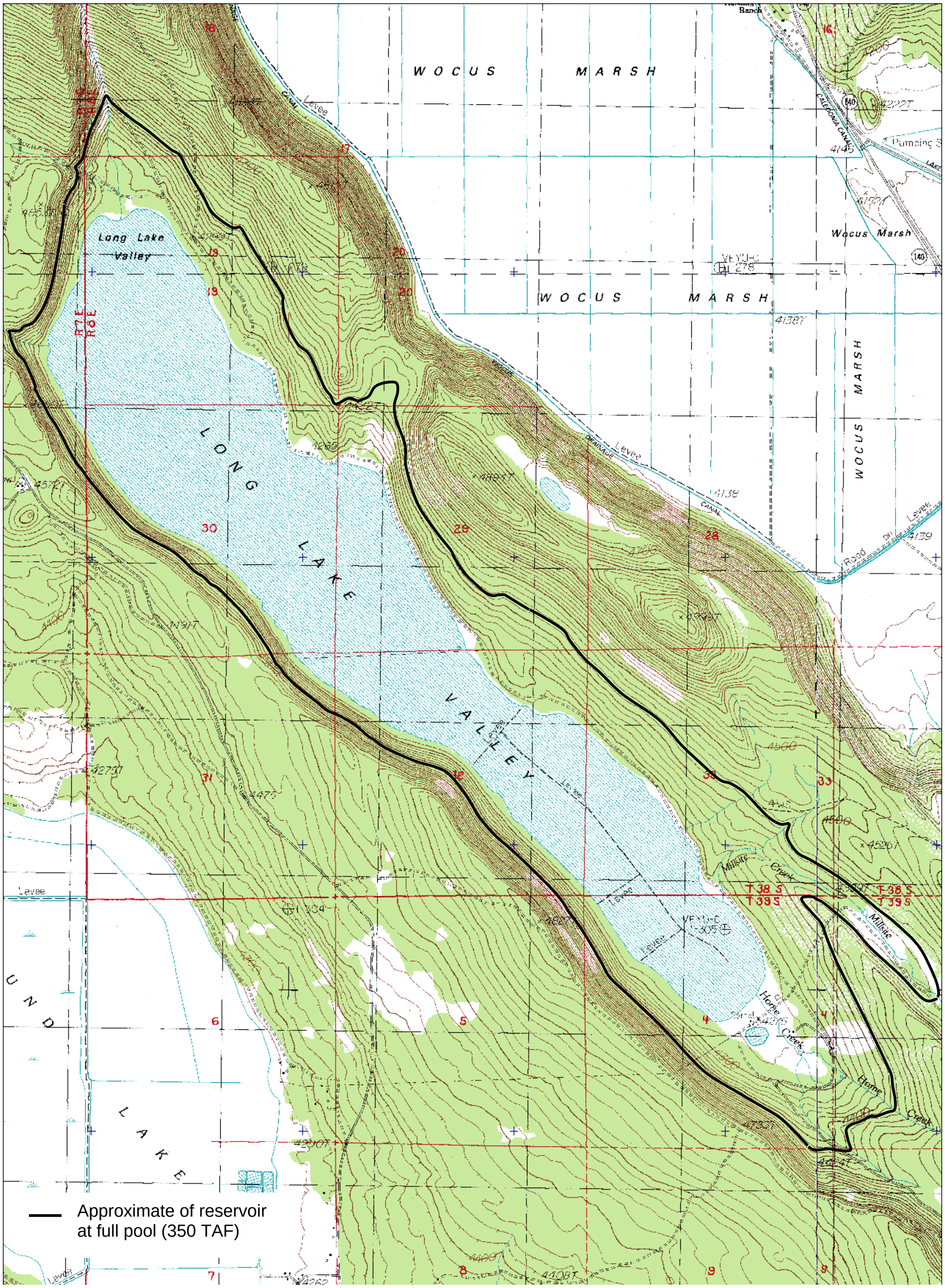
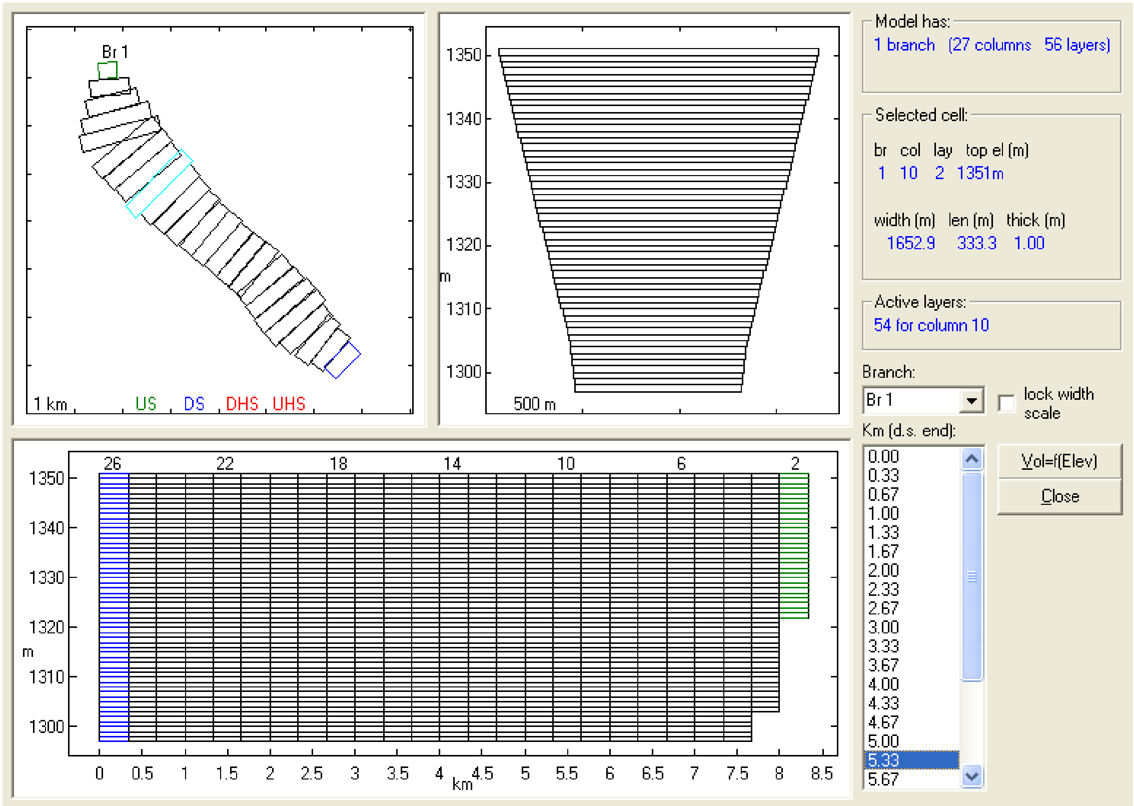


Figure 2. Topography in the vicinity of the proposed Long Lake Valley Reservoir.

2.1.1 Reservoir Bathymetry for CE-QUAL-W2

The bathymetry for the LLV was derived from DELORME's 3-D TopoQuads, based on USGS 7.5-Minute Quadrangle Maps. Segment numbers, orientation, number of layers, lengths, widths, and water surface elevation are different features of the reservoir bathymetry estimated from the quadrangle maps mentioned above. The model representation is shown in Figure 3.



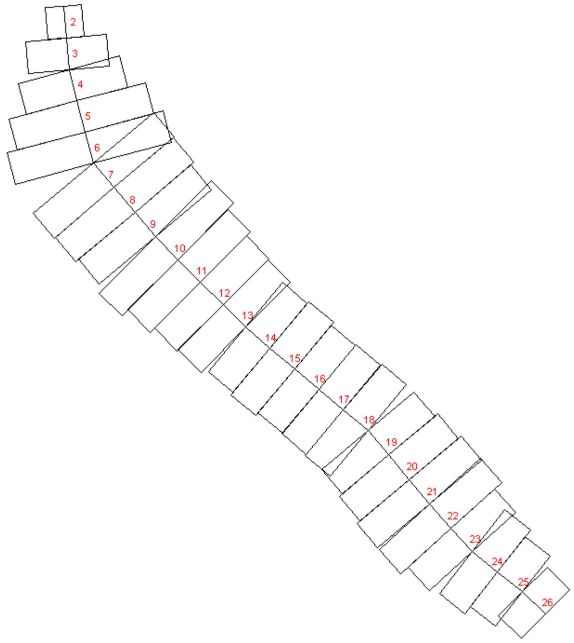


Figure 3. CE-QUAL-W2 representation of LLV: (top) plan view, representative vertical layer structure for segment 10, and longitudinal segment and profile representation, (bottom) plan view with segment assignments (figures produced by AGPM, v 3.29).

The CE-QUAL-W2 representation of LLV has one branch, with 25 active segments, all 333.33 m in length. Layers thickness is uniform throughout the model domain at 1.0 m. All segments have 49 active layers except segment 2 (26 active layers) and 3 (43 active layers). Bottom roughness was represented by a Manning coefficient of 0.04 for each segment.

This reservoir bathymetry was used to accommodate the range of options simulated in this study. LLV is modeled as an off stream reservoir, and to represent inflow and outflow conditions in CE-QUAL-W2, lateral outflows were used at the appropriate segments. The bottom elevation of the most downstream segments (south eastern end of the reservoir) is higher than the inlet/outlet and higher than the lower SLOW elevations. This condition triggered a critical error in the current CE-QUAL-W2 framework where the bottom of the downstream segments needed to be at least as low as the inlet. Two meter wide layers were added to the bottom of segments at the downstream end of the reservoir to allow the model to operate without adversely impacting results. Sensitivity testing was conducted with these layers expanded up to 100 meters to determine if these modifications adversely affected results. Based on graphical examination of temperature, algae, and dissolved oxygen, little if any visible difference was observed in simulation results viewed with the Animation and Graphics Portfolio Manager (AGPM, v 3.29) viewer[1]. The areas near these narrow segments did show greater transient changes in

[1] AGPM is a third party software produced by Loginetics, Inc., and allows for the display (tabular, graphical, and animation) of various water quality simulation results from CE QUAL W2 for reservoirs.

constituents for short periods at irregular and infrequent intervals when compared to the main body of the reservoir, but the volume of water is small and did not affect overall reservoir simulation results. This modification and results were presented and reviewed by the USGS, Portland Office. USGS identified the approach as a reasonable method to overcome this limitation in CE-QUAL-W2 and noted that they had employed similar methods in the past. Such methods are acceptable so long as the volume which experiences those transient changes is small compared to the rest of the reservoir, which is the condition of the current model application.

2.2 Keno Reservoir

The CE-QUAL-W2 model used for Lake Ewauna and Keno Reservoir to assess the potential water quality implications on discharged LLV water to the vicinity of Miller Island. This version is consistent with the current version employed by both PacifiCorp in current relicensing studies and Tetra Tech (Tetra Tech is the consultant for USEPA, State of Oregon, and State of California) Klamath River Total Maximum Daily Load studies. Details of previous applications are addressed in PacifiCorp (2005) and ODEQ (1995).

3 Boundary conditions

Boundary conditions for the LLV model application required representative flow regime for imports and releases from LLV, water quality flows associated with imports from Upper Klamath Lake, and meteorological conditions.

3.1 LLV Flow Boundary Conditions

The model simulations performed for this study form an initial exploration of the general sensitivity of LLV operations, and the potential effect those operations may have on water quality both in the reservoir and in the Klamath River below Link River Dam. Watercourse was given latitude to explore operational alternatives and provide feedback to Reclamation. The operational schedules (including pumped storage) described below are consistent with verbal discussions and written documents provided by Reclamation to Watercourse.

For all simulations the inflow point to LLV was located near Wocus Bay, drawing water from UKL. The inlet invert elevation was approximately 1,301.5 m (4,270.0 ft), based on Reclamation supplied pre-design drawings. Maximum capacity of inflows and withdrawals was set to 1,000 cfs. Timing of all inflows occurred from January 1 through mid-April. Withdrawals were simulated at two locations both as lateral withdrawals, and occurred from June 1 through the end of September. Three combinations of bottom and selective withdrawal at two locations that were employed are summarized in Table 1. Inflows for all simulations were set at 500 cfs except for the full reservoir scenarios that used 1,000 cfs. Similarly all withdrawals were set at 500 cfs except for the full reservoir scenarios that used 1,000 cfs. Specific simulations are described in detail below.

Table 1. Simulated Withdrawal Types

Discharge Point	Model Location (Segment/Km)	Outlet Elevation(s) (meters)	Type
Wocus Bay	7/6.33	1,303.93	Bottom
Wocus Bay	7/6.33	1,340.00 1,330.00 1,320.00 1,310.00 1,303.93	SLOW
Miller Island	23/1.00	1,340.00 1,330.00 1,320.00 1,310.00 1,303.93	SLOW

Note: All simulations utilized bottom inflow regardless of outflow type

Selective withdrawal was implemented by preprocessing a set of withdrawal flows for the year long simulation. A spreadsheet based mass balance utility was developed with logic to blend water from withdrawal elevations between the near surface outlet and the next lower outlet. The spreadsheet made use of the elevation capacity curve (Figure 4), inflows, and outflows. Transition between outlets during reservoir drawdown was based on the depth of the uppermost active (submerged) outlet. When water surface elevations were within three meters of the centerline elevation of the upper most active withdrawal outlet, the flows were blended in a linear fashion with the next lowest outlet. This interval of SLOW centerline elevations was for modeling purposes and design criteria (e.g., vortices development) were not considered. For example, if the water surface was two meters from the centerline of the uppermost outlet, two-thirds of the water would be withdrawn from the upper outlet and one-third from the next lower outlet. At most, only two outlets were active at one time. When reservoir water surface elevation reached the centerline elevation of the upper most active outlet, all flow was allocated to the next lower withdrawal outlet.

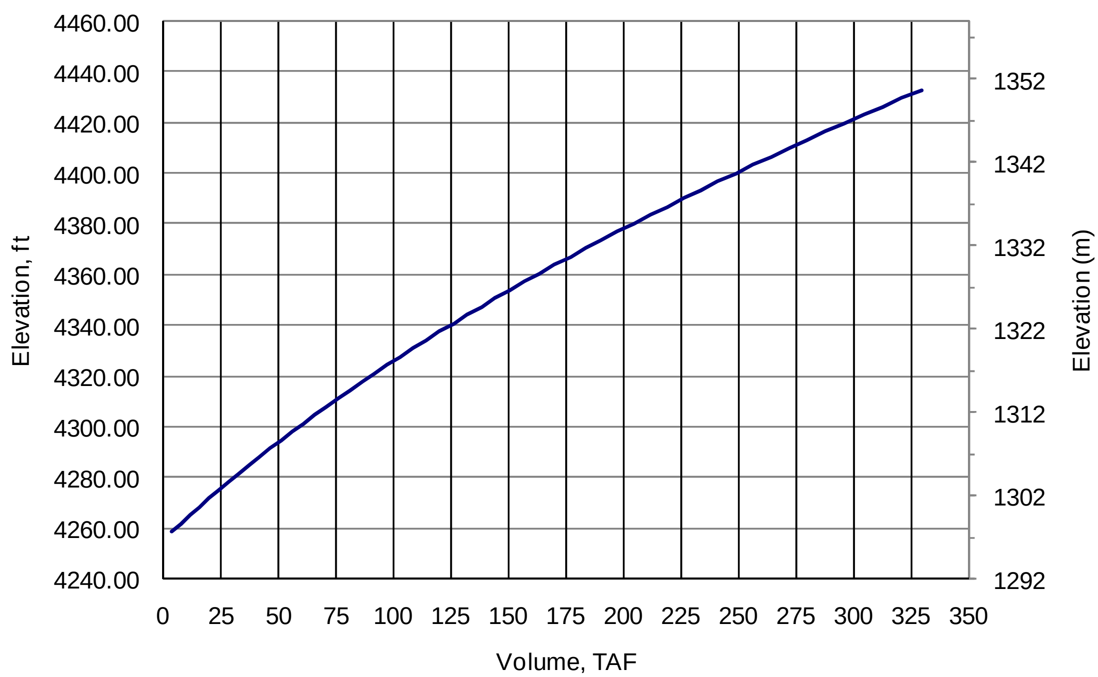


Figure 4. Simulated LLV elevation/storage curve

The pumped storage schedule was developed as follows. For all months, except December, the discharge was 1,000 cfs for five hours from 3:00 pm to 8:00 pm, and the reservoir was filled for ten hours from 10:00 pm to 8:00 am at a rate of 500 cfs. During

December an additional peak release of 1,000 cfs was added from 6:00 am to 9:00 am and re-fill was added at the rate of 500 cfs for six hours from 9:00 am to 3:00 pm. The refill for the afternoon/evening peak shifted two hours earlier in order to complete re-fill by the time the morning peak was set to start. The length of refill was extended to twice the discharge time and therefore half the capacity. The refill rate reduction was aimed at reducing potential de-stratification affects on the reservoir, and may result in more economical performance depending on how power production rates are structured and how the pumping plant is designed.

All simulations incorporating pumped storage operations utilized SLOW at segment 7 or 23 and inflow near the bottom of segment 23. No pumped storage operations occurred during the filling or release process described earlier. While the operation of pumped storage was temporally limited to periods when fill and release were not occurring at the request of Reclamation, there may be opportunities to utilize those operations during such fill and release periods. Those operations may be considered in the future if Reclamation wishes to pursue additional exploration of operational alternatives.

3.2 LLV Water Quality Data

Calendar year 2004 data were chosen because data were readily available, the period represents a recent approximately "average" runoff year, and simulations for Lake Ewauna-Keno Reservoir were readily available. Boundary data used for the water quality constituent inflow files were compiled after reviewing several data sources. Klamath Tribes grab sample data from UKL (used sample depths for one meter at Wocus Bay) were plotted with Reclamation continuous probe data (UKL at Link Dam, site KR254.4) for water temperature, dissolved oxygen (DO) and pH (Figure 5 and Figure 6). The Klamath Tribes water quality data use the name Wocus Bay as a sample site in this region. Based on graphical examination of grab sample data for water temperature and DO, and to a lesser extent pH, were in reasonable agreement. pH appeared more variable during summer than DO and water temperature, probably in response to extensive primary production during summer months. Continuous temperature and DO probe data from Reclamation were used, with data gaps filled via linear interpolation. Grab sample data from the Klamath Tribes was used for the remaining constituents. For months where there were no observations in 2004 (e.g., winter months), the monthly mean values from Klamath Tribes data during the 1990-2005 period were used. For December there were no Wocus Bay observations, so Fremont Bridge grab sample data were used. The Freemont bridge site data, located at the southern end of UKL approximately 1/3 of a mile upstream from Link Dam, was deemed a reasonable replacement due to the relatively low biological activity in UKL and the expectation of more spatial uniformity during winter.

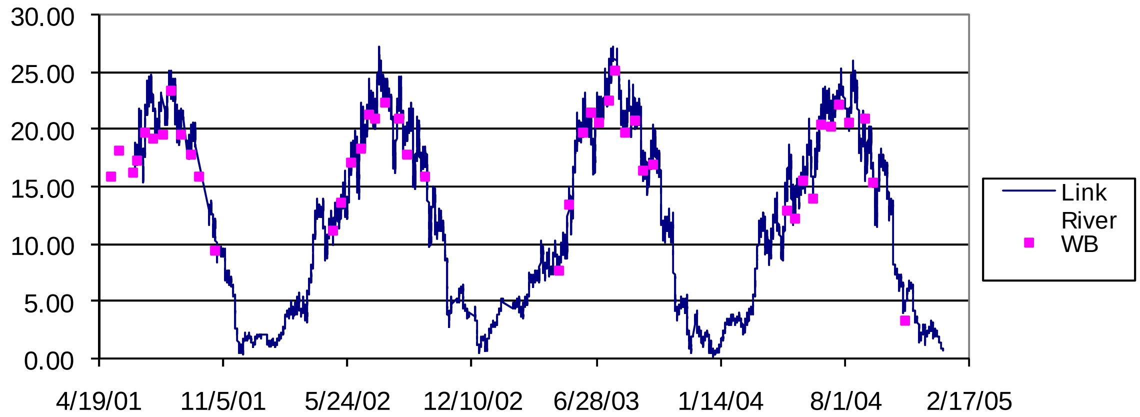


Figure 5. Water temperature observations at Link River Dam and Wocus Bay (WB).

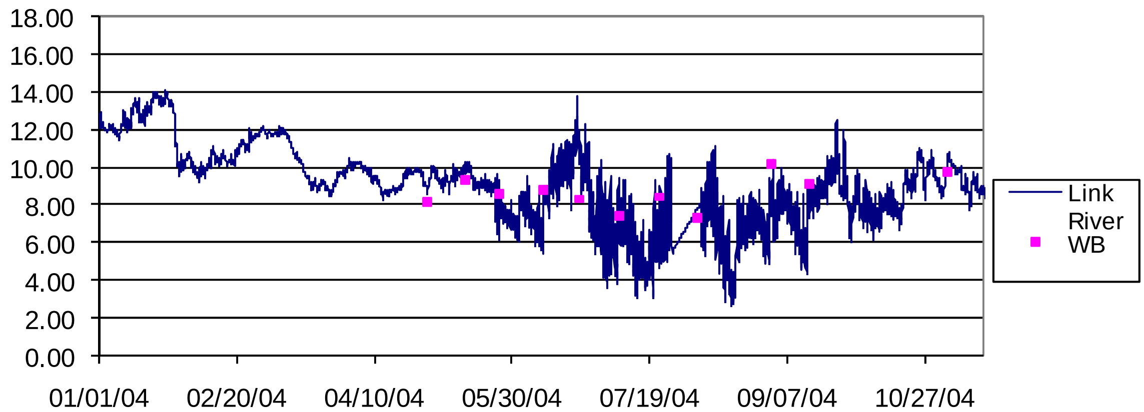


Figure 6 Dissolved oxygen observations at Link River Dam and Wocus Bay (WB).

For initial conditions of constituents lacking field observations, the following calculations were used (measured constituents included chlorophyll am SRP, total nitrogen, nitrate, ammonium):

Algae = chlorophyll a * 0.67
Algae1 = Algae * 0.99
Algae2 = Algae*0.01
PO_4 - IF(total phosphorous – Algae*0.01)< SRP then
PO_4 =SRP
Else
PO_4 = (total phosphorous – Algae*0.01)
End IF
Total organic nitrogen (TON) = Total nitrogen-nitrate– ammonium
Total organic matter (TOM) = (TON-(Algae*0.07))/0.07
Refractory organic matter = TOM*0.8
Labile organic matter = TOM*0.2

Initial water quality conditions are critical to the LLV model simulations considering the small amount of inflows and outflow compared to the storage capacity. All reservoir simulations start on January 1 with isothermal conditions in LLV. Initial conditions as shown in Table 2, and are assumed uniform throughout the reservoir. Test simulations generally showed little longitudinal variability except during the warmer months when pumped storage operations were implemented – a period far removed from initial conditions.

Table 2. Initial concentration for each concentration in LLV CE-QUAL-W2 model.

Icon	Constituent	Initial Concentration (g/m^3)
TDS	Total Dissolved Solid	100.0
TRACER	Conservative Tracer	100.0
AGE	Residence Time	0.000
COL1	Coliform Group 1	0.000
ISS1	Inorganic Suspended Solids Group 1	25.00
PO4	Dissolved Inorganic Phosphorus	0.08
NH4	Ammonium	0.69
NO3	Nitrate – Nitrite	0.13
FE	Iron	0.00
LDOM	Labile Dissolved Organic Matter	0.00
RDOM	Refractory Dissolved Organic Matter	12.28
LPOM	Labile Particulate Organic Matter	3.07
RPOM	Refractory Particulate Organic Matter	0.00
CBOD1	Carbonaceous Biochemical Oxygen Demand Group 1	0.00
ALG1	Algal Group 1	0.21
ALG2	Algal Group 2	0.01
DO	Dissolved Oxygen	13.32
TIC	Total Inorganic Carbon	13.01
ALK	Alkalinity	50.0
TIN	Water temperature	0.60 (^{o}C)

Two algae species were included in the model simulations, with parameter setting for algae species one (algae1) representing a cooler water species and algae species two (Algae 2) represented a warmer water species (defined by temperature preferences in CE-QUAL-W2). Algal species were partitioned from a single calculated input at 99 percent to algae one and 1 percent to algae two because filling of the reservoir was assumed to take place during the cooler periods of the year. Growth rates and temperature preferences were used to differentiate algal species. Parameters were adjusted to represent algae included growth and mortality rates, light extinction coefficients, settling rates, half saturation constants, and other factors.

3.3 LLV Meteorological Boundary Conditions

Meteorological data used in the LLV CE-QUAL-W2 application are consistent with the current version of the CE-QUAL-W2 model used for Lake Ewauna and Keno Reservoir. Wind speed for one day in September was reduced by reducing the wind sheltering coefficient to 0.1 from 0.5 to overcome a numerical instability. The effect of this change in any of the results is considered insignificant in the overall simulation as well as with any comparative assessment.

3.4 Klamath River Boundary conditions

The Klamath River reach from Link River to Keno Reservoir was modeled with CE-QUAL-W2 to determine the potential effect of discharges from LLV to the Klamath River at two locations: Miller Island and Link River Dam. Link River inflow forms the upstream boundary conditions for the Lake Ewauna/Keno Reservoir model. For the purposes of this exploratory study, conditions at Link River Dam and Link River at Lake Ewauna were considered approximately equivalent. Calendar year 2004 was used as the baseline conditions to compare simulated discharges from LLV. Discharges to Miller Island were represented as a tributary inflow, while discharges at Link River Dam were included in the Link River inflow water quality.

For discharge at Miller Island, inflow at Link River was modified to accommodate LLV discharge such that the total inflow was the same. Specifically, Link River Dam release was reduced in an equal amount to LLV discharge on a daily average basis. A minimum flow of 100 cfs at Link River Dam was imposed. These assumptions do not reproduce exactly the same outflow at Keno because discharges at Miller Island do not have to traverse the entire reservoir. Nonetheless, for this scoping level analysis, the assumption is deemed acceptable.

For discharge at Link River Dam, water quality from LLV was blended into the boundary condition at Lake Ewauna using a mass balance model. Link River Dam releases were reduced as in the previous scenario to accommodate LLV discharges. This release and Link River water quality, coupled with simulated LLV flow and water quality were used to calculate daily conditions. In both scenarios, algae from Long Lake were converted to organic matter, under the assumption that algae would not survive transit. This organic matter was assumed labile and partitioned 80 percent particulate and 20 percent dissolved, consistent with default partitioning in CE-QUAL-W2 when converting algae to organic matter.

4 Simulations

Simulations were completed for LLV to explore the range of operations and water quality response. Subsequently, outflow quantity and water quality were used as inputs to the Lake Ewauna-Keno reservoir model.

4.1 LLV

Multiple simulations were performed for the purposes of exploring operational impacts to water quality, as well as sensitivity to certain model parameters. A summary of simulations used to explore operational impacts on water quality is presented in Table 3. Several storage levels, withdrawal operations, and pumped storage operations were employed to bracket potential water quality response. High, medium, and low storage conditions identified in Table 3 corresponded to starting elevations for LLV. SLOW and pumped storage operations were described previously. During pumped storage operations no water was discharged to Miller Island even though that location was being used for direct releases to Miller Island from June through September, i.e., all pumped storage operations were assumed to return to Wocus Bay. Naming the selective withdrawal location Miller Island does not imply releases were made to Miller Island during those operations rather this particular scenario was used to examine the water quality impacts associated with using that withdrawal location.

Table 3. Model Simulation Summary

Description	Scenario	Fill rate cfs	Elevation Start/Maximum meters	With-drawal rate cfs	With-drawal Type /Segment
1. High Lake no fill	High_NoFill	0.0	1,350.00/1,350.00	0.0	N/A
2. Medium Lake fill max	Med_FillMax	1,000	1,320.53/1,350.21	1,000	Bottom/7
3. Low Lake fill half	WB two_7	500	1,311.70/1,329.95	500	Bottom/7
4. Low Lake fill half SW WB	WB SW two_7	500	1,311.70/1,330.02	500	SW/7
5. Low Lake fill half SW MI	MI SW two_23	500	1,311.70/1,330.02	500	SW/23
6. Low Lake fill half SW PS WB	MI PS SW two_7	500	1,311.70/1,330.02	500/250	SW/7
7. Low Lake fill half SW PS MI	MI PS SW two_23	500	1,311.70/1,330.02	500/250	SW/23
8. Low Lake no fill	Low no fill	0.0	1,311.70/1,311.70	0.0	N/A
9. Low Lake no fill PS MI*	Low no fill PS 23	0.0	1,311.70/1,311.70	0.0	SW/7
10. Low Lake no fill PS WB*	Low no fill PS 23	0.0	1,311.70/1,311.70	0.0	SW/7

Note: All simulations filled from the Wocus Bay inlet located near the bottom of segment 7.
SW - SLOW
PS - pumped storage
WB - Wocus Bay segment 7
MI - Miller Island segment 23
* - No operation filling or releases for supply but pumped storage operations were in effect all year at rates described for other pumped storage operations

Reclamation indicated the operation of LLV would typically utilize the middle storage region of the reservoir. Therefore, most simulations started low, filled to approximately half full and ended approximately at the starting elevation. Additional simulations were performed to test the sensitivity of different parameters and boundary conditions such as algae parameters, wind sheltering coefficients, and bathymetry modifications which are summarized in Table 4. Sensitivity analysis occurred throughout the model implementation process, so the baseline for comparison associated with any particular analysis varied. For example bathymetry testing occurred early in the process while algae sensitivity occurred later in the model process.

4.2 Keno Reservoir

While the primary purpose was exploring water quality changes in LLV, the potential impacts associated with discharge to Keno reservoir was also explored. As noted previously, Keno Reservoir was modeled with CE-QUAL-W2. Simulations WB SW two_7, MI SW two_7, and MI PS SW two_23, (Table 3) were modeled with discharge to Keno Reservoir at Miller Island and Link River Dam.

Table 4. Model sensitivity simulations.

Base Simulation	Scenario	Parameters Adjusted	Number of Simulations
Low Lake fill half	WB two_7	Narrow bottom layers	2
Low Lake fill half	WB two_7	AG	6
Low Lake fill half	WB two_7	AT1, AT2, AT3, AT4	6
Low Lake fill half	WB two_7	ASAT	2
Low Lake fill half	WB two_7	AS	2
Low Lake fill half	WB two_7	EXH2O	3
Low Lake fill half	WB two_7	EXA	3
Low Lake fill half SW MI	MI SW two_7	AHSN, ASAT	1
Low Lake fill half SW MI	MI SW two_7	AHSN, ASAT AS	1
Low Lake fill half SW MI	MI SW two_7	WSC	6

AG – Algal growth rate
AT1 - Lower temperature for algal growth, °C
AT2 - Lower temperature for maximum algal growth
AT3 - Upper temperature for maximum algal growth
AT4 - Upper temperature for algal growth
EXH20 – Light extinction coefficient for water
EXA – Light extinction due to algae
ASAT - saturating light intensity at the maximum photosynthetic rate
AS – Algae settling rate
AHSN - Half saturation Nitrogen
WSC – Wind sheltering coefficient (approximately 6 simulations)

5 Results

Model simulations produced considerable amounts of information. By and large model results were examined in the AGPM postprocessor. Several sensitivity tests were completed to assess model response to various conditions and were subsequently examined. From these results several findings are reported, including seasonal stratification effects, the impact of epilimnion algal populations on water quality, hypolimnion conditions, operational impacts at low storage, and discharge impacts on Keno Reservoir.

5.1 General Simulation Sensitivity

General sensitivity testing included assessing algae parameter sensitivity and wind sheltering. The goal of this exercise was not to exhaustively assess all potential combinations of water quality parameters and coefficients, but rather to identify a few areas of sensitivity and select a set of final parameters for application of the model.

One area of exploration was the simulation of the algal growth in the epilimnion at appropriate times and depths. Initial model runs contained low algal concentrations early in the season, followed by a relatively deep layer of higher concentrations later in the year. Algae production was occurring near 10 meter depths and showed nutrient depletion in the water column above this depth. The nutrient depletion occurs shortly after the onset of notable algae production in the spring. Starting with parameter values from the Keno Reservoir application of CE-QUAL-W2, light extinction coefficients, algal temperature preferences, and algal growth rates for the two algal species were varied to determine the range of system response. After several exploratory simulations, Watercourse discussed model results via phone and internet based online meetings with Annett Sullivan and Stewart Rounds of the USGS Portland office – both experienced CE-

QUAL-W2 water quality modelers. USGS suggested several changes that may better represent blue green algae species in this region. Changes included reducing the saturating light intensity at the maximum photosynthetic rate (ASAT) from 75 W/m^2 (original value) to 25 W/m^2. A lower ASAT value allows algae to grow more readily under lower light conditions. This change increases production and concentration of algae in the reservoir, but did not change the elevation of production in the water column. Second, USGS staff suggested that a value for nitrogen half saturation factor could be set to zero (original value 0.014 mg/l), representing the ability of blue green algae to fix atmospheric nitrogen. With the nitrogen half saturation factor set to zero, inorganic nitrogen was present in notable concentration in near surface waters, unlike the previous value of results where concentrations were at or near zero. However, under these conditions phosphorous becomes depleted in surface waters and algae subsequently occupy deeper waters, similar to previous simulations. This condition is counter intuitive because algae not located at the water surface would be unable to fix atmospheric nitrogen Assessment of negative settling velocities was also applied to test the buoyancy compensation ability of blue green algae. While these changes were valuable suggestions and added insight to the sensitivity of the model, the original values for ASAT, nitrogen half saturation, and settling velocities were retained.

USGS noted that wind sheltering coefficients were set to low values (10 percent) for December, January, and February and set to 100 percent for the remainder of the year. The wind sheltering coefficients were changed to values of 0.5 (50 percent) for the entire year due to the topographic sheltering around the reservoir. USGS also discussed their opinion that the inorganic suspended solids (ISS1) value of 25 mg/L was high. The associated settling rate (SSS) of 1.0 implies that the sediment is small, such as fine silt. These values were carried over from the Keno Reservoir model and were not changed due to lack of any additional field data.

5.2 Seasonal Stratification Effects

Unlike shallower bodies of water (e.g., Upper Klamath Lake or Keno reservoir), LLV would be sufficiently deep to stratify seasonally, exhibiting a cool hypolimnion at depth, a transitional thermocline, and a warm well mixed epilimnion near the surface. Simulations suggest that temperature stratification in LLV generally formed in late March and increased in strength through the summer. Fall cooling resulted in isothermal conditions around the first of November. Stratification strength, depth of the thermocline, and thickness of the epilimnion were largely driven by meteorological conditions, but also dependant on storage, operations, and withdrawal (e.g., bottom withdrawal vs. SLOW).

Generally, retaining higher storage volumes led to a large, cool hypolimnion, and a relatively thin or shallow epilimnion. This condition is shown for June 30 in Figure 7 where the reservoir initial condition was near capacity and no withdrawals occurred. In contrast, when initial reservoir storage was set at half capacity and filled over the next three and a half months, hypolimnion temperatures were notable warmer and thickness of the thermocline slightly larger (Figure 8). Filling LLV with UKL water in January and February has little effect on thermal conditions in the reservoir because both water bodies are similar in temperature throughout the water column. However, as day length and solar altitude increases in late winter, thermal loading to both LLV and UKL increases. The shallow waters of UKL are slightly warmer than the bottom waters of LLV and thus inputs tend to warm LLV. These slightly warmer inputs are also less dense (more buoyant) than LLV bottom waters and tend to rise in the reservoir, imparting mixing energy into reservoir. Finally, bottom withdrawal from the reservoir tends to evacuate the deepest, coldest water from the reservoir, leading to warmer hypolimnetic temperatures in the June 30 results shown in Figure 8. For withdrawal operations, SLOW strategies were subsequently explored to preserve deeper, cold waters through the summer period.

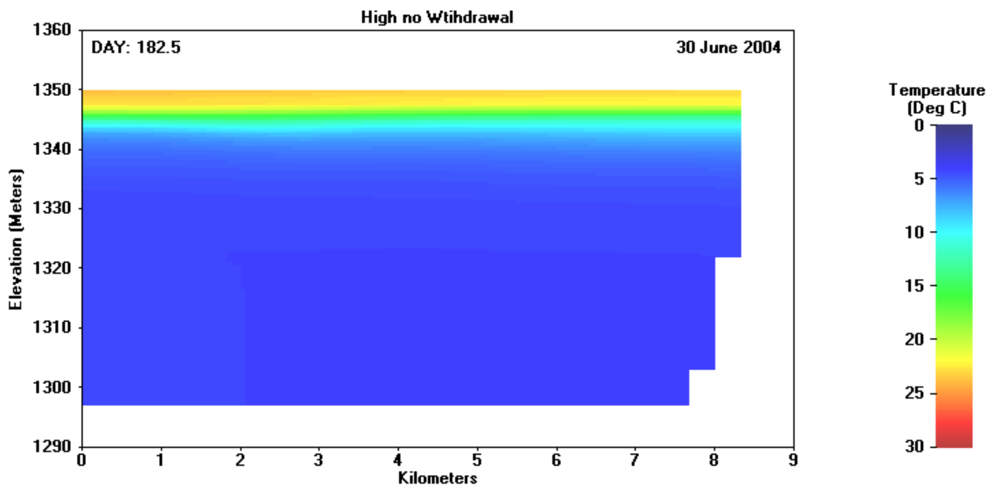


Figure 7. Water temperature under static high reservoir elevation, no inputs, or withdrawals.

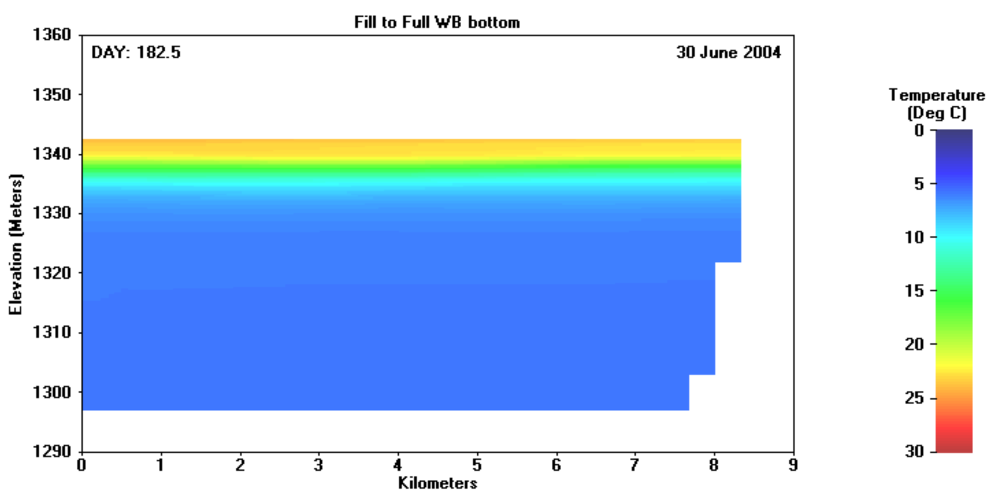


Figure 8. Water temperature with initial storage approximately 50 percent reservoir capacity and filling to approximately 100 percent capacity (shown after one month of drawdown).

5.3 Selective Withdrawal Outlet Works (SLOW)

Selective withdrawal is a common practice in reservoir operations wherein water is withdrawn from one or more different elevations at varying times of year. SLOW are often used to manage cold water supplies within the reservoir for temperature management in downstream river reaches. In certain cases, SLOW are also used in the management of other water quality parameters.

In LLV simulations, SLOW assumptions impact affected water temperature, the thermal structure of the reservoir and outflow temperatures by withdrawing warmer water from near the top of the reservoir, thereby preserving a larger cold water pool in the hypolimnion. SLOW assumptions presented in Section 3.1 are critical to interpreting the output from SLOW simulations, namely, that withdrawal from the reservoir transitioned from one outlet to the next as surface elevation declined through the drawdown period. There are two SLOW simulations shown in Figure 9, filling to medium storage from Wocus Bay and subsequent SLOW discharge to (a) Wocus Bay (WBSW two_7) and to (b) the Klamath River from the downstream end of LLV (MI SW two_23). Differences in outflow temperatures between Wocus Bay and Miller Island were minimal. However, these uniformly distributed releases from June through September illustrate distinct increases and subsequent reductions in temperature, ranging from approximately 7^{o}C to over 20^{o}C. This variability is due to the SLOW flow transitions between the discrete outlet elevations, which are spaced at 10 meter vertical increments within the reservoir. Specifically, when water surface elevation drops to the vicinity of an outlet, a larger proportion of warmer surface waters are entrained. As flow transitions to the next deepest outlet, a larger proportion of deeper, cooler waters are entrained. Notice in Figure 10 (as well as other graphical depictions of thermal conditions throughout this report) that during summer stratification the total depth of the epilimnion and thermocline is typically less than 10 meters. Thus, the transition from one outlet to a subsequent lower outlet effectively represents a transition from an epilimnetic release to a hypolimnetic release. This finding sheds insight into potential design and operations considerations of SLOW at LLV. For example, to manage cold water storage and release temperatures to the Klamath River, outlet works would probably be spaced at intervals less than 10 meters vertically, and withdrawals from two or more outlets may need to be blended to attain desired release temperatures. Although feasible in the CE-QUAL-W2 framework, exploring optimal outlet works elevations and associated flow scheduling was not completed in this study. Because management options are limited with bottom only withdrawal, most of the results in the remaining portions of the report focus on SLOW simulations.

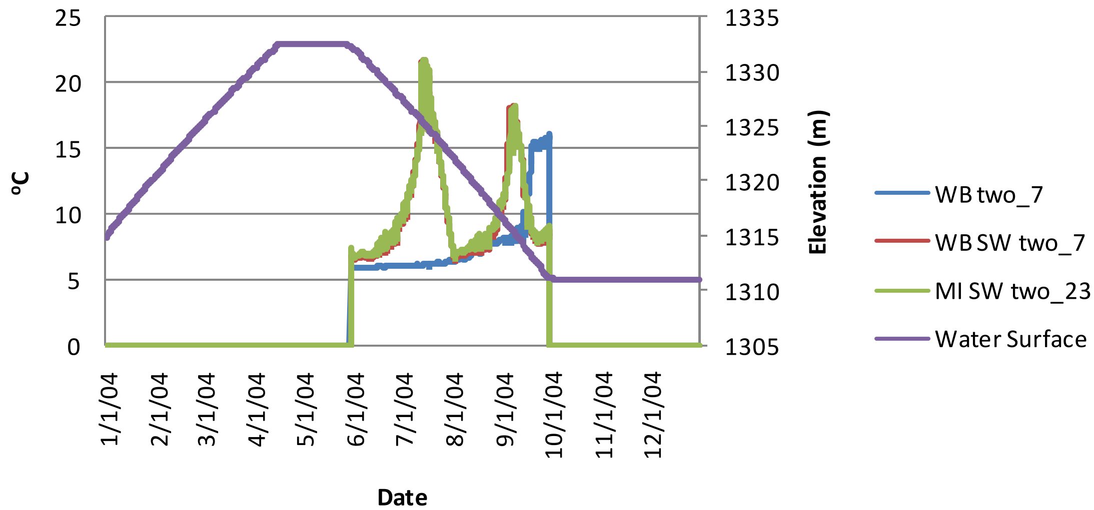


Figure 9. Water temperature comparison for bottom withdrawal at LLV and discharge to Wocus Bay and SLOW at LLV and discharge to Wocus Bay and Miller Island. Water surface elevation is consistent for all simulations shown.

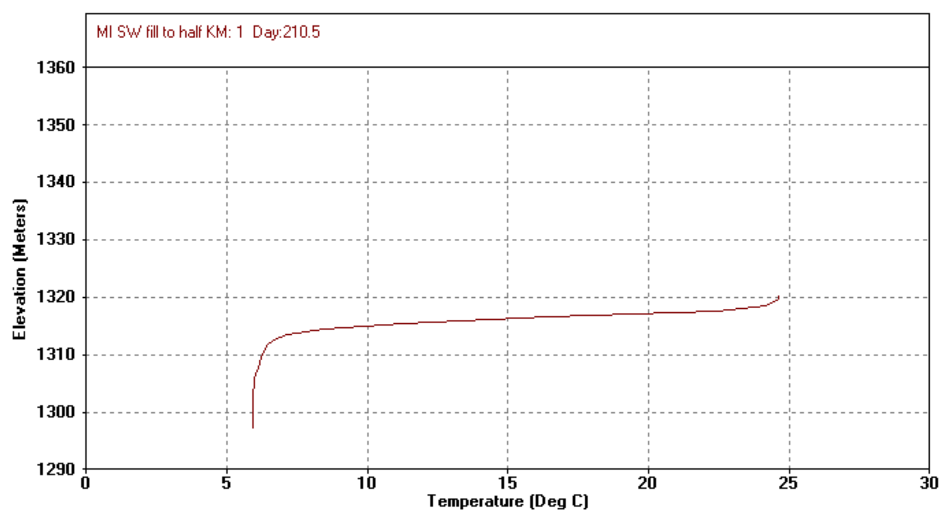


Figure 10. Water temperature profile for SLOW at LLV and discharge to Miller Island simulation (MI SW two_23): July 31.

An additional simulation result for filling to medium storage from Wocus Bay with bottom withdrawal (WB Two_7) is also shown in Figure 9. The bottom withdrawal produces a uniform cold water release throughout the summer; however, in mid-September cold water supplies at the outlet elevation are exhausted and temperatures increase notably. Comparing the depth of the epilimnion in early fall, Figure 11 and Figure 12 respectively, indicates that the bottom withdrawal has effectively evacuated proportionally more of the hypolimnion, resulting in greater epilimnetic depth and subsequent elevated release temperatures. These simulations suggest that that under the conditions of filling from low to medium storage there is probably sufficient water to maintain release temperatures on the order of 10^{o}C through the summer, but probably insufficient water to maintain colder releases. Additional simulations were completed to determine required minimum pool to avoid exhausting cold water supplies if only bottom withdrawal was employed at LLV. A starting elevation of approximately 81 TAF and an elevation of 1,315.0 m (the original simulation assumed 65 TAF and elevation 1,311.7 m) would be required to maintain release temperatures under 10^{o}C through September. These simulations suggest that SLOW would be necessary to effectively manage cold water resources to maintain a stable release temperature, to control release temperatures within a desired range, and ensure the cold water pool was not exhausted during the summer period. Subsequent simulations suggest that temperature benefits from LLV are modest by the time waters reach Keno Dam. Cooler waters in Keno may provide a beneficial influence on water quality conditions therein, but further exploration is required. If thermal benefits are not realized or are not sufficiently significant, or water quality benefits of SLOW are modest, the value of SLOW may be minimal.

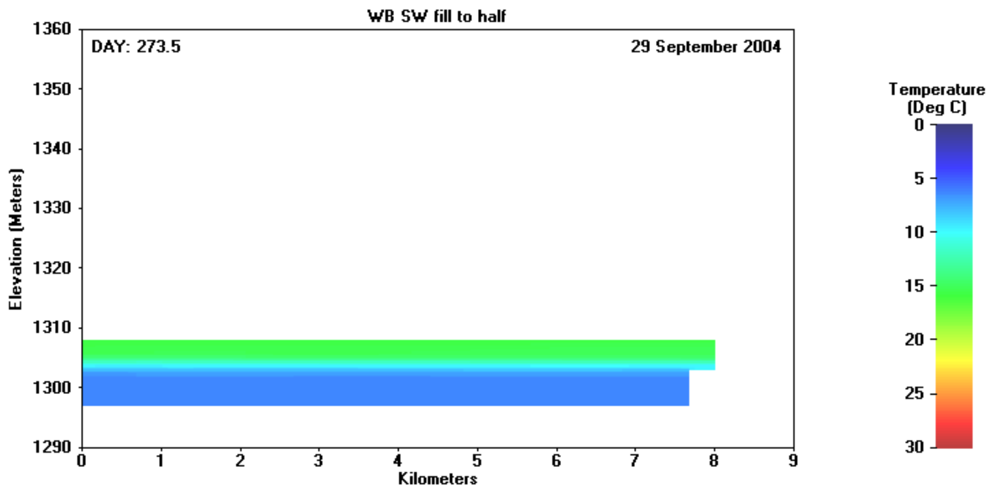


Figure 11. Water temperature for SLOW simulation (WB SW two_7).

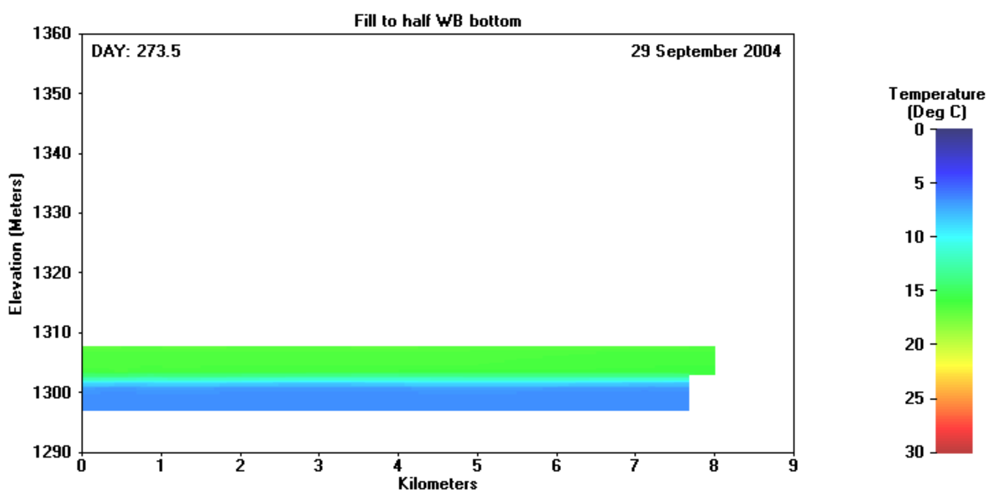


Figure 12. Temperature for bottom withdrawal simulation (WB two_7).

5.4 Epilimnion Algae Production

In general, algae production occurs in LLV from April through October. Of the two species represented, Algae1 (cooler water species) production started in early April and was active in the top several meters of the epilimnion. Because filling terminates in April and stratification segregates the reservoir, by early June nutrients are mostly depleted in surface waters. In response to these nutrient conditions, phytoplankton is present deeper in the lower water column. As summer progresses a transition from Algae1 to Algae 2 (warmer species) occurs. Algae2 subsequently displaces Algae1 throughout a relatively thin zone of production approximately five meters below the surface (Figure 13). This deeper layer of primary production suggests a balance between nutrient availability along the thermocline and light limitation with depth. This zone of algae production coincides with a zone of higher DO concentrations bounded by lower concentrations above and below (Figure 14). These conditions persist until mid-October when algae production starts to decline.

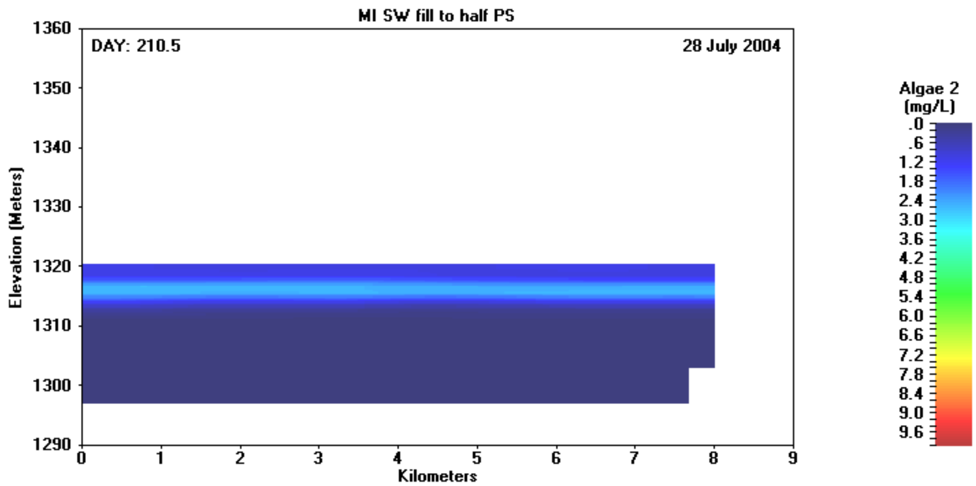


Figure 13. Algae concentrations in late July (MI PS SW two_23).

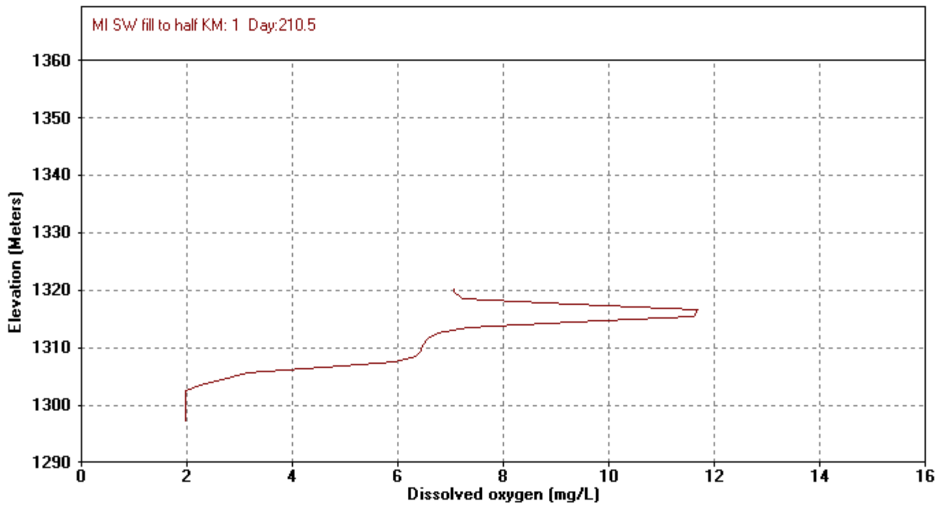


Figure 14. Dissolved oxygen profile for July 30th. Typical profile with peak in zone of maximum algal concentration (MI SW two_23).

SLOW versus bottom release (at Wocus Bay) operations affected algae production during summer periods. SLOW tended to result in a sharp band of algae at approximately 5 meters deep by the end of the summer, while bottom withdrawal presented lower concentrations distributed relatively uniformly through the epilimnion and metalimnion (Figure 15 and Figure 16). SLOW operations are hypothesized to remove nutrient depleted near surface waters and allow more mixing in between the epilimnion and the relatively shallow metalimnion which may entrain nutrients from deeper in the reservoir. In contrast, the bottom withdrawal removed hypolimnetic waters and resulting in a sharper thermocline and deeper epilimnion, which is more resistant to mixing. Therefore, the epilimnion and metalimnion contain lower concentrations of nutrients resulting in overall low primary production.

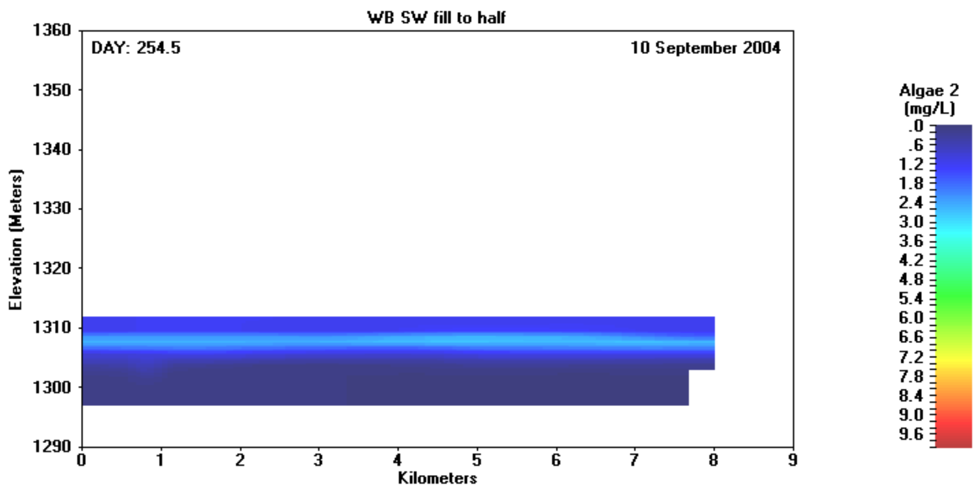


Figure 15. Algae production with SLOW at Wocus Bay.

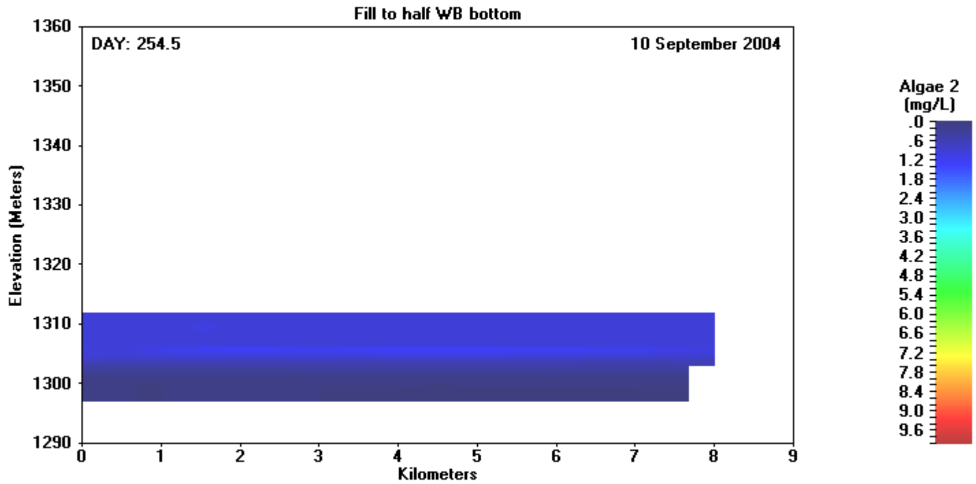


Figure 16. Algae production with bottom withdrawal at Wocus Bay.

Pumped storage operations create another dynamic not observed in the "fill and release" only scenarios. Seasonal reservoir filling occurs largely during winter; however, pumped storage operations may occur during the primary production season (late spring through early fall). These operations can have direct implications on water quality, particularly because the epilimnion may experience nutrient depletion. Examples of local and larger scale impacts of pumped storage operations are shown in Figure 17 and Figure 18 for DO and phosphorous, respectively. Inflows enter approximately kilometer 6.5. After 15 days of pumped storage operations, effects are apparent several kilometers down the reservoir.

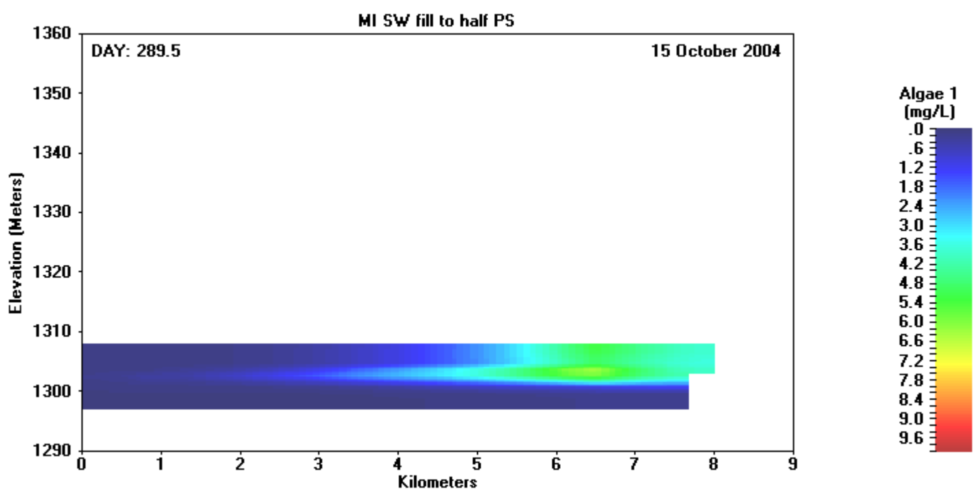


Figure 17. Algae1 conditions 15 days after start of pumped storage operations on October 1 (MI PS SW two_23).

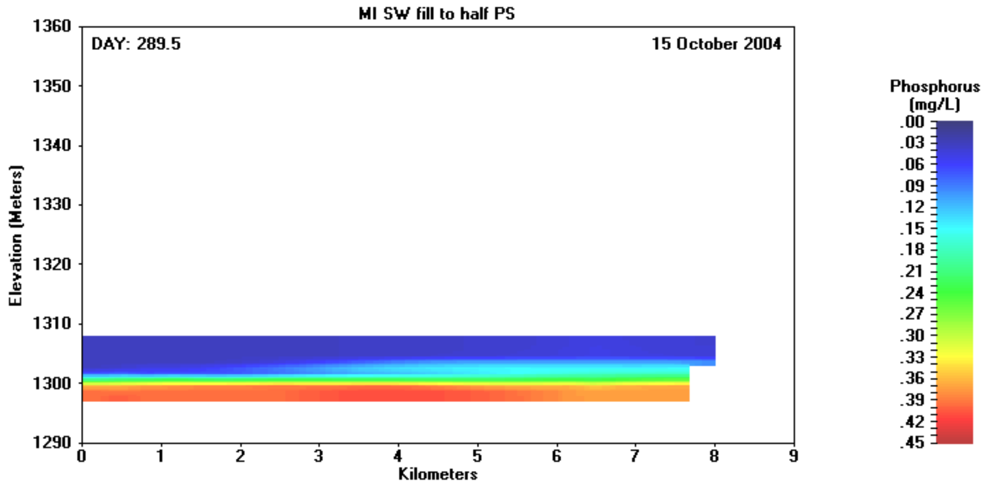


Figure 18. Phosphorous conditions 15 days after start of pumped storage operations on October 1 (MI PS SW two_23).

Additional simulations were completed to explore different modeled representations of phytoplankton, particularly Algae2. For example, growth rates, half saturation constants, settling rates, and light limitation were modified to represent attributes of blue-green algae. In some cases negative settling rates were used to represent buoyancy, and as mentioned previously the half saturation constant for nitrogen was set to zero in some cases to represent an ability of Algae2 to fix nitrogen. In nearly all cases, nutrient limitation ultimately played a role in standing crop and distribution. Although LLV would be filled with eutrophic waters from UKL, reservoir morphology, stratification dynamics, coupled with light and nutrient limitation, limits the habitat available for primary producers to the epilimnion and metalimnion. During summer, these upper layers form a relatively shallow region – ranging from five to eight meters deep. Without influx of nutrients such as inflows/imports, the phytoplankton in the near surface waters face ultimately deplete available nutrients. Simulations suggest that seasonal internal loading from sediments occurs in LLV – the assumption being that these sediments consist of an accumulation of organic matter from primary production within the reservoir and organic matter imported to the reservoir from UKL (during initial filling there will also be inundation of vegetation which will impart an oxygen demand on reservoir waters). However, these nutrients are trapped below the thermocline during the summer growth period and are largely unavailable. An important aspect of this process is that during winter, these nutrients are distributed throughout the reservoir under isothermal conditions and are available the subsequent growing season. Over the long term this internal loading process will lead to increased eutrophication. Critical to long term water quality management is the timing and quality of export or release from LLV. For example, if during the summer period releases were dominated by surface waters depleted of nutrients, the reservoir would experience a net increase through time and face increasing eutrophication potential. Such processes and assessments were not analyzed in this project, but should be examined if LLV is identified as a desired project to construct.

5.5 Hypolimnion Demands

Simulations indicate that LLV would be prone to strong seasonal stratification. Because LLV storage consists nearly completely of UKL imported, eutrophic water, DO concentrations in the hypolimnion are of interest. Model results indicate that waters near the bed exhibits signs of anoxia as early as May. The thickness of the anoxic layer continues to build upward from the bottom to a maximum of around 10 meters, until fall turn over mixes the reservoir to a uniform DO concentration. Bottom withdrawal tends to evacuate the hypolimnion resulting in a thinner layer of anoxic water compared to when SLOW are implemented (Figure 19 and Figure 20).

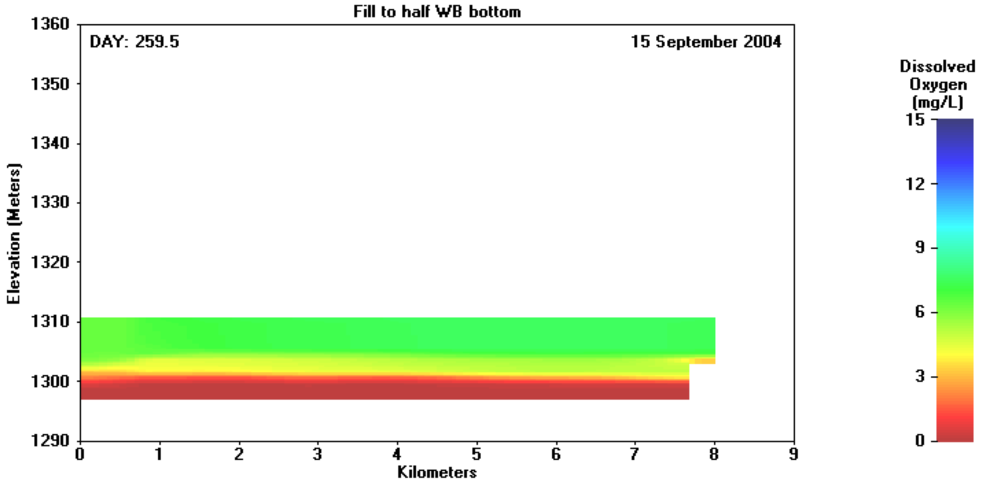


Figure 19. DO with bottom withdrawal (WB two_7)

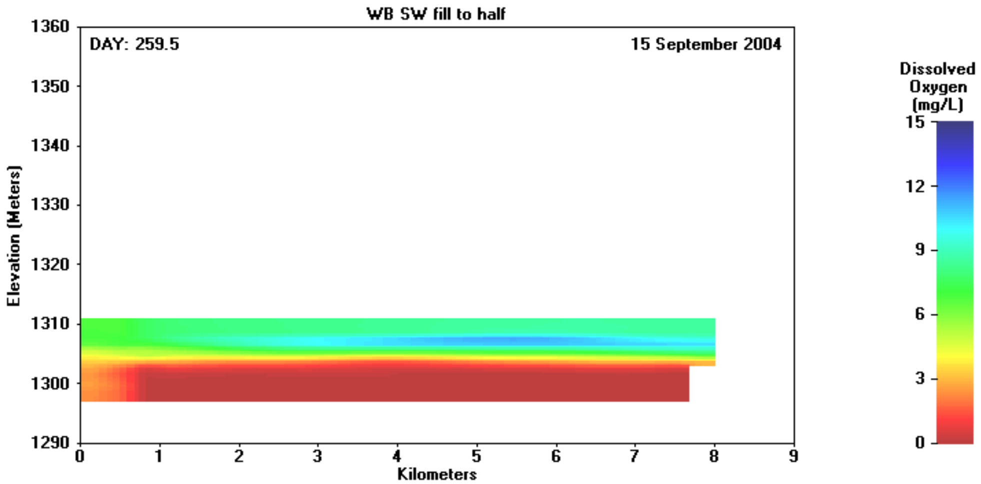


Figure 20. DO with SLOW WB SW two_7.

Bottom only withdrawals also result in nutrients occupying a thinner layer of higher concentrations near the reservoir bottom as compared to the SLOW operations (Figure 21 and Figure 22). This corresponds to a smaller hypolimnetic volume resulting from the bottom only withdrawal (Figure 23), as compared to the hypolimnion resulting from SLOW operations (Figure 24).

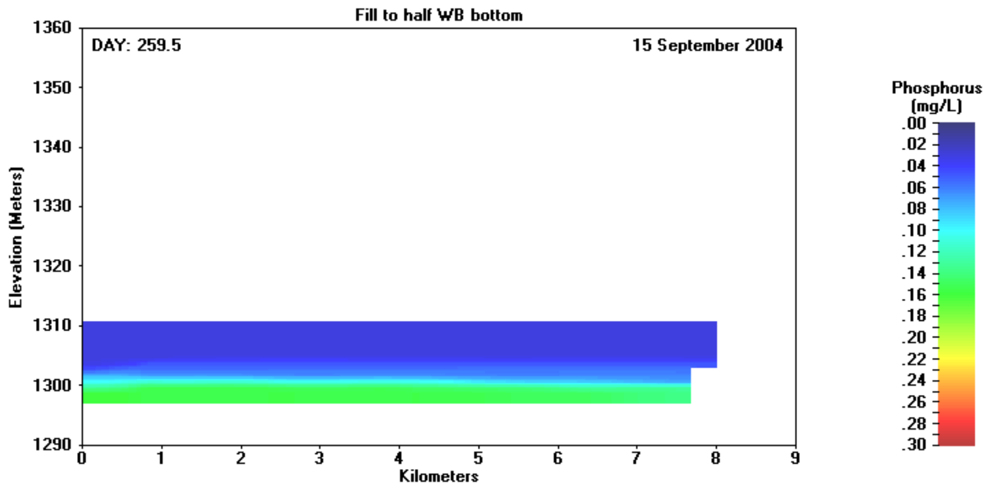


Figure 21. Phosphorus with bottom withdrawal (WB two_7).

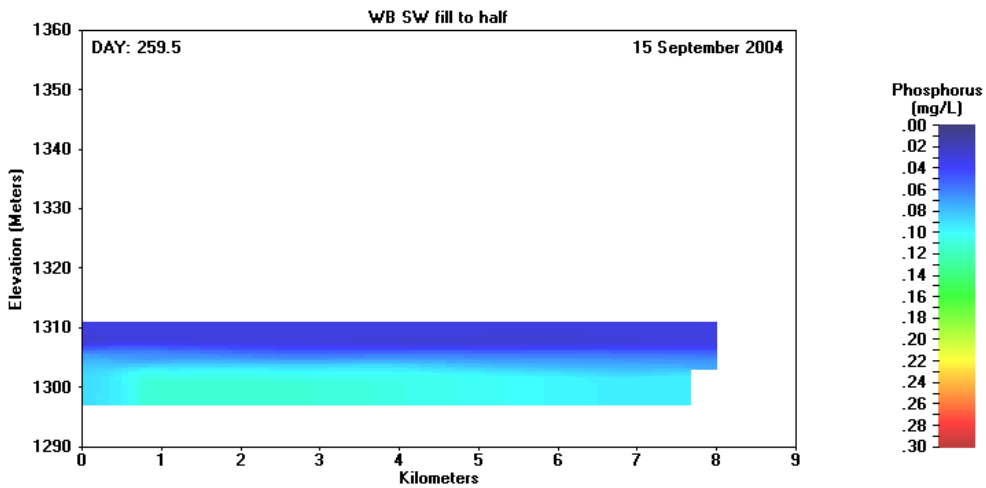


Figure 22. Phosphorus with SLOW (WB SW two_7).

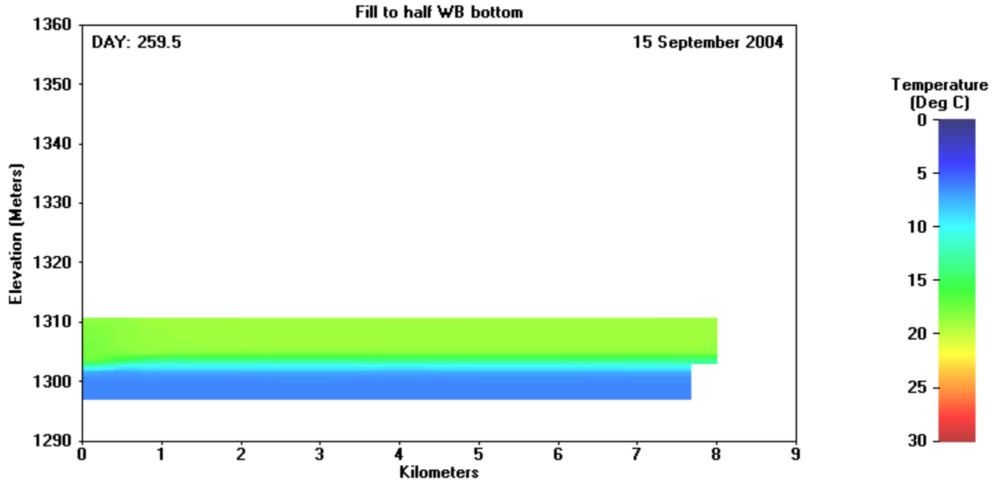


Figure 23. Temperature with bottom withdrawal (WB two_7).

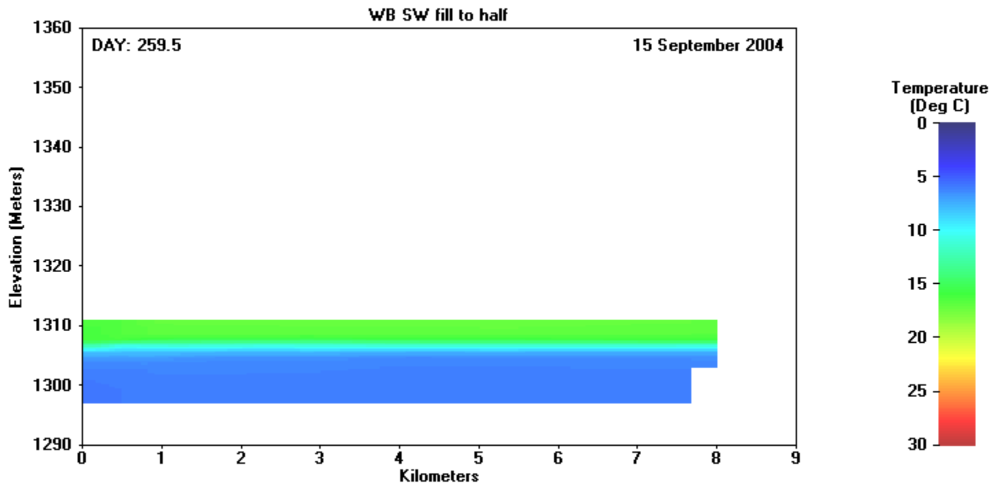


Figure 24. Temperature with SLOW (WB SW two_7).

By late September the effects of earlier pumped storage are evident in slightly less anoxic depth in the hypolimnion as compared to a simulation with no pumped storage in the spring. When pumped storage resumes on October 1, DO levels will begin to decrease at higher elevations in a zone near the reservoir inlet. Approximately two weeks into the fall DO concentrations associated with pumped storage operations have reached a point of maximum impact (Figure 25 and Figure 26). DO levels begin to improve after this two week period the reservoir then turns over at the end of October. After turn over the simulations appear very similar to the no pumped storage simulation. At the end of the year, simulation results indicate slightly higher DO levels with pumped storage operations compared to the non- pumped storage condition. In general phosphorous and ammonium increase in the vicinity of the inlet during fall pumped storage operations.

The nutrient increase is due to a combination of higher inflow concentrations as well as local mixing of more nutrient rich water near the bottom of LLV reservoir.

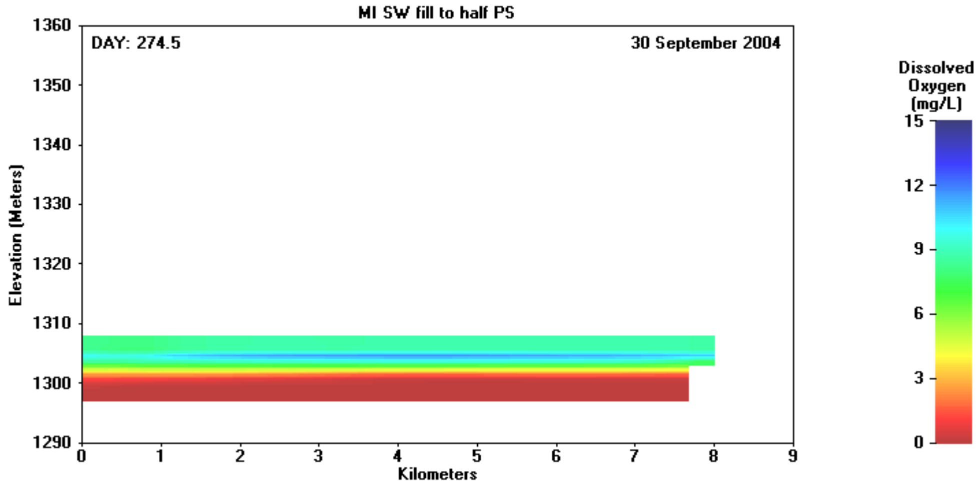


Figure 25. Dissolved oxygen concentrations prior to start of pumped storage operations on October 1 (MI PS SW two_23).

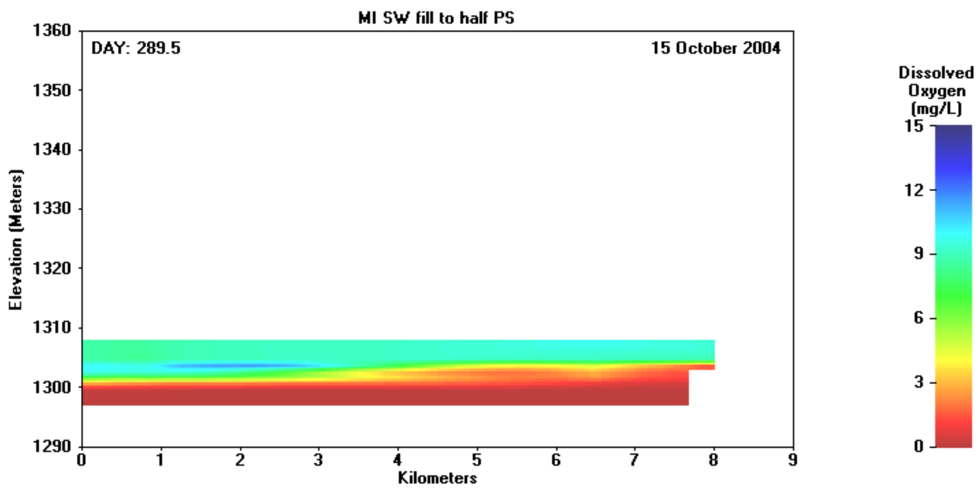


Figure 26. Mixing of dissolved oxygen concentrations two weeks after the start of pumped storage operations on October 1 (MI PS SW two_23).

5.6 Operational Impacts at Static Low Storage Volumes

Under drier hydrologic conditions LLV may receive little or no imports during the year. Several simulations were performed where elevation of LLV remained at low storage (around 65 TAF) throughout the year. Generally, if LLV remains at low storage, summer water quality conditions show considerable impairment compared to simulations where the reservoir was seasonally filling and drawdown. For example, DO concentrations mid-July indicate a considerably larger volume of water is anoxic under the static low storage conditions with pumped storage operations (Figure 27) compared to the filling and drawdown (Figure 28). Similarly, mid-July phosphorus concentrations in near bottom waters are several times larger for the static low storage condition (Figure 29), than the filling and drawdown condition (Figure 30). More severe, persistent, and extensive anoxia leads to sediment nutrient release of phosphorus under the static low storage case. This internal nutrient cycling, as noted previously, is a source of phosphorus and can support long term eutrophication of the reservoir.

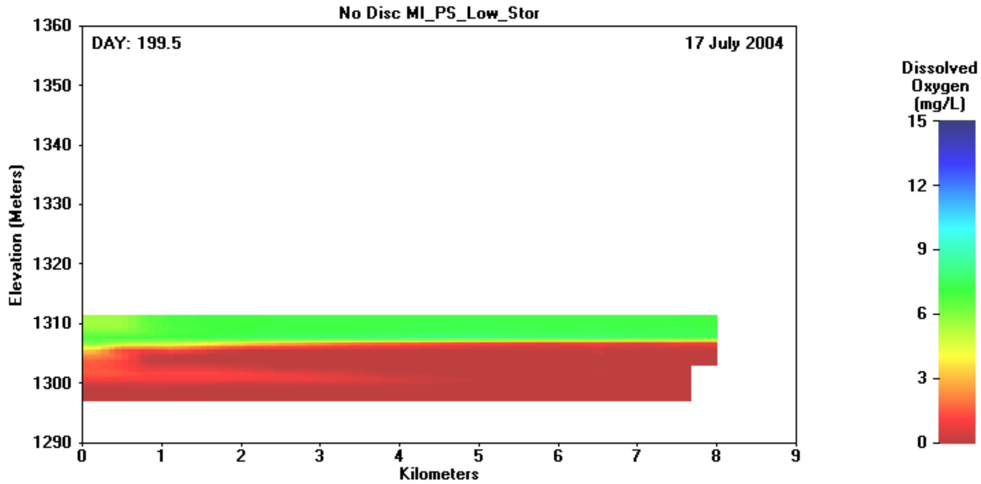


Figure 27. Dissolved oxygen concentrations under static reservoir elevation with pumped storage operations.

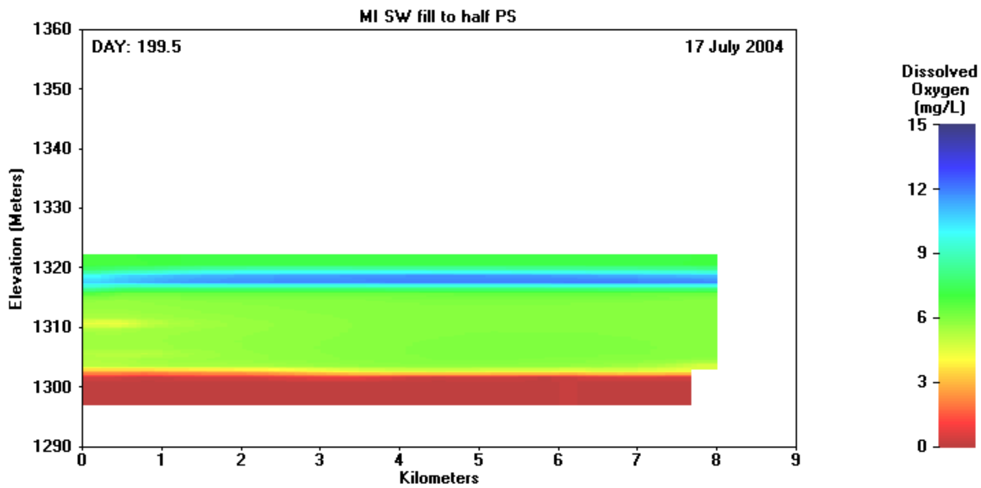


Figure 28. Dissolved oxygen concentrations under fill and drawdown reservoir elevation with pumped storage operations.

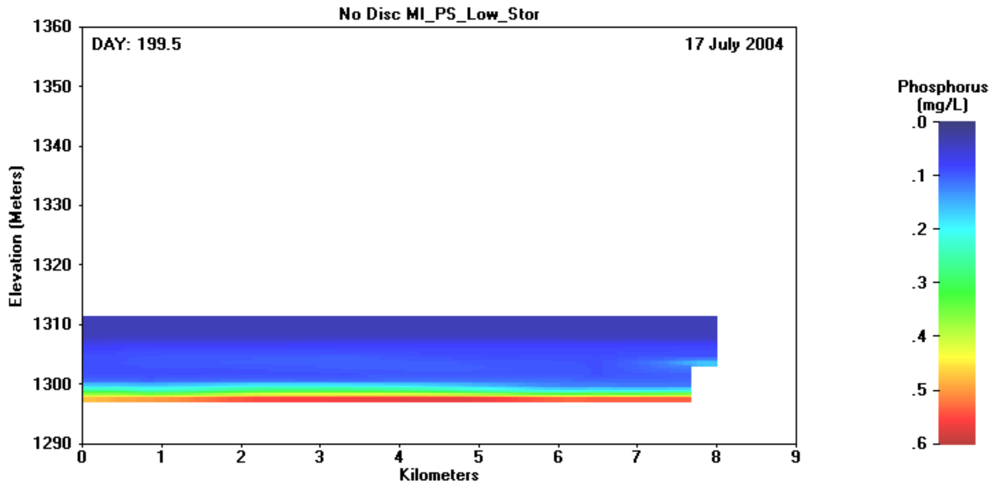


Figure 29. Phosphorus concentrations under static reservoir elevation with pumped storage operations.

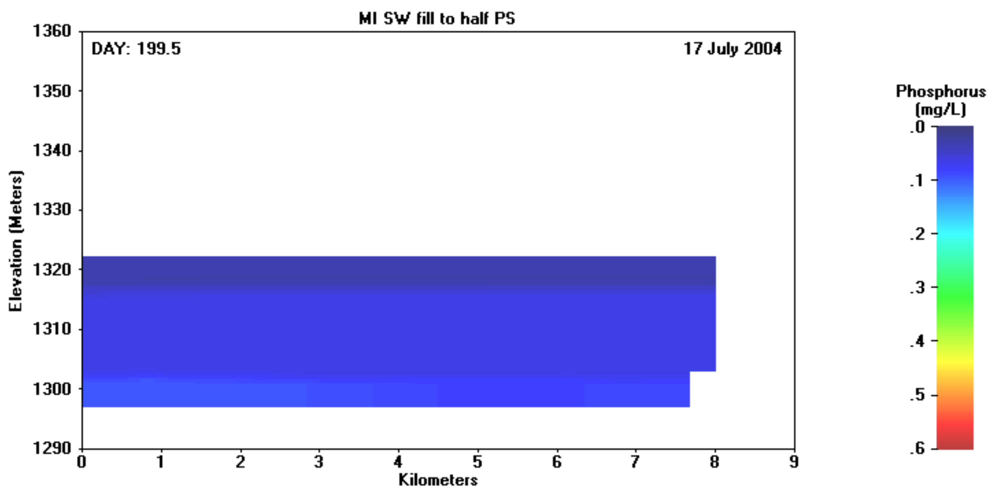


Figure 30. Phosphorus concentrations under fill and drawdown reservoir elevation with pumped storage operations.

Simulations of the static low elevation conditions suggest that pumped storage operations degrade overall water quality in LLV due to increased loading from UKL, internal loading, and/or mixing of anoxic water from the hypolimnion. Pump storage operations appears to notably modify the stratification and reduce the cold water pool (compared in Figure 31 and Figure 32. System wide anoxia is notably more extensive under pumped storage operations (Figure 33), than without (Figure 34). As further sensitivity, the pumped storage withdrawal location was moved from the location at 6 km to the location at 2 km (the inlet site), but only modest differences in water quality were observed.

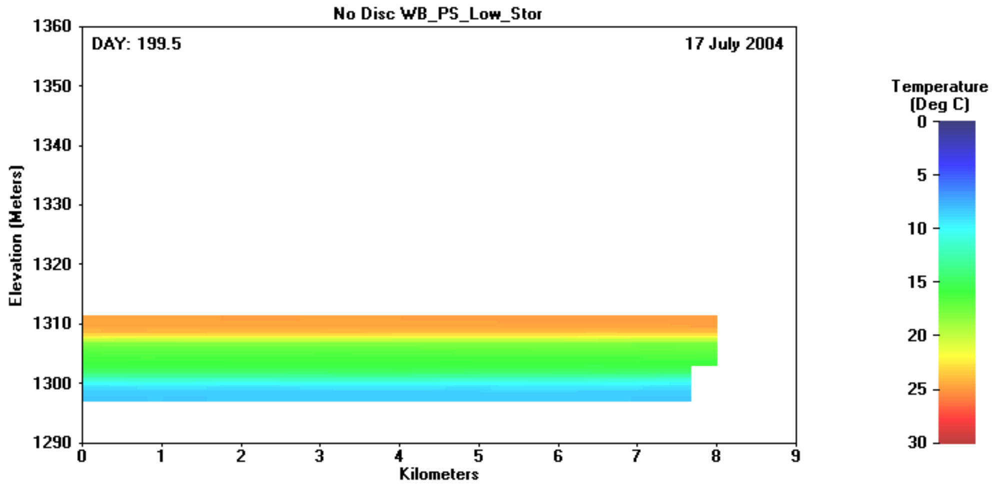


Figure 31. Water temperature under static reservoir elevation with pumped storage operations.

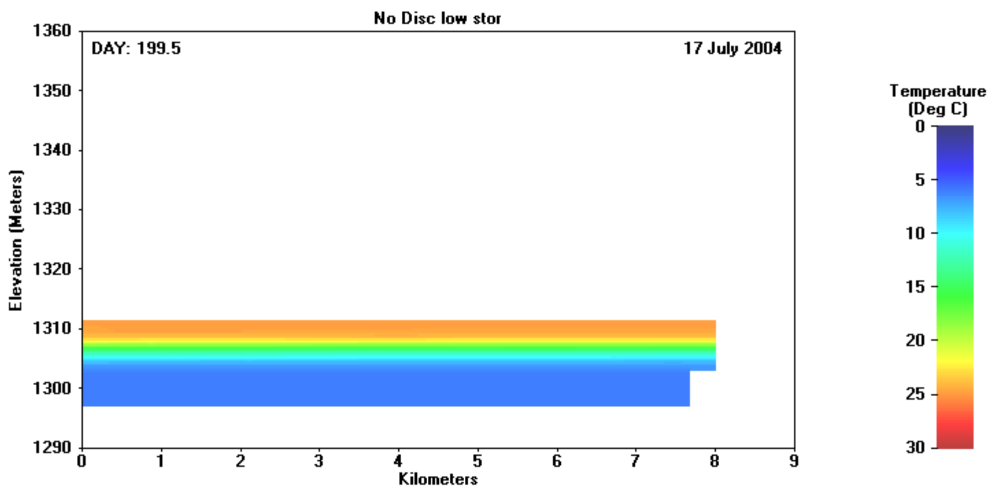


Figure 32. Water temperature under static low reservoir elevation without pumped storage operations.

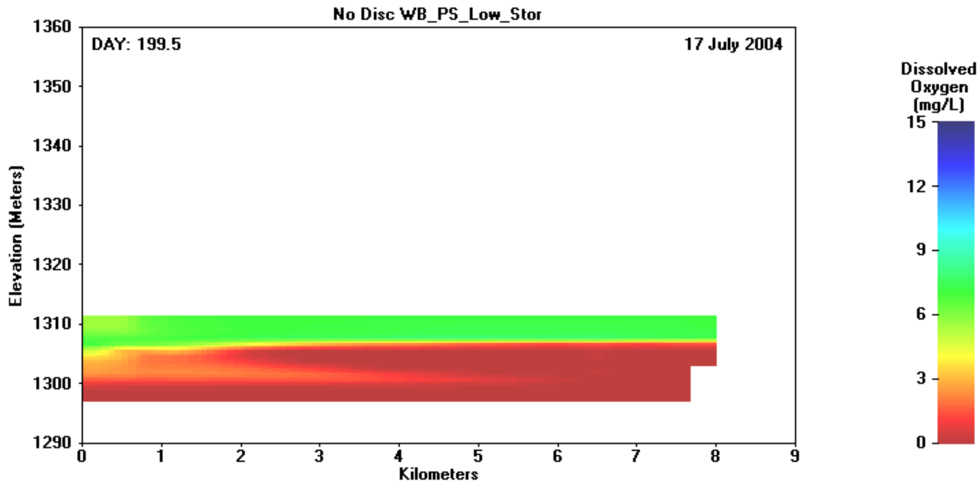


Figure 33. Dissolved oxygen concentrations under static reservoir elevation with pumped storage operations.

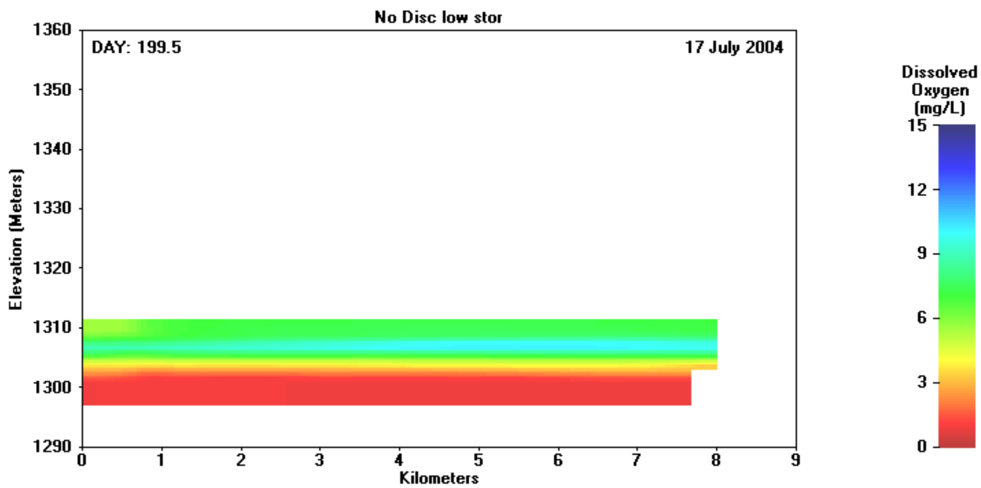


Figure 34. Dissolved oxygen concentrations under static reservoir elevation without pumped storage operations.

5.7 Long Lake Valley Reservoir Discharge Impacts to Keno Reservoir

Water quality impacts of LLV discharge on the Klamath River reach impounded by Keno Dam were assessed for selected alternatives at two discharge points, Miller Island and Link River Dam.

5.7.1 Miller Island Discharge

The effect of summer period discharges from LLV on Klamath River temperatures was examined for three conditions: bottom withdrawal, SLOW, and SLOW with pumped storage operations. Bottom withdrawal operations were intended to look at cool water releases, while SLOW conditions examined warm water releases. SLOW with pumped storage operations was not appreciably different than without pumped storage and are not presented herein.

Cold water inputs from the bottom withdrawal operations for mid-July indicate that locally there is a considerable effect. Daily temperatures at Miller Island are approximately 11^{o}C, representing a greater than 50 percent reduction over baseline temperatures of approximately 24^{o}C (Figure 35). However, extended transit time through the reservoir (several days) and exposure to atmosphere in the relatively wide, shallow impoundment resulted in water temperatures at Keno of approximately 23^{o}C, approximately 2 to 3^{o}C cooler than baseline conditions. For the SLOW release representing warmer, near surface waters from LLV, water temperatures at Miller Island were approximately 18^{o}C (Figure 36). Temperatures at Keno were approximately 24^{o}C. The bottom withdrawal discharge was approximately 6^{o}C, while the SLOW discharge was approximately 17^{o}C, yet the difference at Keno Dam was less than 1^{o}C. Similar conditions are present near the end of the discharge period in mid-September; however, discharge and receiving water temperature differences are not as marked. These simulations suggest that downstream effects of LLV, e.g., below Keno Dam, are most likely modest. Further, examination of conditions in Lake Ewauna upstream of the discharge point indicates warmer temperatures under LLV discharge. Reduced flows at Link River Dam under these postulated conditions results in longer transit times, leading to increased water temperatures upstream of Miller Island.

LLV could be used to create favorable thermal conditions in the Keno Impoundment, similar to large scale thermal refugia. Challenges with active management of such refugia are maintaining a persistent cool water region in a run of the river reservoir – loss of cold water for even a day or two could strand fish in a rapidly heating environment.

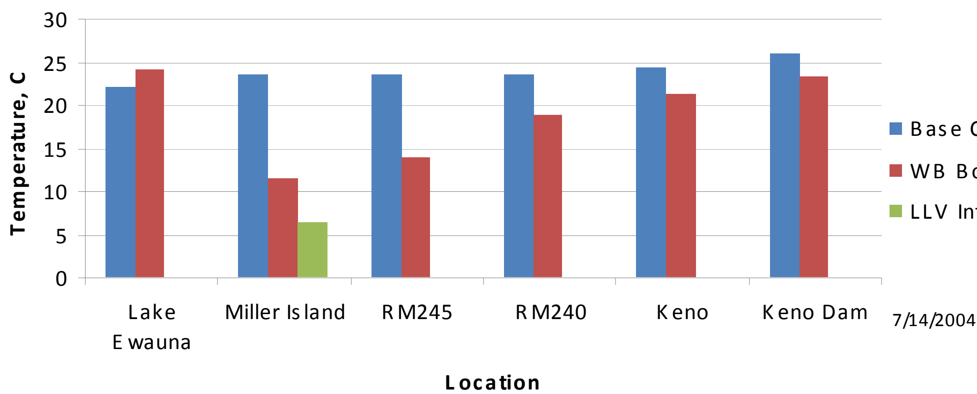


Figure 35. Longitudinal temperature conditions in Keno Reservoir for bottom withdrawal (cold water) and discharge at Miller Island: July 14 (LLV Inflow is inflow into Keno Reservoir model).

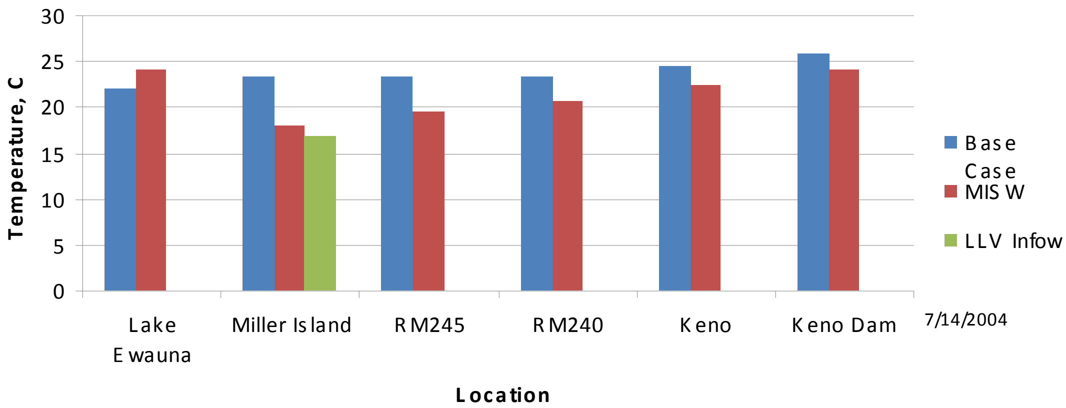


Figure 36. Longitudinal temperature conditions in Keno Reservoir for SLOW (warm water) and discharge at Miller Island: July 14 (LLV Inflow is inflow into Keno Reservoir model).

Dissolved oxygen conditions did not produce dramatically different conditions for bottom withdrawal because Keno Reservoir experiences low DO during summer time – similar to the bottom waters of LLV. Further, reaeration tends to moderate differences. SLOW results, although introducing higher DO waters to Keno Reservoir, did not appreciably change conditions in the Klamath River. These results seem less than intuitive, but the large oxygen demand existing in Keno Reservoir may explain why differences were minimal between baseline and the two discharge scenarios.

Differences in nutrients concentrations were consistent with findings of LLV studies described above. Namely, nutrient concentrations from LLV were generally lower and, through dilution lowered concentrations in the reservoir downstream of the discharge site. Conditions were variable, but differences were moderated by the time waters reached Keno Dam. Presumably the moderating affects are due to physical, chemical, and biological influences of Keno Reservoir, which dominate with distance and time from Link River.

5.7.2 Link River Dam Discharge

Discharge from Link River Dam was modeled using the Lake Ewauna/Keno CE-QUAL-W2 model under the assumption that water quality conditions at Link River Dam were approximately equivalent to conditions for Link River at Lake Ewauna. This is a short river reach (approximately 1.9 km), and previous modeling in the Link River reach suggests this is a reasonable approximation for this scoping analysis. As noted previously, Link River Dam releases were reduced by an equivalent amount of LLV discharge to conserve flow volume on a daily basis and a mass balance was used to blend the two water quantities and qualities. Bottom withdrawal, SLOW and SLOW with pumped storage were simulated; however, pumped storage results only differed slightly from SLOW without pumped storage and thus are not presented herein.

Temperature results from these simulations are similar in character to the discharge at Miller Island. For bottom withdrawal operations, temperatures in July near the head of Lake Ewauna are reduced from approximately 22^{o}C for the baseline case to 11^{o}C including LLV discharges (Figure 37). Temperatures quickly increase, and by Miller

Island temperatures are nearly 20°C and rise steadily to Keno Dam, where there is less than 1°C difference between the baseline and LLV discharge scenario.

Withdrawals via SLOW, representing warmer near surface waters from LLV, provides about a 5°C reduction near the head of Lake Ewauna, and follow a similar warming trend towards Keno Dam (Figure 38). The difference between the two runs is negligible at Keno Dam. That is, a warm near surface release from LLV produces the same thermal signal at Keno Dam as a cold bottom water release. For both bottom withdrawal and SLOW, similar conditions are present near the end of the discharge period in mid-September; however, discharge and receiving water temperature differences are not as marked.

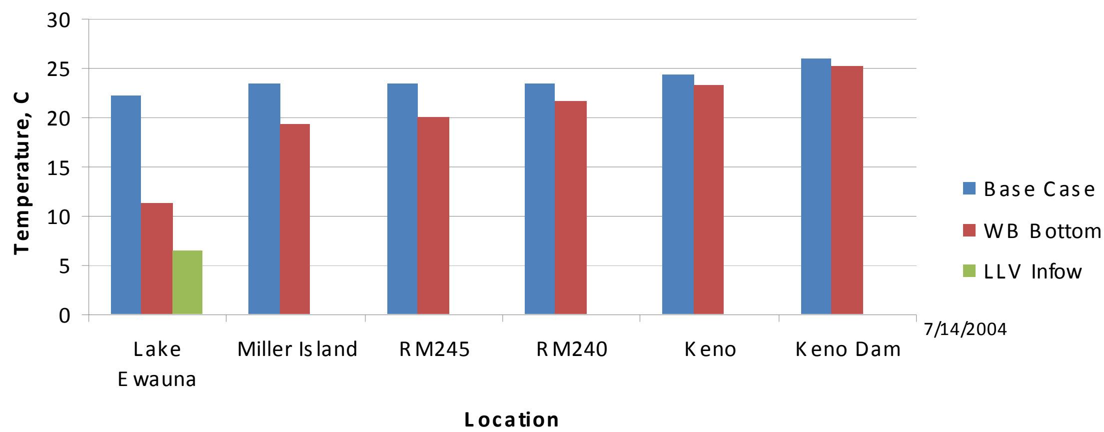


Figure 37. Longitudinal temperature conditions in Keno Reservoir for bottom withdrawal (cold water) and discharge at Link River Dam: July 14.

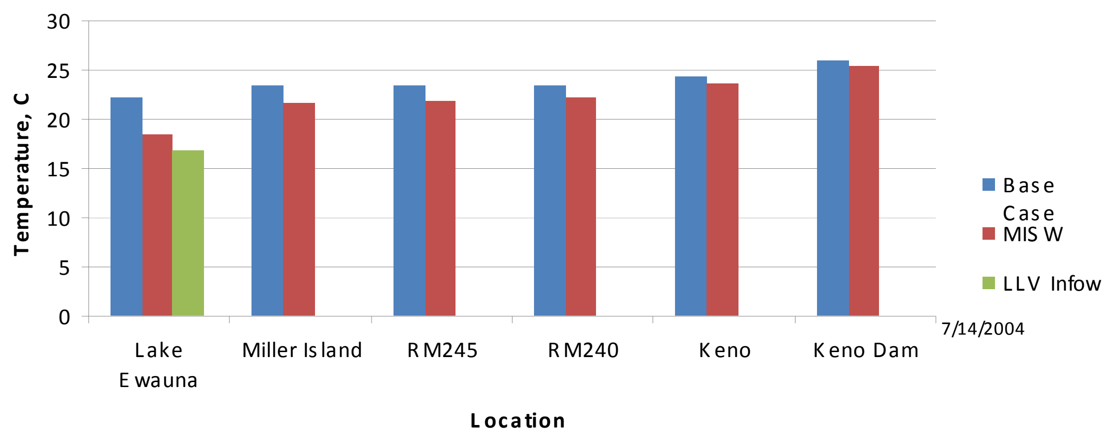


Figure 38. Longitudinal temperature conditions in Keno Reservoir for SLOW (warm water) and discharge at Link River Dam: July 14.

Dissolved oxygen conditions did not produce dramatically different conditions downstream of Lake Ewauna, most likely due to reaeration, and minimal differences occurred at Keno Dam for each case. Local differences occurred in nutrients near Link

River inflows; but with distance downstream differences diminished. At Keno Dam conditions were largely similar, suggesting that the physical, chemical, and biological influences of Keno Reservoir dominate with distance and time from Link River.

Differences in nutrients concentrations were consistent with findings of LLV studies described above. Namely, nutrient concentrations from LLV were generally lower and, through dilution lowered concentrations in the reservoir downstream of the discharge site. Conditions were variable, but differences were moderated by the time waters reached Keno Dam. Presumably the moderating affects are due to internal chemistry dynamics in the reservoir.

6 Conclusion/Summary

Three levels of reservoir storage (high, medium and low) were combined with various operational scenarios including filling and drawdown releases from a single low level outlet as well as SLOW, constant storage, and pumped storage. For the majority of the simulations reservoir storage started low, filled to a half capacity state, and then was drawn down to a low elevation at the end of the year. The results from these simulations provided an exploration of operations and resulting in reservoir water quality differences between simulations. Additionally, the impact of LLV releases on water quality in the Klamath River was assessed for discharge points at Miller Island and Link River Dam. Below are bullet point summaries of key findings for LLV reservoir conditions and Klamath River conditions.

Long Lake Valley Reservoir

- LLV is of sufficient size and depth that the reservoir will experience strong seasonal thermal stratification. At low storage (e.g., less than approximately 10 meters of depth, the reservoir may not stratify seasonally). This seasonal stratification of LLV is a critical element of reservoir water quality.

- Generally, higher storage volumes resulted in cooler in-reservoir water temperatures and epilimnion depth was relatively small compared to when active drawdown and filling operations are imposed. The full reservoir conditions retained cooler water and had lower concentrations of algal growth as compared to the simulations with lower starting storage volumes.

- After the onset of algae growth near the surface there is a transition to higher algal concentrations in deeper water due to near surface nutrient depletion. Even with the epilimnion mixing (e.g., wind) during the summer there seems to be insufficient energy to increase the nutrient levels sufficiently to allow algae to grow in near surface waters.

- LLV reservoir and Howard Bay/Wocus Bay arm of UKL are fundamentally different in their geometry, hydrology and nutrient loading. Therefore differences in water quality between the two water bodies is expected, and the relative differences between source and receiving waters may be important considerations during operational planning.

- Bottom withdrawal as a sole operational strategy limits management options for release water quality management. Limitations include inefficient use of cold water storage, subsaturation DO conditions, and larger carryover volumes to ensure cold water supplies are not exhausted. A prudent approach to water quality management would make use of SLOW and/or fill elevations which would provide the most flexibility for long term water quality management of in-reservoir and discharge waters. Depending on the time of year when filling and when waters are withdrawn (including short term pumped storage), selective placement or withdrawal of water from the reservoir could help manage water quality in the reservoir and in releases (e.g., by maintaining stratification, epilimnetic volumes).

- SLOW logic used in these simulations was a simple representation for modeling purposes, blending water based on water surface elevation and outlet elevations spaced at 10 meter intervals. Simulated strong stratification of LLV reservoir suggests that more closely spaced outlets, at vertical intervals of approximately five meters may be required over the anticipated operational range to control release temperature and water quality. Managing LLV reservoir for release water quality will be a challenging task likely requiring near real time monitoring to capture temporal and spatial distribution of water quality constituent(s) of interest.

- Pumped storage both mixes the reservoir at times when it would otherwise be in a relatively stable state, and also potentially imports nutrient laden water from UKL during the primary production growth season. Because pumped storage utilized a low level inlet, the mixing energy increases temperatures slightly in the hypolimnion, but seemed to have little or no impact on the timing of reservoir turnover. At low lake levels, pumped storage operations can have a greater impact on water quality in LLV, particularly near the inlet, due to importation of lower quality water and from hydraulic mixing associated with the jet and buoyant effect from warm inputs in the cool hypolimnion. May consider isolated recirculation facility in reclaimed Wocus Marsh that could be used exclusively for recirculated pumped storage water. This would include placing water back in a small storage facility so the same water would be used for pumped storage operations. Such a facility could overcome regulatory criteria regarding receiving water discharge limitations or could minimize the input of organic matter and nutrients from UKL. This facility could be explored in a future study.

- Reclamation may be able to realize economic benefit by conducting pumped storage operations during times of winter/spring filling and summer/fall releases. This could be accomplished if there is excess capacity in the system after meeting the respective fill and release requirements. This could be explored further in a future study.

- One consideration not evaluated but may be of importance is the sensitivity to initial conditions. While the start of the simulation used conditions that may be found in UKL the differences in LLV dynamics resulted in different water quality than which it started. Future studies may include multi-year simulations to look at potential longer term conditions. A second consideration is that initial filling may disturb sediments with unknown nutrient load. This could have unknown impacts during the initial fill and initial water quality conditions. Soil sampling for nutrient content prior to construction may help identify possible impacts to water quality.

- Generally the LLV longitudinal water quality variations during simulations were relatively small, the exception being during pumped storage early fall. Withdrawal location had more noticeably impacts reservoir release quality when a pumped storage schedule was active (versus a non-pumped storage schedule). The water quality differences are most noticeable in fall when SLOW located a the southern end of the reservoir discharges higher water quality and lower temperatures as compared to the northern end near the inlet. These discharge differences are due to the water quality differences between the source and receiving waters. SLOW with pumped storage applied near the inlet (i.e. Wocus Marsh) is noticeably affected by the inflows from pumped storage as compared to a release point at the downstream end of the reservoir (e.g., releases for Miller Island).

- Generally, if the LLV storage remains low all year (i.e. static) at approximately 64.9 TAF the water quality from summer onward is diminished in all respects as compared to when filling and drawdown operations occur. Although water quality conditions are largely similar at the onset of stratification for both static low storage as well as fill and drawdown operations, the larger hypolimnion from fill and drawdown operations moderates water quality conditions. These relative conditions occurred regardless if pumped storage was implemented in either scenario.

- For the static, low storage condition, pumped storage operations resulted in an overall reduction in water quality in LLV due to increased loading from UKL, internal loading, and mixing of anoxic water in the deeper waters. Stratification is not as pronounced and the hypolimnion volume is smaller when pumped storage operations are in effect during static low storage conditions.

Klamath River

- Discharge at Miller Island is sufficiently far upstream that any water quality benefits are modest by the time release waters reach Keno Dam. Temperatures warm relatively quickly in the downstream direction, DO conditions respond strongly to reservoir conditions as well as exchanges with the atmosphere, and nutrient conditions, although locally different, are generally similar in character to baseline conditions at Keno Dam.

- Discharges at Link River Dam are sufficiently far upstream that water quality benefits are minimal by the time water reaches Keno Dam for reasons similar to those stated in the previous point.

- Local water quality benefits occur at both locations for temperature, and with lesser influence for DO and nutrients. For example, local thermal refugia could be created and managed via LLV discharge. However, in a run of the river reservoir such as Keno reservoir, failure to maintain appropriate temperatures for even a day or two could expose aquatic organisms to rapidly rising temperatures.

- The three previous points suggest that current physical, chemical, and biological processes in Keno Reservoir during summer months overwhelm any improved water quality inputs.

- Inputs at Miller Island may affect downstream water quality conditions through dilution, but may also adversely affect upstream water quality conditions through reduced releases from Link River Dam and increased transit time between Link River and Miller Island. Exploration of reverse flows due to Lost River diversion channel withdrawals were not examined herein. In terms of temperature control and direct water quality benefits, there are clear challenges: temperature control and water quality benefits are minimal in the Klamath River below Keno Dam is via releases from Long Lake valley reservoir under assumed operations. One of the principal challenges is maintaining a persistent condition (without interruption) to retain an improved water quality in reaches downstream of Link Dam.

- If a release location were included at Keno Dam, similar limitations to the previous bullet point would be of concern (e.g., impairment in Keno Reservoir), with a few caveats. First, if conveyance were in a tunnel/pipeline from LLV to Keno Dam, heating would probably be minimal. Watercourse has completed heating in tunnels in other regions and found rates on the order of 0.01^{o}C per 1000 feet. Even if these estimates are off by an order of magnitude, the heating en route to Keno would be minor. However, tunnel/pipeline conveyance would preclude reaeration, so any low dissolved oxygen conditions and associated water quality would be conveyed to Keno. If in-reservoir treatment options were employed to ameliorate water quality, a final condition would still be diluted at the discharge point due to flow requirements at Link River. For example, to meet current Biological Opinion flows of 1000 cfs during summer periods at Iron Gate Dam a total release at Keno would have to be approximately 700 cfs (with an estimated 300 cfs of net accretion between Keno Dam and Iron Gate Dam). Thus LLV releases of up to approximately 300 cfs to 400 cfs would be necessary to augment Link Dam releases and accommodate operations within the Keno Reservoir reach. This dilution would considerably reduce the thermal benefit. Further, LLV flows would not be continuously available either within year or from year-to-year. If listed species relied on these intermittent thermal "refugia," Reclamation may be required to maintain such features in the river, placing the economics and benefit of the LLV outlet tunnel/pipeline release point alternative in question.

Recommendations
This study also identifies areas for future work should additional studies be initiated. These include, but are not limited to:

- Convert the CE-QUAL-W2 model to more recent versions (v3.5 or v3.6) and test against existing simulation results. In addition, explore additional algae species representation and parameter selection, first order sediment processes, and other appropriate water quality modeling variables/processes will be implemented within CE-QUAL-W2 model.
- Recently additional geometric data has been acquired for LLV. This data should be used to update model geometry (and test). Also specify more detailed geometric representations of inlet and outlet works. If these elements require flow and water quality modeling to refine pre-design consideration, identify range of potential conditions. If treatment facilities are envisioned (e.g., discharge aeration, pretreatment aeration, in-reservoir oxygenation/aeration), identify location, capacity, and other pertinent features.
- A wider range of operational information would better constrain the analysis. Define more comprehensive hydrology, inflows, outflows, storage rules for Long Lake Valley. Operational elements may include fill rates, minimum pool volumes, reservoir storage rules, carryover storage targets, selective input and withdrawal, pumped storage schemes, outlet tower design and operations, and other operational facets. These elements may require water quality modeling to refine operations.
- Evaluate local conditions at the Wocus Drain discharge point or terminus configuration. Specifically, explore potential local water quality impacts due to discharge to UKL from LLV and examine potential configurations, if applicable, that would minimize or ameliorate impacts.
- Water quality boundary conditions could be improved through additional monitoring. Monitoring water quality in the Howard Bay and Wocus Marsh region, including drains to the local area, would provide additional insight into potential water quality conditions of water imported to LLV. Parameters should include temperature, dissolved oxygen, pH, specific conductance, nutrients, organic matter, algae and chlorophyll a and other necessary parameters to compliment model input.
- Confirm any LLV water quality release benefits for a discharge point at Keno Dam to the Klamath River downstream of Keno Dam.
- Additional, site specific meteorological data can collected in Long Lake Valley to assess local conditions. These conditions could be compared to long-term meteorological stations in the vicinity (e.g., AgriMet KFLO).

7 References

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Appendix E—Attributes of HydroGeoSphere

HydroGeoSphere (HGS) is a powerful numerical simulator developed for supporting water resource and engineering projects pertaining to hydrologic systems with surface and subsurface flow and mass transport components.

In terms of simulation capability and computational aspects the HGS code has the following attributes:

Fluid flow

- Complete hydrologic cycle modeling using detailed physics of surface and subsurface flow in one integrated code. The surface regime can be represented as 2-D areal flow for the entire surface or as 2-D runoff into 1-D channels. The subsurface regime consists of unsaturated/saturated flow. Both regimes naturally interact with each other through considerations of the physics of flow between them.
- Physically-based accounting of all components of the hydrologic cycle water budget.
- Accurate delineation and tracking of the water table position, taking into account flow in the unsaturated zone, delayed yield and vertical flow components.
- Handling of nonponding or prescribed ponding recharge conditions.
- Handling of seepage face boundary conditions.
- Automatic and correct apportioning of the total flow rate of a multi-layer well to the well nodes, including the simulation of water flow and solute mixing within the water column in the well.
- Accommodation of wellbore storage.
- Arbitrary combinations of porous, discretely-fractured, dual-porosity (subsurface domain divided into a mobile and an immobile domain) and dual-permeability (flow occurs in both primary and secondary porosity systems) media for the subsurface.

Numerical methods

- Treating of surface and subsurface water regimes as one flow system provides for a robust mass conserved solution scheme, which is essential for systems with strong interactions between regimes.

- Advanced computational algorithms and a flexible, user-friendly interface allow the code to perform unprecedented, fully-integrated, 3-D simulation/animation on a personal computer.
- Unstructured finite-element grids.
- Finite-difference options.
- 8-node block or 6-node prism elements, 3- and 4-node plate elements for fractures and surface water, and 2-node line elements for well and tile drains.
- Adaptive time-stepping schemes with automatic generation and control of time steps.
- Straightforward organization and control of simulation output.
- Robust and efficient Newton-Raphson linearization option.
- Flexible pre- and post-processing capabilities.

For field applications and research investigations, HydroGeoSphere can be used to perform event-based and continuous simulations on widely varying spatial scales ranging from single soil column profiles to large-scale basins, which may include several catchments. Examples of field applications of HydroGeoSphere include:

- Integrated water resource assessment
- Watershed hydrologic analysis, including impacts of land-use or climate-change impacts on both surface and subsurface water.
- Floodplain hydrologic analysis.
- Fluvial hydraulic analysis.
- Contaminant migration and fate in both surface and subsurface water.
- Thermal/temperature transport in both surface and subsurface water.

Operation and Input Options

HydroGeoSphere simulator enjoys the benefit of having already available and affordable GUI tools for grid generation and subsurface flow model input as well as TecPlot for 3-D visualization and animation. In order to handle spatial data analysis and visualization of surface water domain, GIS tools such as ArcView and ArcInfo may be used. There are four steps involved in solving a given problem using HydroGeoSphere:

- Build the necessary data files for the pre-processor **grok.**
- Run **grok** to generate the input data files for **HydroGeoSphere**.
- Run **HydroGeoSphere** to solve the problem and generate output data files.
- Post-process the output files to visualize and analyze the results and produce reports.

Appendix F—Geospatial databases created or obtained for the Long Lake Valley project

cont13506_g	Contour 1350.6 meters above sea level. ASCII file ~ 4431 feet. Represents the lake level at 350,000 AF fill - low level fill.
etzone2000	Shapefile not in local database - available on Regional Geospatial Database. The following are in units are in inches/day averaged over the 12 months is: 0.11833 inches/day, 43.2 inches/year. NOTE: More than the rainfall.
fauCAD.shp	Faults from REF2 in CAD files. This is just the hidden faults in the area.
fauCAD.DXF	DXF file generated from above
e_kla_cm	Elevation data in centimeters (z-value) for the model extent boundary including buffer. This is the 30 meter NED database.
e_llv_m	Elevation data in meters (z-value too) for the area roughly covering the bedrock area. This is in units of meters!!! NED data.
LYR6.asc	Surface elevation for the smaller extent of Long Lake valley - just covers the bedrock area. The values here are in units of meters!
h_kla_g	Hillshade created from above file - this covers a very large area in the Klamath Area office!
Geol_CAD_l.shp	Geology - surface, from REF2 - line file
Geol_CAD.shp	Geology - surface, from line file above. These are polygons in GIS.
LYR01	Base elevation layer - generated by using modext_pg.shp, field BASE. Tba formation - assume this is all Tba. Base set to 200’ below what is roughly the ground water table in Round Lake Valley.

LYR02	Tba2 base
lyr02_contour.shp	Contours generated for this layer.
LYR03	Tba1 base
lyr03_contour.shp	Contours generated for this layer.
LYR04	Qtwb & Qbpb base
lyr04_contour.shp	Contours generated for this layer.
LYR05	Lake bed sediment layer see processing notes
lyr_contour05.shp	contours for this layer.
LYR06	Surface elevation generated from e_llv_m.
Modext_l_desc.shp	Model extent line format - similar to below,
Modext.shp	Model extent in line format for support to GridBuilder - has fault lines and connector lines in it as one single line.
precip60-90_p.shp	PRISM Precipitation data for the Klamath Long Lake Valley. Polygons. Unm for this database. Model used 22.5 inches annually.
Prekla##_g	PRISM Precipitation data for Klamath Long Lake Valley - GRID databases. Units in mm for this.
prekla14_g	

Count: 378
Minimum: 36209
Maximum: 75334
Sum: 20116559
Mean: 53218.410053
Standard Deviation: 10328.065701

X_sectCAD.shp	Cross Sections - surface, from REF2 in UTM zone 10 NAD 83.

Appendix G—*Upper Klamath Offstream Storage Study at Long Lake Valley—Constructability Review*, November 2007

RECLAMATION
Managing Water in the West

Upper Klamath Offstream Storage Study at Long Lake Valley

Constructability Review - November 2007

Klamath Project, Oregon – Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

January 2008

U.S. Department of the Interior
Mission Statement

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

Mission of the Bureau of Reclamation

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

Upper Klamath Offstream Storage Study
at Long Lake Valley
Constructability Review

Signature Sheet

Team Members:

Al Bernstein, PE - Technical Service Center Team Leader	Date
Carlton Smith, PE - Technical Service Center Construction Member	Date
Mike O'Shea, PE - Technical Service Center Pump-Generation Design Member	Date
Frank Blackett, PE - Technical Service Center Geotechnical Member	Date
Randy Wyatt - Mid-Pacific Construction Officer Construction Member	Date
Lauren Carly, PE - Mid-Pacific Construction Officer Project Management Member	Date
Maury Kruth, PE - Mid-Pacific Regional Office Planning and Power Infrastructure Member	Date

Table of Contents

I. Introduction

In October 2007 it was proposed by the Klamath Basin Area Office (KBAO) that a Constructability Review Team be assembled to review all studies and investigations that have been carried out to-date for the proposed use of Long Lake Valley (LLV) as an offstream storage reservoir. The formal request for the formation of this team was received from Dave Gore, Mid-Pacific (MP) Regional Engineer (October 11, 2006 e-mail to Lowell Pimley, Acting TSC Director).

The purpose of the Constructability Review was to:

- Evaluate the Upper Klamath Offstream Storage Study at Long Lake Valley Reconnaissance Level Cost Estimate, March 2006 (Recon Report) to determine whether this report meets Reclamation's guidelines for Appraisal Level project requirements, and if not, identify additional requirements needed to meet the Appraisal Level requirements.
- Evaluate other investigations and studies conducted to-date to determine if they fulfill Reclamation's guidelines for Appraisal Level project requirements and if not, identify additional requirements needed to meet the Appraisal Level requirements.
- Identify issues that should be studied during the feasibility design phase.

The Review Team consisted of the following Reclamation members:

- Al Bernstein, P.E., Technical Service Center (TSC), Team Leader
- Carlton Smith, P.E., Technical Service Center, Construction Member
- Mike O'Shea, P.E., Technical Service Center, Pump-Generation Design Member
- Frank Blackett, P.E., Technical Service Center, Geotechnical Member
- Randy Wyatt, Mid-Pacific Construction Office (MPCO), Construction Member
- Lauren Carly, P.E., Mid-Pacific Construction Office, Project Management Member
- Maury Kruth, P.E., Mid-Pacific Regional Office (MPRO), Planning And Power Infrastructure Member

Mike O'Shea was also assisted by Dave Edwards, P.E. (water conveyance issues), Bob Zelenka, P.E. and John Brooks, P.E. (hydraulic equipment issues). All of these individuals are from the TSC.

On the morning of November 6, 2007, the Review Team was given an overview of the project by KBAO staff followed by a technical project briefing by members of the design team from the MPRO. Items discussed were the project features, geotechnical investigations and hydrogeologic modeling investigations. On the afternoon of November 6, the team went on a site visit of the proposed project.

The Review Team presented their preliminary findings and recommendations regarding the Appraisal Level study on Friday, November 9, 2007 to KBAO and MPRO staff.

II. Background

In 1987, the Bureau of Reclamation (Reclamation) began studies on the potential of constructing and operating an offstream storage project involving a system of three reservoirs in the Upper Klamath area. In 2003, the 1987 study was revised and updated for only one of the reservoirs: Long Lake Valley. Additional geologic investigations were conducted by MPRO in 2004 and 2005 which indicated that the water holding capability of Long Lake Valley was more probable than originally considered.

In 2006, the Bureau of Reclamation (Reclamation) initiated the Upper Klamath Basin Offstream Storage (UKBOS) investigation. The UKBOS investigation is based on the 1987 study and is evaluating potential offstream water storage projects in the upper Klamath River Basin that could improve water supply and reliability, provide fish and wildlife benefits, and provide additional water for agricultural uses. Storage of excess winter/spring run-off is a potential solution to water shortages in the Klamath River Basin. Carry-over storage could be obtained via many alternatives including Long Lake Valley. Currently the UKBOS investigation is in the appraisal level planning phase, with authorization to proceed to feasibility level. The basis for the appraisal level planning design is Upper Klamath Offstream Storage Study at Long Lake Valley Reconnaissance Level Cost Estimate March 2006 (Recon Report), which is based on the study performed by MPRO staff in 1988 and updated in 1993.

III. General Comments

The investigations, analysis, and designs performed to date for the project represent a substantial effort. A few weeks before the on-site team meeting on November 6-9, 2007, the Team received the following documents to review from the MP Regional Office:

- Long Lake Valley Offstream Storage Study - Geologic and Hydrologic Investigations March 2006
- Geary Canal ODF&W Proposed Fish Screen Site Cone Penetrometer Test Data Report June 2006
- Upper Klamath Offstream Storage Study at Long Lake Valley Reconnaissance Level Cost Estimate March 2006 (Recon Report)
- Upper Klamath Offstream Storage Study Appraisal Report February 1987

- Shannon & Wilsons Independent Geotechnical Review Upper Klamath Offstream Storage Study January 1983
- Development of Carry-Over Pumped Storage by J.C. Boyle January 11, 1960

During the review, the Review Team was provided additional materials including:

- Cultural Resources Overview for the Long Lake Valley Off-stream Storage Appraisal Study, Klamath County, Oregon
- Numerous correspondence regarding Clean Water Act Requirement permits
- Sub-Appraisal Cost Estimates and Water Treatment Recommendations, Upper Klamath Lake Water Quality Assessment, January 2007 (Jurenka)
- Long Lake Alternative Modeling, August 2007 (Parker)
- Quantity estimate worksheets used for the Long Lake Valley Reconnaissance Level Cost Estimate

Due to the depth of study performed in the Reconnaissance Level Cost Estimate (Recon Report) which was based on previous studies performed by the Mid-Pacific Regional Office, the KBAO concluded that the Recon Report could be used as the basis for an appraisal design. The Review Team was tasked to review the Recon Report as an appraisal design and to determine if (1) the Recon Report and other investigations/studies conducted to-date fulfill Reclamation's guidelines for appraisal level project requirements and (2) the Recon Report contains any fatal flaws.

In order to accomplish this review, the Review Team decided to (1) determine issues regarding the overall project, (2) review each feature of the project in detail, (3) determine issues in the Recon Report that need to be addressed to meet Appraisal Level project requirements, and (4) determine issues that will need to be addressed during the feasibility design. In addition, the Review Team evaluated other issues such as project management, schedule and environmental compliance. In considering comments and recommendations for the feasibility level, the Review Team assumed that this project will follow the normal Final Design Process, before procurement.

IV. Overall Review of Project

During the review of the documents, the Review Team identified several overall project issues that need to be addressed. These issues are basic elements of the project and should be included in a final appraisal report and are issues that should be considered for the certification process (FAC TRMR-22 and FAC TRMR-23). The Review Team also assumed that a feasibility design would be performed before the project proceeded to final design and procurement.

A. Is there sufficient water available for the project? After the Klamath Basin Restoration Agreement (KBRA) is finalized and a potential operation scheme is determined, a study should be performed to determine if sufficient water is available for the project needs.

B. Will the lake hold water? Earlier reports indicated that leakage from LLV may occur, however recent reports indicate that the addition of a lining may prevent significant leakage. The report "Long Lake Valley Offstream Storage Study, Geologic and Hydrologic Investigations in Long Lake Valley, Klamath Project, Klamath County, Oregon, March 2006" states ".... [the basalt bedrock] needs to be covered by additional lining, or the water loss in this area should be calculated using the hydraulic conductivity...". A peer review of all studies should be performed to verify that LLV can satisfactorily retain water and the treatment, if any, needed to ensure water retainage.

C. Is the cost of this project consistent with the benefit of three years supply of water? Based on recent hydrology studies, the lake can hold up to three years worth of water storage. However, recent dry years have extended past three years. More detailed discussions should be conducted to determine if the cost of this project justifies the benefit of three years supply of water.

D. If the appraisal level benefit-cost ratio is marginally above 1.0, will the escalation of costs and the corresponding reduction of the benefit-cost ratio jeopardize the project? In spite of our best guess at contingencies, recent history has shown a tendency for appraisal costs to escalate through design phases.

E. Is there a conflict between operations for water supply (agriculture) and interests with lake perimeter land owners and potential land developers and are they expecting a year-round lake with a relatively constant pool?

F. Has the interaction of Wocus Drainage Canal water and Long Lake Valley (LLV) water been studied or sufficiently evaluated for water quality issues? Per the layout outlined in the Recon Report, Wocas Drainage Canal discharges into the pumping plant intake channel. This could produce undesirable or unacceptable water quality issues for pumping into LLV. Although the Wocas Drainage Canal currently discharges into Upper Klamath Lake (UKL) and water will be pumped from UKL into LLV, the Recon Report provides a more direct means for transfer of the drainage water into LLV. Evaluation of the Wocas Drainage Canal drainage water may be necessary prior to making the assumption that this channel and the pumping plant intake channel can be combined into one channel.

G. Has a Project Management Plan (PMP) been prepared? The development of a PMP helps to ensure that items not covered by designers are considered (real estate, ESA, funding and financing)

H. Based on the latest schedule, dated November 28, 2007, it appears that KBAO plans to use the feasibility phase as final design. Our comments assume that feasibility phase will be followed by a normal final design phase (concept design followed by final design).

I. Are additional geotechnical investigations scheduled to be performed? Due to the high risk to costs and visibility of this project, a preliminary geotechnical investigation program of the proposed canal alignment, different proposed tunnel alignments and fish facility, can resolved several issues at the appraisal design level.

J. Designs and costs estimates developed at the feasibility level should be certified per TRMR-22.

V. Review of Reconnaissance Level Report

Per request from KBAO, the Recon Report was reviewed as an appraisal design. The Review Team studied each feature listed in the Recon Report with respect to both its independent function and its function with the other features. General comments and recommendations are listed below. In some cases, the same comments and/or recommendations apply to several features. In this case, the comments and/or recommendations will be listed in the first feature and referenced throughout the rest of the features.

A. Canal Conveyance System and Fish Facility

1. The proposed canal conveyance system in the Recon Report entails the construction of a new canal and the relocation of the existing Wocus Drainage Canal. This would result in the construction of approximately 6.1 miles of new canal (3.6 miles of conveyance canal and 2.5 miles of relocated Wocus Drainage Canal). The relocated Wocus Drainage Canal would be approximately 13 feet in depth, the same as the new conveyance channel, and located to the east of the new conveyance channel. Based on visual observation, this appears to be approximately twice the depth of the existing drainage channel. The actual requirements of the Wocus Drainage Canal should be closely evaluated to determine the dimensions required. In addition, the size of the new conveyance canal appears to be excessive for the required 1,000 or 2,000 ft^3/s

requirement. The actual size of the canal should be closely evaluated.

Considering that the letter to Oregon Department of Environmental Quality stated that inflows to Long Lake Valley (LLV) will occur between November and May, a dual purpose, single canal should be considered further if inflows do not conflict with drainage needs, which would typically be in June – September. However a single canal may present water quality problems.   Water returning from Long Lake reservoir could be in a better condition then the current return agricultural waters of the Wocus Drainage Canal. Future water quality issues may arise that may require treatment of the water.

Recommendation - The option of two canals verses one canal should be studied during the feasibility design phase. If the two canal option is selected, the Wocus Drainage Canal should be improved and narrowed while maintaining its present alignment as closely as possible. A second canal with a parallel alignment with Wocus Drainage Canal following an alignment on the west side of the Wocus Drainage Canal between UKL and any future Long Lake Valley Pumping Plant should be considered.

2. New canals present significant geotechnical and construction concerns (see items 3 and 4 below). These concerns should be very closely evaluated prior to making a final determination of the location of the canal. A cost analysis should be performed to evaluate the relative difference between tunneling costs (relocation of tunnel to reduce or eliminate canal length) and canal construction costs. Based upon this analysis, careful consideration should be given to selecting the location for the tunnel. (Note: It is acknowledged that this cost analysis may be somewhat difficult to perform because of unknown geological conditions along alternate tunnel alignments. The recommendation to perform a preliminary geotechnical investigation program discussed in items 3 and 4 below will aid in performing the evaluation of costs.)

3. The soil foundation conditions along the proposed conveyance channel have not been investigated. However, it is also acknowledges that based upon the information provided to date, and the experience of the geological team member for this review, construction of the canal system would present significant challenges.

   The existing Wocus Drainage Canal indicates that bank stabilization and maintenance is an ongoing concern. The existing canal appears to be relatively shallow, with an estimated depth, based upon visual observations, of less than five or six feet with evidence of bank erosion. The proposed improvements would include excavating 13 feet below existing grade for both new canals followed by the placement of 12 feet of embankment fill on both sides of the new conveyance channel. The top of both embankments will include either an O&M Road or Service Road, both of which are proposed to be paved.

There are several geotechnical issues associated with the design and construction of the canals.

a. The soils in the area appear to be saturated with the groundwater level very near the surface. It was reported by the design team that prior to the construction of the Wocus Drainage Canal, the entire area consisted of a swamp. The soils are also reported to be a very low density mixture of diatomaceous earth and volcanic airfall tuff (volcanaclastic). When dry, some of these soils will actually float in water. These soil conditions may allow the excavation of a canal provided that excavation equipment is located outside of the canal. The canal may operate relatively well if continuously full of water. However, there is evidence that the local farmer routinely cleans soils out of the canals that are likely the result of sloughing of the canal sides.

b. The soils along the proposed conveyance channel do not appear suitable for constructing a 13-foot deep canal followed by the placement of a surcharge load (12-foot high embankment) along the top of the canal, without extensive improvements, maintenance, and/or operational restrictions. The soils appear to be very compressible, which would result in significant settlement with the placement of any load on the native soils. The 2H:1V channel slopes would most likely deform, if not fail, with the placement of the embankments without some type of stabilization. Stabilization would be very difficult to provide without significant effort.

c. In addition to the settlement issue, the project area is located within a seismically active area. The soils are likely not liquefiable in the event of an earthquake, but the channel walls would likely experience large deformations during a seismic event resulting in the canal filling with soils.

d. Some of the bank erosion may be due to cattle watering along the canal.

Recommendation: It is recommended that a preliminary geotechnical investigation along the proposed canal route be performed.

4. Various options exist for constructing the canal. One option is the use of sheetpiles along both sides of the canal for the entire length of the canal. The piles would be driven to sufficient depth to allow for the placement of the embankment fill behind the sheetpiles. An alternative to the proposed embankment may be available that would include some type of coating or covering to prevent leakage through the sheetpile wall that would reduce or eliminate the need for embankment fill. However, it must be noted that past experience in these types of soils indicate that without sufficient embedment, the sheetpiles easily fail when excavating adjacent to them.

   Another option for constructing the new canal would be an extensive over-excavation of the canal geometry followed by the placement of rock to stabilize the surface prior to the placement of compacted fill. A geotextile of some kind may also be utilized to stabilize the foundation. The over-excavation could entail as much as 5 to 10 feet or more beyond the final limits of the canal. It is recognized that both of these options are expensive. In addition, provisions must be provided during construction to preserve cattle access and water along the canal or an alternative watering system should be provided.

   Recommendation - A comparative cost analysis between constructing a new canal and a revised tunnel alignment, based upon the results of the preliminary geotechnical investigation, should be performed.

5. Per the Recon Report, O&M and Service roads would be constructed on top of both embankments along the conveyance canal. It appears that both roads are to be paved with three inches of asphalt concrete over 6 inches of base material. If the planned traffic for each road is different, then appropriate pavement designs should be performed.

6. The Recon-level concept for the canal prism indicates a bottom width of 70 ft. for the 1000 cfs flow condition. This results in a flow velocity of approximately 0.45 fps with a water surface elevation of 4140 in the intake canal for 1000 cfs and 0.9 fps for 2000 cfs. The documents available for review did not indicate why this unusually low flow velocity would be required.

   Recommendation - The geometry of the new conveyance canal should be refined. The canal prism could be significantly reduced in size if more conventional flow velocities are assumed. The Review Team suggests that a canal bottom width of 40 ft. would be adequate to provide acceptable flow velocities (< 3 fps) for the 1000 or 2000 cfs flow rates.

7. The existing canal embankment as presently proposed will be built upon an undetermined amount of unsuitable material and will present potential foundation problems.

   Recommendation - Investigate the utilization of a pipeline in lieu of an open canal. While upgrade of the existing Wocus Drainage Canal would be required, future maintenance problems with the canal may offset initial installation costs of a pipeline.

8. Assuming common canal construction methods are, the first stage of construction for the canals will probably require over-excavation of unsuitable materials to suitable foundation levels. Segregation of the materials (suitable and unsuitable) would need to occur in a coordinated fashion as excavation progressed. Both materials could be utilized in a zoned canal embankment with unsuitable material being placed in the outer zones of the embankment or in adjacent waste embankments. Additional temporary stockpile areas will also be needed to place materials from the initial excavations until embankment foundations were readied. Based only on visual observation, it is expected there will be a sizeable amount of unsuitable material removed.

   Recommendation - Additional soil investigations during the feasibility phase should be performed to identify types and quantities of suitable and unsuitable materials and temporary construction use areas need to be investigated

9. The fish screen facility is anticipated to be constructed at the confluence of Caledonia Canal and Howard Bay south of the Highway 140 bridge. The soil conditions at this location are also presently unknown, but anticipated to be similar to those along the proposed canal alignment. Subsurface conditions could actually be worse as the fish facility would be constructed in wet conditions. The foundation loads of the fish facility are unknown, but not anticipated to be extremely large. The highway bridge appears to be functioning properly without any notable signs of distress. It appears most likely that the highway bridge is founded upon driven piles. This indicates that the fish screen facility could likely be founded on a driven pile foundation. However, it would be necessary to obtain site specific information from a subsurface investigation program

prior to making a final determination.

Recommendation - The ODOT should be contacted regarding the availability of the geotechnical report for the design and construction of the bridge passing over Highway 140. In addition, the flow requirements under Highway 140 bridge should be confirmed. If additional capacity is required, evaluate re-aligning of the road on the southeast side of the bridge, which would allow widening of the channel, based upon coordination with ODOT.

10. The proposed location of the fish facility just south of the Highway 140 bridge may be problematic due to the accumulation of sediments in front and in back of the screen. Unlike A-Canal Fish Screen there will be a limited amount of available space or volume available to accommodate buildup of sediments. Sedimentation transport into canal sections and ultimately to the pumping plant would present future maintenance issues with removal of sediments being required and ultimately wearing on pump and/or turbine runners.

    Recommendations - The fish screen should be relocated to the north side of the bridge where there is a larger area to accommodate sediment buildup. A silt catch should be provided and a deeper approach channel excavated to allow for sediment collection at one point. In addition, further study of existing streambed elevations should take place along with future sedimentation studies to determine any potential problem. The relocation of the fish screen to the north side of the bridge also eliminates any required upgrades of the existing Highway 140 bridge, which would be necessary due to potential scour problems.

11. The proposed check structure located adjacent to the fish screen structure which discharges Long Lake Valley waters into Upper Klamath Lake could cause fish attraction issues for certain fish species and ultimately result in cycling of fish through the fish screen system.

    Recommendation - The fish screen and the check structure should be two different structures; the separation between the structures should help to eliminate the fish cycling.

12. The currently selected location of the fish screen structure just south of the Highway 140 presents severe limitations for construction access and locating of staging areas. The structure is flanked on the right by the highway and existing

canal or marsh. The left side of the structure is flanked by the remaining canal width and then the steep mountain slope.

13. If the current intake arrangement is retained, the fish screen structure location should be relocated to the north of the highway where suitable staging area and access is available.

14. The selection of the A Canal Fish Screen as a basis for estimating the fish screening requirements at UKL is considered an effective and valid approach for this purpose. However there is also additional information available from other fish screen projects which would address site specific conditions at this location.

    Recommendation: Three fish screen layouts should be considered: double v (like a canal), single V flat plate screen (like GCID or Tracy) and a vertical traveling water screen (depending on the lake level fluctuations).

15. Wocus Drainage Canal and swamp areas will need to be unwatered for the excavation and embankment phases of construction or a bypass of irrigation waters would be required. The actual installation of the unwatering system would need to occur prior to the canal outage since there is a limited time available during the actual outage period. It is expected that there would be a considerable amount of time for the actual unwatering for the 3 ½ mile long canal.

    A sizeable collection pipe system and settlement pond area will also need to be considered or several individual settlement ponds prior to discharging water back into Upper Klamath Lake. Other discharge areas, such as the unaffected portion of Caledonia Canal, the Wocus Drainage Canal, and adjacent farm land should be investigated as percolation areas to reduce costs of dewatering.

16. Design considerations for permanent relief of ground water pressure should also be considered as there is likely to be runoff from the adjacent hill/mountains and Wocus Marsh area. Cross drainage and any other drainage considerations will need additional consideration. A concrete or shotcrete lined canal could also be considered and would allow for steeper side slopes.

17. The construction of any facilities in Howard Bay will be problematic due to the need to construct a cofferdam within the lake and to maintain flow in the Caledonia Canal past the construction site. The current appraisal level estimates have

$690,000 and $976,000 for control of water for the 1000 cfs and 2000 cfs fish screen structure alternatives, respectively. The specific details on how these estimates were derived were not provided. Control of water for excavations is typically problematic and the lack of exploration data at the site would seem to increase the risk of increased costs. During the feasibility design, the control of water scheme should be developed further.

18. Issues associated with returning fish, particularly endangered fish, to UKL need to be addressed as soon as possible to reduce risks of significant design changes required on future design efforts.

B. Intake Canal and Bypass Release Structures

1. The intake canal and bypass release structure is located at the pumping plant and is used for dissipating the energy from water released from Long Lake Valley. The structure will likely consist of a fairly heavy concrete structure and basin.

2. The geotechnical issues for the intake canal and bypass release structure are very much the same as for the new canals.

   Recommendation: It is recommended that a preliminary geotechnical investigation along the proposed intake canal and bypass release structure should be performed.

3. It is not clear from the Recon Report if the earth-lined canal referred to in Figure 5 includes an imported, select earth lining material or is simply the native, excavated material. Based on the review of the quantity estimate worksheets it does not appear that a select lining material has been included in the cost estimate. The volume of this material will be significant and will, most likely, be imported. The design assumptions for this feature should be clarified.

4. Reverse flow (flow from LLV to UKL) will require significant energy dissipation. The hydraulic head could be as large as 300 ft. The area available to dissipate this energy is very limited. The current Recon Report concept is to use jet flow valves releasing water into the pumping plant intake channel. The impact of the hydraulic jet from these valve releases will produce significant turbulence and surge with wave action in the earth lined channel. Although this concept calls for lining the channel with a 2 ft. depth of riprap, the erosive effect of this reverse flow condition may produce unacceptable operation and maintenance conditions.

Recommendations – The Waddell P/G Plant is an example of an existing facility that is required to bypass and release large flows into a pumping plant intake channel. The dissipation of energy for a large hydraulic head was required at this facility to protect the concrete lined intake/discharge channel for bypass flows. This P/G plant bypass structure used large fixed cone valves housed in a baffled, reinforced concrete structure to dissipate the energy and provide low flow velocities over the bypass structure outlet sill. This type of bypass structure eliminates the turbulent and erosive flow characteristics associated with the jet flow valves currently depicted in the Recon-level concept. If a bypass structure is not feasible, then grouted riprap, shotcrete or a concrete lined inlet channel should be used

5. The intake channel is described as 200 ft. long and 200 ft. wide. The length of this channel is helpful in eliminating the uneven flow characteristics associated with an abrupt 90^o change in flow direction. However, the analysis and design to ensure that uneven flow issues can be properly addressed to ensure the required flow characteristics at the pump can be complicated and expensive.

   Recommendation - The elimination of any flow direction changes for the pumping plant and intake channel layout will simplify and improve the hydraulic analysis, design, operation and maintenance of the pumping facility.

C. <u>Pumping Plant</u>

1. As acknowledged by all team members, a site-specific subsurface investigation is required for this site. The site presented for the pumping plant in the report reviewed would likely present similar challenges as the other aspects of the project for the design of the foundation. If the location is not moved, foundations could possibly consist of deeply driven piles, or possibly, drilled shafts. Discussions were made with the planning team geologist during the site visit regarding the possibility of moving the site to the west in order to place the structure on more favorable subsurface conditions. Moving the site to the west and within bedrock would likely require excavations into the slope of the hillside. This may require additional slope stabilization depending upon the excavation. If the structure could be established on bedrock, shallow foundations would most likely be adequate. Based upon the schematic provided for review, moving the plant to the west would result in a substantial cut into the hillside. This may result

in significant excavations.

Recommendation - Due to the unacceptable foundation material that is presumed to exist at the proposed pumping plant location, it will be imperative that exploration be performed at this site to permit feasible location of the pumping plant and associated features and proper assessment of foundation issues and cost estimates for the pumping plant. If foundation issues are significant based on the exploration, the Review Team recommends consideration be given to moving the pumping plant to the northern end of Long Lake Valley to reduce the overall length of the conveyance canal.

2. It is not clear from the report what type of pumping unit is being considered for the pumping plant. The type and depth of plant structure, pumping head range capacities, number and size of units, hydraulic mechanical equipment, and auxiliary electrical and mechanical equipment will all be significantly different if the pump is a vertical turbine type unit set in a wet sump or a Francis type unit with a suction tube intake.

3. The operating water surface fluctuates 160 ft. in LLV. It is possible that the intake/discharge tower in LLV will need to produce an artificial head for pumping to reduce the pump head variation. It must be noted that creating an artificial head increases the power requirements for pumping operation and will impact the operation cost estimates.

4. Over-excavation of unsuitable materials below the plant foundation will most likely be required for suitable foundation bearing. Replacement with imported backfill will probably also be required. Impervious backfill may be utilized around the plant substructure with consideration give to pervious materials at yard elevation.

5. The orientation of the plant in relation to the tunnel and the canal conveyance should be investigated. Orientation of the plant at an obtuse angle to the tunnel and canal would help in energy dissipation.

6. Power generation is mentioned in several of the documents provided to the Review Team. Based on data contained in the memo from Nancy Parker (TSC) to the LLV Appraisal Study Team (August 23, 2007) a “good” year’s operation cycle would include 3 – 4 months of continuous pumping and 1 – 3 months of continual releases back to UKL. It also appears that there will likely be stretches of consecutive years (4 – 5) where no pumping and/or reverse flows can be made (very dry or drought

years). Based on this information, incorporating power generation capability will require more detailed evaluation before being considered in future planning or design efforts.

Recommendation – Although the data cited above would indicate that incorporating power generation is not practical, some other factors need to be considered prior to eliminating this completely from consideration. See Section H for electrical power issues. Other alternatives may merit investigation as well. Considerations for operating a P/G plant could include a daily pump-storage operation where no net exchange of water is required between LLV and UKL. This appears to be a significant amount of the time during any given year.

D. Tunnel and Surge Shaft

1. Figure 7 in the Recon Report indicates a 230 ft. deep surge shaft approximately 1,400 ft from the pumping units. This separation (distance) between the surge chamber and the units will not provide suitable surge protection for the units.

   Recommendation – The layout and estimate for the tunnel and surge shaft should be modified based on a location of the surge shaft as close as possible to the pumping plant. Alternatively, the service yard area for the pumping plant or pump-generation plant could allow for a surge chamber within the service yard area. This service yard area would then be sized to include an electrical switchyard facility.

2. The actual geologic conditions along the tunnel alignment are unknown, and could encounter any or all of the different rock and soil conditions in the project area. The subsurface conditions would dictate which tunneling method(s) could and should be used for the project. This will require a coring program along the proposed alignment of the tunnel in order to collect data from the proposed alignment so testing of the core could be performed at the elevation of the tunneling. Discussions took place during this review regarding alternative locations and lengths for the tunnel. Preliminary drilling may be required to aid in the selection of the actual alignment prior to performing a design-level subsurface investigation program.

   Recommendation: A preliminary geotechnical investigation of the potential tunnel alignments should be performed

E. Outlet Works Tower

1. It is not clear from the Recon Report whether fish screening and/or selective level withdrawal was evaluated or considered for the Outlet Works Tower.

2. Based on the probabilistic Seismic Hazard Analysis transmitted to KBAO from Larry Anderson (TSC) (January 11, 2007) the mean hazard curves indicate peak horizontal ground accelerations (PHA) of 0.5 g for the 10,000 year event and 0.76 g for the 50,000 year event. This structure is 200 feet tall and will require significant structural and foundation analysis and design to accommodate these ground accelerations.

   Recommendation - These PHA's should be compared to those used to design the San Luis Dam (Sisk Dam) Intake/Outlet Tower to assist in cost adjustments when applying the San Luis Dam Outlet Works as a basis for estimating the cost for this feature. It is noted that this structure was designed in the 1960's and the seismic criteria for this structure will, most probably, be significantly different than the seismic criteria applicable today. NOTE – If the downstream hazard is evaluated such that the seismic event required for design can be reduced (say 2500 year or 500 year event) then this could significantly reduce the seismic demand and subsequently the cost for this structure

3. As with all other aspects of the project, a site-specific subsurface investigation is required in order to design the foundation for the outlet works tower. The outlet works tower could possibly be the most heavily loaded structure on the project, which would require special consideration of the foundation conditions. If founded on bedrock, a spread foundation would likely be possible, particularly if the bedrock consists of hard basalt. If the bedrock consists of the breccia or sandstone, a spread foundation may still be possible, but would likely require a larger foundation with lower bearing pressures.

   Recommendation: It is recommended that a geotechnical investigation at the proposed outlet tunnel site should be performed.

F. Access Roads

1. The access roads should be designed based upon the appropriate traffic. If heavy truck traffic will use the roads, the proposed pavement design may be insufficient.

   Recommendation: The actual traffic that will use the access roads should be determined.

2. The information provided in the Recon Report for the northern and southern access roads provides some general information. However, additional information needs to be developed to determine the existing conditions of these roads. Roads will need to be upgraded to accommodate not only temporary construction traffic but future recreational traffic.

3. There appear to be adequate access roads into the various construction sites. However, the existing roads would need to be improved, especially for material hauling. Areas requiring reservoir lining would need multiple ramps cut into the mountain slopes for equipment access. Improved haul roads would need to be constructed from the borrow area into the reservoir area and to the conveyance features. Temporary haul roads would be required along the conveyance canal.

4. While a minor cost, contractor staging areas will be required at each feature. The features inside the reservoir would not necessarily involve additional costs; the conveyance features at Howard Bay and Wocus Marsh will require staging areas. These areas will more likely require fill or surfacing to provide a suitable all weather staging area. Any fill on temporary easements will most likely require removal and disposal after construction.

5. The Recon Report cost estimate includes costs for the permanent service and access roads. These roads would be used during construction, but it was not clear whether the remaining construction haul roads and staging areas were included in the line item cost estimates.

G. <u>Reservoir Lining</u>

1. The Recon Report discussed the reservoir lining could be accomplished through the use of a geomembrane or soil liner. The cost estimate prepared for the Recon Report assumed 20 percent of the reservoir area would be lined with a geomembrane. The application of a geomembrane could be problematic. The slope would need to be dressed and bedding placed. The membrane would then be placed and a cover material placed over it. The anchoring of the membrane and protection of the cover material from erosion would need to be resolved, as well as maintaining cover material on the geomembrane, especially on the steeper slopes.

2. During the site visit, it was discussed that using a soil liner as the reservoir lining would seem to be more easily constructable. The placement of a soil liner would include removing the larger blocks of basalt to prepare a relatively even surface prior to

placing soil over these areas. Some treatment may be needed on steeper slopes to produce an even surface; the use of shotcrete or grout may be an option. The prepared surface would follow the general slope of the terrain rather than be leveled horizontally. These areas would then be covered with a minimum of 10 feet of clay soil. The soil would be placed by tracking the material parallel to the slope rather than in horizontal layers; a plating method could also be used. Some compactive effort should be exerted by the dozer or rubber-tire equipment used to place the material. With the primary purpose of the soil liner being to limit seepage, compaction is not as crucial as if the soil was an embankment to retain water.

However, protecting the finished surface of the soil liner would remain a concern. Wave action from the reservoir would most likely erode the soil liner over time. In some areas, particularly the steeper slopes, which range from 10 to 40 percent grade, the entire 10 feet of soil could potentially be removed by erosion over time.

The areas requiring lining are identified as jointed basalt where the air fall tuff that covers the basalt in the surrounding areas has been eroded. This basalt is jointed with a maximum joint spacing of up to 8 feet. The subsurface investigation indicated that the joints in the basalt are not well defined at depth. Therefore, it would seem that the joints may initially carry a moderate amount of seepage, but there may not be a direct connection to the outside basin that would allow this seepage to escape to the regional groundwater. If there is no direct connection between Long Valley Lake and the regional groundwater, the seepage would become bank storage which would return to the reservoir as the water level decreased.

Recommendation: The likelihood or reasonableness of the joints being connected to the regional groundwater should be evaluated.

3. The treatment method and surface area of the steeper slopes were not cost estimated.

4. There is some risk the cost of the reservoir lining could be considerably higher than the appraisal level cost estimate depending on the resolution of the above design and construction details.

H. Electrical Power

1. The report prepared by the KBAO proposes a pumping only operation (without pump/generation capability) for the Long Lake Valley Project (LLV). The backup analyses utilized a Pacificorp power cost estimate of 6.5 cents/kwh for pumping power, with a resulting annual cost of power of approximately $5 million

   In reviewing these assumptions, the Pacificorp energy cost pricing assumption appears to be low relative to the likely price levels that Pacificorp would require for such pumping energy. Current (2007) Pacificorp retail rates are presently in the 10-12 cent/kwh range for delivery of energy. Since the Pacificorp power generation portfolio is heavily coal based, their longer term rates could escalate substantially if proposed taxes on carbon emissions and greenhouse gases were to be adopted. In the timeframe when the LLV project would be operational it would not be surprising to see actual Pacificorp rates for energy to be roughly 2 to 3 times the 6.5 cent/kwh level.

   The KBAO is also currently working to obtain lower cost (Project Use) energy in conjunction with other KBRA related efforts. If these efforts are successful, energy may become available to the LLV project for pumping at effective rates in the 2-3 cent/kwh range, delivered. This would substantially reduce operational costs and might also facilitate the addition of generation to the project.

   Recommendation - The LLV project (base case) as pumping only while considering both higher future Pacificorp energy costs and the possibility of lower cost Project Use energy becoming available should be re-evaluated.

2. The current analysis of the LLV project also is based on a pumping only design and does not include a generation mode for the project. While we agree that this is an appropriate, conservative "base case" for analyzing the project, further analyses should be conducted to determine if adding generation would add value and reduce costs for the project.

   Recommendation - The option of adding power generation to the LLV project should be added to the Appraisal Report, including the possibility of designing features for the later addition of generation if it appears that the economics do not warrant the installation of generation upon start up of the project. (See comment No. C.8 under [C. Pumping Plant].

3. The existing LLV project transmission assumptions anticipate connection to the Pacificorp Klamath Falls substation. Detailed routing and system studies have not been performed. It is not known whether PacifiCorp's existing system has the capability to serve these loads without upgrades or reinforcements. If the LLV project were to require 10 miles or more of 230kv transmission, the Oregon Energy Facilities Siting Council might obtain jurisdiction over the project. Alternatively, it may be possible to plan transmission interconnections to the federal Captain Jack substation in the Klamath Falls area, which could be beneficial to the Klamath irrigation power loads.

   Recommendation - The transmission interconnection options of Pacificorp and also building directly to the Captain Jack substation, most likely at the 115kv voltage level (to ensure that the Oregon Energy Facilities Siting Council does not take jurisdiction over the project) should be analyzed.

4. The LLV project may be able to utilize third party funds for the pump/generation aspects of the project. The California power market is continuing to see extreme pricing fluctuations at certain times, due to a tight supply/demand balance of generation. Several utilities are currently analyzing the economics of pump/generation projects on California reservoirs. It may be possible to obtain third party financing assistance from one of these utilities (including but not limited to Pacificorp) that would see the power generation capability as attractive.

   Recommendation - Informal inquiries with prospective third party utilities that may wish to finance the pumping and generation features of the LLV should be initiated. Such inquiries may help to ascertain the potential value of adding generation features to the project.

5. From a power perspective, daily peaking capability, coupled with the summer peaking capability, may be viewed as attractive. A daily pump/generation operation might also assist in meeting water quality objectives for the LLV project by ensuring that water was being moved into and out of the project on a regular basis.

   Recommendation - The possibility of using daily pump/generation water operations (to enable the project to provide power to the daily system peaks) along with the summer peaking possibilities should be analyzed. In the analysis, the water operation constraints should be examined to determine the maximum amount of peaking capability that could be obtained. (See comment No. C.8 under [C. Pumping Plant].

VI. Issues To Be Studied for Completion of Appraisal Level Design

For the most part, the Review Team determined that work performed to date would fulfill Reclamation's guidelines for Appraisal Level project requirements. However, in addition to the issues listed in Section IV above, there were several additional issues that the Review Team felt should be addressed and completed before the Recon Report could be considered a completed Appraisal Level Design.

A. Final determination as to whether LLV can hold water should be completed.

B. The benefit-cost analysis should be completed.

C. A preliminary geotechnical investigation should be performed at the proposed location of the pumping plant, canal, tunnel, and fish screen structure.

D. Cost item for construction haul roads and staging areas should be added.

E. An operating criteria for filling to and releasing from LLV should be selected. (The potential operating criteria will be established by the KBRA.)

F. An environmental assessment should be prepared and other environmental issues (DEQ and other requirements) should be investigated.

G. The hydrogeologic analysis should be refined and rerun using site specific conditions and operating criteria. In addition, there should be a third party independent review of the analysis.

H. The real estate mapping should be expanded to include all lands involved in the project and title reports should be obtained.
    1. Expand the real estate mapping to include all lands from the portion of Howards' Bay adjacent to the entrance as far out as any fish return pipelines may go, down to the Wocus Drainage Canal and any potential access roads around the reservoir and staging areas.
    2. If title reports have not been obtained during appraisal phase, obtain title reports during early Feasibility Phase for all lands that may possibly be used, even for construction staging. They will identify any liens, utility easements, and other restrictions on lands that may be needed for the project and can affect cost

estimates. This is typically a low cost effort that usually can be done via a contract with a local title company.

I. Exploratory discussions with the owner/operator of the Wocas Drainage Canal should be initiated to determine their concerns, plans for operation, and expectations. Items of concern are:
   1. Times of use of the canal throughout the year and better describe the months when drainage is needed and how the timing of drainage needs would relate to the time of year of intake for filling the reservoir.
   2. The need for cattle watering in the canal (site observations found that cattle have ready access to the canal for water all along the drain. There were no alternate cattle watering sources observed on the field trip
   3. The willingness of the owner to sell the canal land to Reclamation/ or enter into permanent easements for use of the canal.
   4. Explore operation and maintenance issues with possible dual use of the existing canal.

J. The reconnaissance water quality analysis work should continue and be upgraded to an appraisal level (consider a monitoring program). Additional work includes:
   1. Determine the quality of “flood” water (snow melt runoff) contemplated being used for storage, the quality of water that may be taken out of UKL at the time of year when water may be pumped out in anticipation of flood inflows, and quality of the drain water from Wocus Drainage Canal that may be commingled with LLV discharged water.
   2. Perform water quality analyses of mixing various sources to determine if there is any merit to considering water quality during operations (e.g Is it worth taking low quality water out of UKL in the spring and mixing it with snow melt flood runoff water, or are there water quality issues of missing water coming out of LLV with Wocus Drainage Canal drain water?)

K. Technical issues associated with two-way flow through a fish screen should be investigated; if there are no adverse issues, the need for a check structure would be eliminated.

L. Power generation should be considered and evaluated. In addition to determining field costs for the addition of power generation, other issues should be investigated, including whether the Oregon Energy Facilities Siting Council would have jurisdiction on this project and determining power generation criteria (it may be feasible if it is operated on a daily cycle when there are no pump or release demands).

VII. Feasibility Design - Issues to be Studied

Based on the review of the Recon Report, the site visit, and discussions with KBAO and MPRO staff, the Review Team suggests that the following issues should be addressed early in the Feasibility Design process:

A. A Field Exploration Request (FER) for feasibility level design should be developed after the completion and review of the preliminary geotechnical investigation, and final site selection of the project components.

B. The relocation of the pumping plant and tunnel to the northern end of LLV should be investigated. While the length of tunnel would be increased, the need for the canal, and the associated issue identified above, would be eliminated. The Review Team also felt that this relocation would result in a simpler project to construct, operate, and maintain.

C. The orientation of the pumping plant in relation to the tunnel and canal to minimize possible hydraulic issues with the pumps should be considered.

D. The relocation of the fish screen to the north side of the bridge at Howard Bay should be investigated.

E. The need for 402 and 404 permits and permit terms for construction should be verified. Examples include but are not limited to all state and local requirements that may be needed, such as air quality permits, traffic restrictions associated with HWY 140, noise (driving sheet pile for construction of the fish screen and/or the fish bypass/return pipeline out in UKL), etc. In addition, determine all other federal requirements such as from Executive Order 11990 Protection of Wetlands, Section 402 involving the change in volume or quality of agricultural drainage, Executive Order 12898 – Environmental Justice in Minority and Low-Income Populations, Executive order 11988 – Flood Plain Management, and the American Indian Religious Freedom Act of 1978.

F. Exclusion periods for construction work should be determined.

G. The need for the fish screen facility to be dewatered during construction should be determined.

H. Fish return into Upper Klamath Lake should be evaluated to determine if release location is effective in preventing the “continuous loop” for bypassing fish.

VIII. Non-design Issues

The Review Team evaluated other issues associated with this project. Below are comments concerning Schedule, Operation Issues, Project Management, Environmental Compliance, and Water Rights:

A. Schedule

General Comments

1. A number of key phases have been left out of the project development process and schedule, as noted below. These need to be included because at Appraisal, Feasibility and Final Design phases, they have an affect on the following:
   a. The project cost estimate (construction cost estimates and non-contract costs)
      1) The effect on the cost estimate is both on the inclusion of the costs for performing the tasks and; on
      2) determining the effect of inflation and the time value of money
   b. Funding and financing plans.
   c. The perception by the stake holders of when the project will come on line.
2. General tasks can be added to the schedule to represent these without selection of an alternative.

Significant Schedule Issues

The following issues need to be addressed for the Appraisal report, for the reasons listed above.

1. The schedule needs to include an activity for seeking construction authorization and funding through Reclamation/Department of the Interior (DOI) channels, Office of Management and Budget, (OMB), and Congress. This can typically be one to two years.

2. The schedule needs to include a phase for procurement of construction contracts, between phases 6 and 7. For major facilities such as the pumping plant, the solicitation method may be a request for proposals, which typically can take up to six months. This is recognizing that multiple solicitations and awards would likely be made; some not on the critical path. Procurement for lands should be a separate activity, as well as obtaining the agreement for installing the power lines to the project.

3. The schedule needs to include a phase for environmental mitigation.

4. Schedule Line Item 50 -The planning report certification review process has the following issues if “the certification will be sought because it would likely be used or referenced by

Reclamation or project proponents to seek congressional authorization [for construction] or appropriation".

a. Line Item 50 is shown on the schedule during the plan formulation phase, which is characterized at the appraisal level of designs and cost estimates.

   If this Line Item 50 certification is intended to be used to seek construction authorization, it is recommended that the designs, cost estimates and related plan formulation work at the "appraisal phase" be upgraded to feasibility level (still call it appraisal) for the pumping plant, reservoir lining, power supply, fish screen and conveyance canal (big ticket and high risk items) because the certification process requires the level to be identified, and this study will be not at the feasibility phase by the beginning of FY-09. If this Line item 50 certification is not for seeking construction authorization, then suggest it be deleted and use the DEC review as the agency "peer review".

b. The certification process is shown concurrent with many of the tasks needed to be completed before the report can be certified.

   Recommendation - If the certification process needs to be at the end of the "appraisal" phase, schedule it as the last task at the end of Phase three, on the critical path.

5. Schedule Line Item 48 - Having a Design, Estimating and Construction (DEC) review in the first quarter of 2008 is too early in the process because of the lack of level of technical work and plan formulation efforts to support the cost estimates of the top few alternatives.

<u>Other Schedule Issues</u>

1. The following issues should be addressed in the Feasibility Report.

   a. The schedule needs to include a phase for commissioning of the project. Regardless of the alternative, some commissioning should be planned for and reflected in the cost estimate either as a line item or reflected in the contingency amount.

   b. The schedule needs to include an activity for close-out of the project.

2. Schedule Line items 48 and 50 - There is no time between the DEC review and start of certification process for addressing and implementing DEC findings and recommendations.

Recommendation: Schedule two months between the DEC and the certification activities.

3. At the end of each phase - appraisal, feasibility, authorization, mitigation and design – a risk analysis of the schedule and risk mitigation planning should be performed and the risk register revised. [Project Management Body of Knowledge (PMBOK) and Project Management Institute (PMI)]

4. The schedule shows two DEC reviews. The DEC office and the Regional Planning Officer should determine if one well timed DEC review near the end of the Feasibility Phase would be more appropriate.

B. <u>Operation Issues</u>

<u>General Comments</u>

- The priorities for operations between the Long Lake Valley project and storage capacity (e.g. after a dry year) in UKL should be determined in the feasibility report.

<u>Water Quality</u>

- Water quality issues should be determined. For example, if poor quality (high nutrient) water pumped from Howard Bay in to LLV is expected to improve by being stored in LLV or get worse, due to lack of circulation. This should be determined during the plan formulation phase.

<u>Long Lake Alternative Hydrologic Modeling</u>

1. For the Appraisal Report, clarify why the hydrology only encompasses the years from 1961 through 2004, when the February 1987 Appraisal Report states that a 7-year critical dry period occurred from April 1929 to September 1936. The project analysis should include a critical dry period like the 1929 to 1936 period.

2. For the Appraisal report, add an explanation as to why each water year is divided into the 17 time steps and why the half months are used for the March – July time frame.

3. For the Appraisal Report, provide more background information about the flood control rules, since it appears that flood water would be the primary source of Long Lake Valley storage.

4. How the priorities from existing conditions (Iron Gate, UKL storage, Ag and Refuge) change to other priorities (Ag, Refuge, Iron Gate, UKL storage) under the “Future No Action” scenario should be clarified in the Appraisal Report.

5. If the FNA1 criteria form the basis for all FWP runs; does the FNA1 include the augmentation to Iron Gate, since some of the alternatives include a dedicated pipeline to Iron Gate. This could be a significant issue if not resolved before the feasibility phase is started.

6. How the priorities for water supply from LLV are sorted in the “Future with Project” alternatives should be clarified in the appraisal report.

7. Before completion of the Appraisal Report, if the joint operation between LLV and UKL is not set, work to identify and get agreement on the outside range (limits) of possibilities and present analysis of these in the report so the information is available at the Feasibility phase. If an Appraisal Report goes forward to certification and beyond, it could be a fatal flaw if the operating criteria are not set for the project being studied, or at least the limits not set, before investing significant funding in a feasibility study

C. Project Management

It appears that a project management plan has not been developed. However, it is recognized that good work has been done on the total project schedule. This is not a fatal flaw, but without it, the project inherently carries unnecessary risks, particular in areas not addressed by or the responsibility of the TSC design team leader, and usually included in the cost estimates as non-contract costs. Experience with other projects has shown that without an integrated PMP, there is high risk to this project in the areas of funding and financing, real estate (conveyance canal), environmental mitigation and ESA issues, public involvement, repayment, and Native American issues.

Recommendation: Training for the KBAO project team leads of at least a one week introduction to project management level should be provided.

Recommendation: A total project management plan (PMP) (from reconnaissance through construction to begin project operations) should be developed. The PMP should include provisions for revisions at the end of the appraisal, feasibility and design phases (and other major milestones) to provide for the progressively elaborative nature of the project through time.

The PMP should be based on the Project Management Institute's Guide to the Project Management Body of Knowledge (PMBOK). Include sections in the PMP that address the following, which have varying levels of activities that are interrelated and needed to be integrated as the project progresses (see Figure 3-12 in PMBOK) (see example from Cultural Resources):

- Total Project
    - Integration Management
    - Scope Management
    - Schedule Management (great to see a total project schedule at the phase). Develop more on how the schedule is to be managed.
    - Cost Management (budgeting, cost accounting, funding, financing etc.)
    - Quality Management
    - Resource (staffing, equipment, facilities etc.) Management
    - Communications Management (with in Reclamation and external)
    - Risk Management (see attached for a sample risk register). Use the risk management to address the item 14 in the Planning Report Certification list on risk, uncertainties and uncertainties.
    - Procurement Management
    - Each of the above include the following processes:
        - ➢ Initiating
        - ➢ Planning
        - ➢ Executing
        - ➢ Monitoring and Controlling and
        - ➢ Controlling
- Also include sections on:
    - Roles and responsibilities
    - Real Estate
    - Environmental Quality
    - Cultural Resources
    - Safety and Security
    - O&M (operational sequence, roles and responsibilities, contracts needed?)
    - Construction Management.
- The PMP would be needed if the OMB Form 300 would be needed to be filled out and filed.
- The PMP may help with the certification process

D. Environmental Compliance
Fish and Wildlife

1. It appears that consultation per the Fish and Wildlife Coordination Act has not begun and a comprehensive review of environmental impacts has not started. It is recognized that good work has been done in some areas.

   Recommendation: If the goal is to complete the appraisal report and get it certified to be able to go to Congress for a construction authorization, initiate coordination and get an Endangered Species Act (ESA) list during the Appraisal phase. Do the same with the State of Oregon for any species of concern. The list should be revised every two to three years to verify that there have been no changes. This will help to identify any mitigation issues in addition to the wetlands issues, but also identify mitigation that should be considered in the Project Cost Estimate (PCE). It will also help to identify any "work exclusion times" that could affect the duration of construction and thus the costs. See lessons learned from a number of California projects (listing of green sturgeon and work in the water windows), from state species of concern with passerine migratory bird nesting (when and how much clearing can take place), species being considered for listing that may be planned for the future (eels in the Sacramento River, green sturgeon examples).

2. If the goal is to complete an Appraisal Report and get it certified to be able to go to Congress and environmental impacts are a sensitive/high risk issue, environmental assessments, on at least the similar groups of alternatives (Ground water storage, Long Lake Valley and Whiteline reservoir), should be completed and variations within each group should be discussed. This will be an opportunity to get-buy in from stake holders on the detailed description of the "Future No Action" scenario against which the other alternatives are measured, and impacts are determined.

   Recommendation: For the Appraisal study a risk analysis should be performed and risk management plans developed for the various subareas of Environmental Compliance. It should be determined if the state of Oregon has a law parallel to NEPA and if a joint State/Federal document should or needs to be prepared. If not, clearly rule this out in the Appraisal Study

Clean Water Act

Unless this information is already well known from other construction projects in the vicinity of UKL, at the Feasibility Phase, obtain the expected permit conditions and requirements so they are known going into final design for:

a. Section 402 [administered by the National Pollutant Discharge Elimination System (NPDES) Program].
    - General storm water runoff permit (probably only needed for the pumping plant, canal, fish screen, access roads and related work.
    - Point discharge permit for unwatering of the pumping plant, fish screen and canal excavation.
    - The study team is commended for raising the question of the need for a 402 permit for the permanent facility. However, see comments elsewhere on suggestions for additional water quality studies. Also, it was not known at the time of this review what information the Oregon Department of Environmental Quality (ODEQ) had on which to make their decision.
b. Section 404 – Dredge and Fill of Wetlands – for the canal work, fish screen and fish bypass and return pipelines that extend out into UKL. Recommendation: Revisit this issue with the U.S. Army Corps of Engineers (Corps) by providing them a draft of the appraisal report as soon as a draft is available for them to review
c. Section 401 – State Water Quality Certification that states that water quality standards not be violated by discharge of fill or dredged material into waters of the United States, which is required before the Corps will issue a 404 permit.

Other State Requirements

State of Oregon requirements for lake shore line and lake bed disturbance associated with the fish screen and return pipeline and changes to groundwater should be determined at the Feasibility Level.

E. Water Rights

- In the appraisal level report, state the status of water rights involved with the project and identify any needs for water right applications that will be required for the project. Do a risk analysis of when the water rights would need to be obtained to keep them off of the critical path of the project schedule

IX. Conclusion

The investigations, analysis, and designs performed to date for this project represent a substantial effort. The team compliments the KBAO and MPRO staff for the work performed to date. In general, the work performed has been at or above the appraisal level and several activities, such as the wetlands mitigation have been performed much earlier than usual.

In order to meet Reclamation's guidelines for Appraisal Level project requirements, the items listed in Section VI above need to be addressed. Once those items and overall project items listed in Section IV above are addressed, the Appraisal Design should be ready for the Reclamation certification process and the project can proceed to the feasibility design.

Appendix H—*Upper Klamath Basin Offstream Storage Study—Summary of Geologic/Hydrologic Investigations and Reconnaissance Level Cost Estimate*, April 2006

RECLAMATION

Managing Water in the West

Upper Klamath Offstream Storage Study At Long Lake Valley

Summary of Geologic/Hydrologic Investigations and Reconnaissance Level Cost Estimate, April 2006

Klamath Project, Klamath County, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region, MP-200

Part One

Geologic and Hydrologic Investigations

by

Mike McCulla
Project Geologist, MP-230

Part 1

Long Lake Valley is located in Klamath County, Oregon about 4.5 miles west of the city of Klamath Falls. The valley is about 5.5-miles long and up to 1.5-miles wide with a floor elevation of about 4,264 feet. A seasonally-wet lakebed covers the valley floor, with several hundred acres of the land that currently provides pasture for cattle ranching.

In the fall of 2003, the U.S. Bureau of Reclamation (Reclamation), Mid-Pacific Region, Division of Design and Construction, Geology Branch (MP-230) was requested by Reclamation's Klamath Basin Area Office (KBAO) to conduct geologic investigations within the Long Lake Valley area. Investigations were to provide geologic data relevant to determining the suitability of Long Lake Valley for use as an offstream storage reservoir with a capacity of 350,000 to 500,000 acre-feet of water (Photo 1).

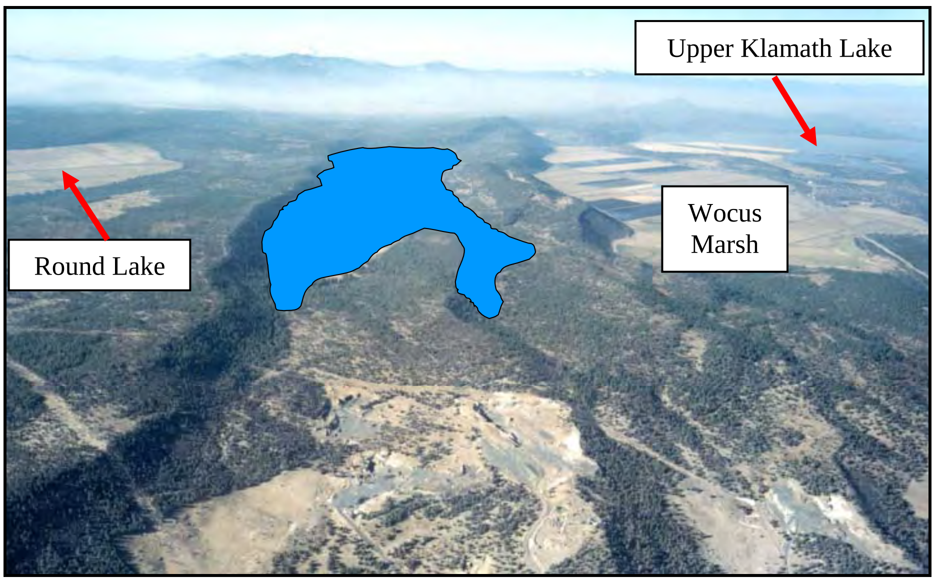


Photo 1. Northwest looking aerial view showing Round Lake, Wocus Marsh Upper Klamath Lake, and an artists conception of a reservoir in Long Lake Valley (blue).

In April 2006 Reclamation's Mid-Pacific Region, Division of Design and Construction, Engineering Branch (MP-210) completed a Reconnaissance Level construction cost estimate study of using Long Lake Valley as an offstream storage reservoir. The study included costs associated with the construction of a pumping plant. Two pumping plant capacities were evaluated, a 1,000 cubic feet per second (cfs) plant and a 2,000 cfs plant. Parameters of the study for a maximum water surface elevation of 4,430 feet, providing a storage capacity of about 350,000 acre-feet of water.

Reconnaissance Level Cost Estimate Summary (350,000 acre-feet storage)

Pumping Plant Capacities	1,000 cfs	2,000 cfs
Field Cost*	$260	$374
Total Construction Cost*	$367	$527

*costs in million dollars

Along the rim of Long Lake Valley there are three low spots that are near or below elevation 4,510 feet, the elevation necessary to allow the storage of 500,000 acre-feet of water. These low spots are designated as the proposed Dam site, Dike-1, and Dike-2. If the proposed offstream storage reservoir uses a maximum water elevation of 4,430-ft., allowing for storage of about 350,000 acre-feet of water, construction of the dam and dikes would be unnecessary. **Reclamation's Engineering Branch (MP-210) was requested by KBAO to only provide a reconnaissance level cost estimate for storage of 350,000 acre-feet of water.**

Geologic Setting

Long Lake Valley is part of a constructional volcanic terrain characterized by basin and range topography that has been dissected by local and regional-scale faulting and erosion. Volcanic lava flows and volcaniclastic sediment forms the sides of the valley and range in composition from basalt to basaltic andesite. Most of the proposed reservoir site is surrounded by flows of basaltic andesite composition.

The predominance of lavas with basaltic andesite, rather than basalt, composition is important for water holding capability because basaltic andesite lava flows forming the sides of the proposed reservoir are generally thicker, more massive, and have much wider spaced joints than most basalt flows. Additionally, the basaltic andesite sides of Long Lake Valley do not host lava tubes, which common to basaltic terrains.

Thick deposits of airfall tuff cover most of the floor and sides of Long Lake Valley, forming a natural lining of very-low to low permeability clay.

Previous Investigations

Offstream storage studies around the Upper Klamath Lake area have been conducted by several organizations, both private and governmental. In 1959 and 1960 Dames and Moore; and California - Oregon Power Company conducted geotechnical investigations for offstream storage in the greater Aspen-Round-Long Lake area, and 13 holes were at Aspen Lake to determine subsurface geology and hydraulic conductivity of individual units.

In 1982 Shannon and Wilson Inc. was contracted by Pacific Power & Light Co. to conduct an independent geotechnical review of offstream storage in the greater Aspen-Round-Long Lake area. Shannon and Wilson drilled 10 additional holes and excavated several test pits to determine subsurface geology and hydraulic conductivity of individual units. They focused most of their work in the Aspen Lake area located about 4-mi. northwest of Long Lake Valley, with less work in Round and Long Lake valleys.

Many of the lava flow and airfall tuff units are aerially extensive through the greater Long Lake, Round Lake, and Aspen Lake area have similar geotechnical properties. For this reason the and hydraulic conductivity test data in Dames and Moore 1959-1960 and Shannon & Wilson 1982 & 1983 are largely applicable to volcanic units present within Long Lake Valley.

Current Investigations

Area reconnaissance and geologic mapping in the fall of 2003 revealed the presence of several rock units within Long Lake Valley believed to have hydrologic characteristics favorable for water storage. From mid-August through October 2004 and from mid-July through August 2005 a drilling program was carried out in Long Lake Valley to determine the local geologic stratigraphy, and to perform hydrologic conductivity tests on the various rock types present throughout the basin. This work included:

- Subsurface investigations in 44 drill holes, including 10 diamond-core holes, 14 hollow-stem flight-auger holes, and 20 cone penetrometer test holes (Figure 1).
- Well permeameter field testing of lakebed sediment (Qlb) in two drill holes.
- Pressure hydraulic conductivity testing (packer tests) in diamond core holes.
- Unsaturated falling head hydraulic conductivity testing in flight auger drill holes.
- Saturated constant head and falling head hydraulic conductivity testing in both diamond-core and flight-auger drill holes.
- Laboratory testing for hydraulic conductivity of both lakebed sediment (Qlb) and airfall tuff (Qt).
- Laboratory Analysis of 81 samples for physical properties and gradations, and two in-place density tests (Appendix C).

Hydraulic Conductivity of Major Geologic Units

Rock and sediment in Long Lake Valley have been separated into units with similar relative permeability values. The terms HIGH, MODERATE, LOW, AND VERY LOW permeability were taken from Figure 5.5 of Reclamation's Groundwater Manuel. Permeability of these units is correlated with the hydraulic conductivity (K) test data.

Lakebed Sediment, airfall tuff, and colluvium form a natural low to very-low permeability lining in Long Lake Valley that covers up to 90% of the proposed reservoir storage area (Chart 1).

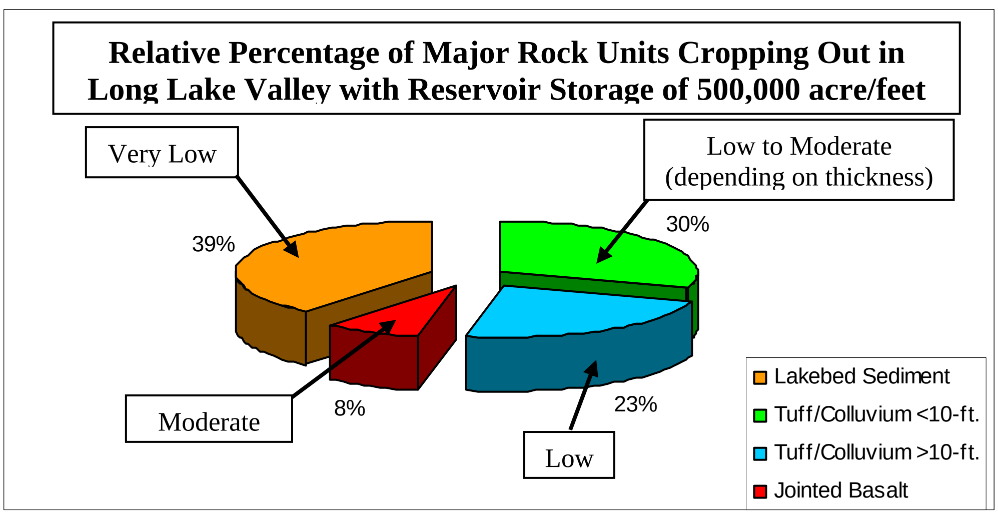


Chart 1. Percentage of major rock units cropping out below el 4,510 feet in Long Lake Valley and their assigned relative permeability.

Lakebed Sediment – Qlb (Photo 2)
This unit, drilled to a depth of 83.9 feet, covers the floor of Long Lake Valley and consists of organic rich mud, clay, silt, and sand. Based on down-hole well permeameter test data and laboratory testing of undisturbed drill samples, **the relative permeability of the lakebed sediment is LOW to VERY LOW with a hydraulic conductivity (K) range of $1x10^{-2}$ and $1x10^{-6}$ ft/day, and a best overall estimate of $1x10^{-4}$ ft/day.**

Airfall Tuff and Lapilli Tuff – Qt (Photo 3)
Over the past 1.5 million years (Ma) eruptions from volcanoes have deposited multiple layers of volcanic ash and lapilli (gravel size ash) throughout the greater Long Lake Valley, Round Lake Valley, Wocus Marsh area. These surface and near-surface deposits of ash are generally thickest (10- to 20 feet) near the valley floor and thin going up the sides of the valley. In some locations ash is mixed with clayey colluvium.
Both the deposits of ash and ash/colluvium have a LOW relative permeability with a Hydraulic Conductivity (K) range of $5x10^{-1}$ to $5x10^{-5}$ ft/day, and a best estimate of $5.0x10^{-2}$ ft/day.

Photo 2. Very low permeability lakebed sediment (Qlb). Photo 3. Low permeability airfall tuff (Qt).

Tertiary to Quaternary age Lava Flows - Tba_1, QTwb, and Qbpb (Photo 4)
The rim and high walls of Long Lake Valley are composed of a thick series of lava flows including: Tertiary Basaltic Andesite (Tba_1), Quaternary to Tertiary Basalt of Wocus Marsh (QTwb), and Quaternary age Basaltic Andesite of Porter Butte Qbpb). These flows are generally 10 to 15-ft. thick, and up to 50 feet thick, forming steep to vertical walls on the western and northern sides of the valley.

Test data indicates **that lava flows comprising the Tertiary Basaltic Andesite (Tab_1) unit have a MODERATE relative permeability with a hydraulic conductivity (K) ranging between K= 2 and $1x10^{-2}$ ft/day, and a best estimate of about K= $5x10^{-}1$ ft/day**.

Volcaniclastic Sediment - Tba_2 (Photo 5)
Beneath the lava flows are relatively thick deposits of volcaniclastic sediment and tuff breccia interbedded with thin, relatively discontinuous lava flows (Tba_2).

The volcaniclastic sediment and tuff breccia in Tba_2 is expected to have a broad range of permeability, but overall classified as MODERATE to LOW relative permeability with a Hydraulic Conductivity (K) between 1 and $1x10^{-2}$ ft/day, and a best estimate of about $1x10^{-1}$ ft/day.

Photo 4. Diamond core of basaltic andesite lava (Tba_1).

Photo 5. Diamond core of tuff breccia (Tba_2).

Long Lake Valley is surrounded and underlain by a complex assemblage of volcanic rocks and sediments. Drilling confirmed the presence of rock units with favorably low to moderate permeability underlying surface outcrops of jointed vesicular lava flows. The hydraulic conductivity of major rock units cropping out at the surface in Long Lake Valley are listed in Table 1.

Hydraulic conductivity data collected by Reclamation (2004 – 2005) in Long Lake Valley is overall similar to data collected over the greater Aspen-Round-Long Lake Valley area by Dames and Moore (1959 – 1960) and Shannon and Wilson (1982).

Comparison of Data Sets		
Rock Unit	**Reclamation 2004/2005** Hydraulic Conductivity (ft/day)	**Shannon & Wilson 1983** Hydraulic Conductivity (ft/day)
Lakebed Sediment	$1x10^{-4}$	$4.8x10^{-3}$
Airfall Tuff & Colluvium	$5x10^{-2}$	$1.4x10^{-2}$
Jointed Vesicular Basalt	$5x10^{-1}$	$2.9x10^{-1}$

Table 1. Comparison of hydraulic conductivity test data (best estimate) for major rock units in the greater Aspen, Round, and Long Lake Valley areas.

Conclusions

I. Long Lake Valley hosts several geologic characteristics favorable for its use as an offstream pump storage reservoir site.

- Its area/capacity curves show that it can contain a large volume.
- It is a closed basin with a natural low to very low relative permeability lining covering 80% to 95% of the area likely to be inundated by offstream storage of 350,000 to 500,000 acre-feet of water.
- For areas that require lining, borrow sources of material with relatively low permeability can be obtained locally, within the valley or within one to two miles of the project area.

II. Currently there is a moderate understanding of the complex volcanic geology of the Long Lake Valley. Major rock units have been identified, and their relative stratigraphic positions determined. Through a series of subsurface investigations, data has been collected indicating the general range of hydraulic conductivity (K) values in various rock types. Additionally, there is a significantly large amount of hydraulic conductivity data on similar rock types within the surrounding area (Aspen Lake and Round Lake valleys) in the Shannon & Wilson (1982) report.

Combining the currently understood geology of Long Lake Valley with the hydraulic conductivity data provides a moderate understanding of the range of relative permeability of major rock units comprising the basin.

III. There is a basic disconnect between expected hydraulic conductivity of major rock units in the Long Lake Valley basin, based on casual surface observations, versus data collected using a variety of hydraulic conductivity test methods. Seeing the basin rim and northern end of the valley composed primarily of jointed basaltic lava flows suggests a potentially high water loss.

When studied in detail, the basin has a natural lining of low to very-low permeability lakebed sediment and airfall tuff covering the bottom and sides of most of the valley. Outcrops of jointed basalt comprise only 3% to 8% of rock units cropping out below the proposed reservoir surface elevations. Hydraulic conductivity tests indicate that these lava flows have an overall moderate relative permeability.

IV. The maximum water surface elevation of the proposed reservoir has a direct bearing on the potential water loss due to infiltration into rock units, as well as the project cost. The higher the maximum water surface of the proposed reservoir, the greater contact the water has with jointed basalt flows and the higher the potential water loss. Additionally, a reservoir surface at el 4,510-ft. (storing up to 500,000 acre-feet) requires the construction of at least one embankment dam (up to 2,400-ft. long) and possibly two dikes, adding considerably to the project cost.

Constructing a reservoir with a maximum water surface at el 4,430-ft. (storing up to 350,000 acre-feet) would not require the construction of a dam or any dikes, and reduces the area of the reservoir that may potentially require lining.

V. Rock types in the valley can be characterized by their hydraulic conductivity into four major groups with the following relative permeability (Chart 1):

Low to Very Low Permeability (K = 10^{-2} to 10^{-6}ft/day) – Lakebed Sediment

Low Permeability (K = 10^{-1} to $1x10^{-4}$ ft/day) – Airfall Tuff / Lapilli Tuff, Colluvium, and Tertiary basaltic vent deposits of cinder and ash.

Moderate to mostly Low Permeability (K = 1 to $1x10^{-2}$ ft/day) – Volcaniclastic Sediment interbedded with thin basalt flows.

Moderate Permeability (K = 2 to $1x10^{-2}$, mostly $5x10^{-1}$ ft/day) – Lava Flows of intensely to slightly fractured Tertiary age Basaltic Andesite, Tertiary to Quaternary age Basalt of Wocus Marsh, and Quaternary age Basalt of Porter Butte.

VI. Geologic investigations integrated with hydraulic conductivity data collected by Reclamation (2004 – 2005), combined with data collected by Dames and Moore (1959 – 1960), and by Shannon and Wilson (1982) provides sufficient data to establish a reasonable accurate groundwater model.

A groundwater modeler using state-of-the-art software, such as HydroGeoSphere, should be able to determine potential water loss from a proposed reservoir. The HydroGeoSphere software can model a reservoir at various depths of operation, the major directions of groundwater seepage, and provide engineers with data that will allow them to determine the cost effectiveness of placing additional reservoir lining.

Part Two

Reconnaissance Level Cost Estimate

by

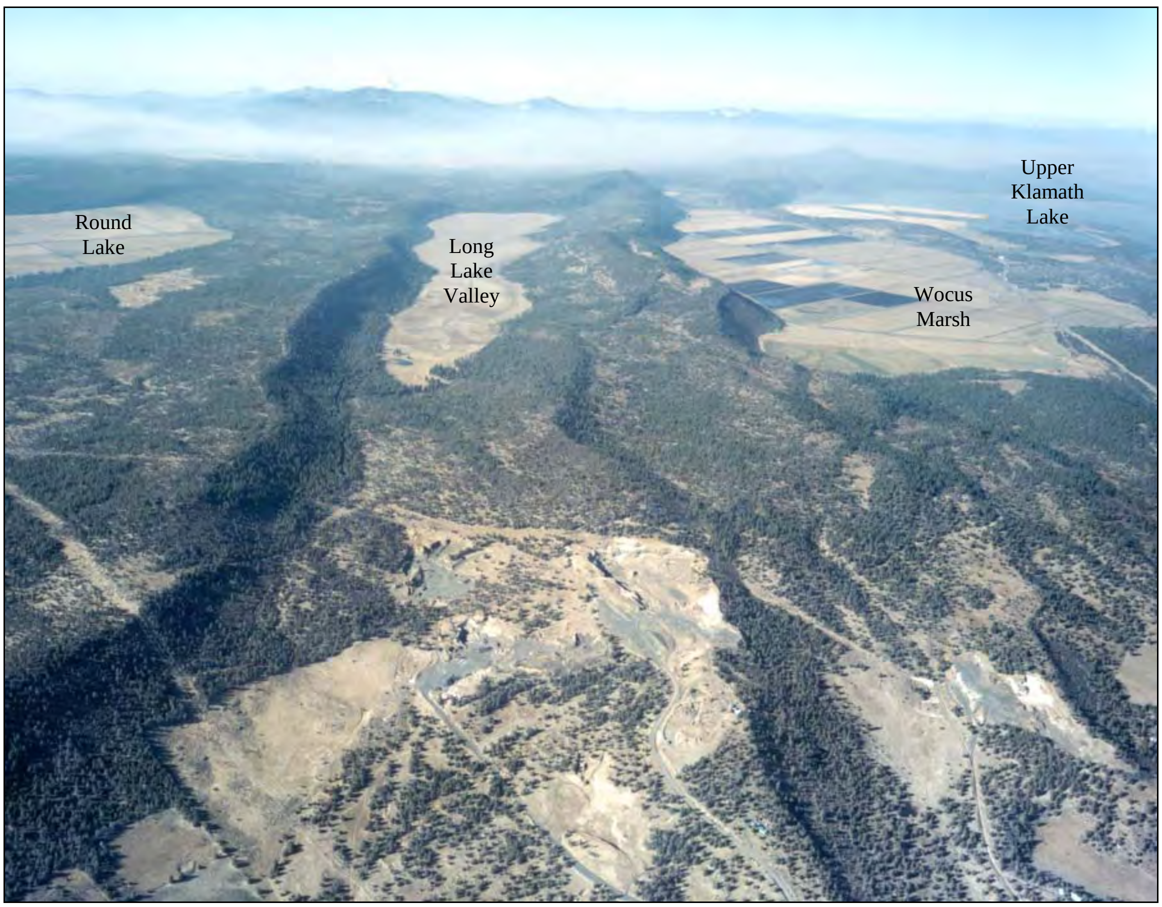
Jim Goodwin
Civil Engineer, MP-210

Appendix I—*Upper Klamath Offstream Storage Study at Long Lake Valley—Reconnaissance Level Cost Estimate*, March 2006

RECLAMATION
Managing Water in the West

Upper Klamath Offstream Storage Study At Long Lake Valley

Reconnaissance Level Cost Estimate



Klamath Project, Klamath County, Oregon
March 2006
U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region, MP-210

Table of Contents

1. Background

In December 2005 the U.S. Bureau of Reclamation's Klamath Basin Area Office (KBAO) requested the Mid-Pacific Region, Division of Design and Construction, Engineering Branch (MP-210) to perform an appraisal level study to evaluate using Long Lake Valley as an offstream storage reservoir. Due to the limited time, staff availability, and minimal available design data, MP-210 proposed and was approved to complete a reconnaissance level construction cost estimate instead. This study examined costs to pump water from the Upper Klamath Lake and store it in Long Lake Valley during the winter months. Water would be released back into Upper Klamath Lake during the drier months. Two pumping plant capacities were evaluated: 1,000 and 2,000 cubic feet per second (cfs). The water would be stored to a maximum water surface elevation 4430 feet in Long Lake which was reported to provide 350,000 acre-feet of offstream storage.

Reclamation Mid-Pacific Region previously completed an Appraisal Report in February 1987 titled Upper Klamath Offstream Storage Study (Ref 2). The 1987 study examined the potential of constructing and operating an offstream storage project involving a system of three reservoirs: Long Lake, Round Lake, and Aspen Lake. The reservoirs would be hydraulically connected by tunnels which would be filled by a single pump-generating plant called Aspen Lake Pumping-Generating Plant. In September 2003, the 1987 study findings were revised and cost indexed. The revision included a new cost breakdown for a "Long Lake Only" storage scenario and an alternative approach to lining the reservoir. Since the 2003 re-evaluation of the 1987 study, additional geologic investigations were conducted by the Geology Branch (MP-230) in 2004 and 2005. These investigations indicate that the water holding capability of Long Lake Valley is much more promising than originally estimated.

This reconnaissance estimate differs from the previous estimates in several areas:

- To comply with current fishery issues in Upper Klamath Lake, a fish screen structure would be incorporated upstream of any new pumping plant intake
- Construction of a dam and dikes is unnecessary since maximum water surface is set at El. 4430 and the three identified low spots around Long Lake rim are at approximately El. 4500. We further assumed that an emergency overflow spillway would not be necessary for this scenario.
- The pumping plant is designed for pumping only, not pumping-generating.
- New geologic findings indicate that less than 20 percent of the total reservoir area needs lining.

This "re-formulated" offstream storage project described in the following section incorporates these considerations but there may be other factors that are not addressed. This reconnaissance level study uses data that is available but may not reflect all factors that need to be taken into account to determine the feasibility of the project.

2. Project Features Description

Refer to Figure 1 for general location of project features. The offstream storage project consists of ten project features to be constructed:

1. Canal conveyance system
2. New fish facility and check structures
3. Intake channel and bypass release structures
4. Pumping plant (pump only, not pump-generating)
5. Concrete lined tunnel
6. Surge shaft
7. Outlet works tower and access bridge
8. Access roads
9. Reservoir lining
10. Electrical power to project features.

2.1. Canal Conveyance System and Fish Facility

Refer to Figures 2, 3, 4, and 5.

For both the 1,000 and 2,000 cfs pumping capacity, the existing Caledonia Canal and Wocus Drainage Canal alignments will be improved to convey flow from Upper Klamath Lake to the new pumping plant which will lift the water into Long Lake Reservoir. The new pumping plant will draw water from Howard Bay under the Highway 140 Bridge, and through a new canal intake structure. The intake structure will include trash racks, a fish screen facility, and head works. Similar to the designs of A Canal Fish Screen, the new trash rack has an automatic cleaning facility and six manually operated bulkheads. Construction of the vee-shaped fish screen facility and bypass system includes: stainless steel wedge wire fish screens; a flow control baffle system; a screen cleaning system; a bypass flow control weir; a backup engine generator set; a bifurcation structure; a fish friendly pump and motor system; and a pressure fish bypass pipeline discharging back into Upper Klamath Lake. Both the fish screen and bypass system are computer and electrically controlled systems. The headgate structure consists of six gates which will also be electrical-motor-operated. A single vee arrangement was assumed for the 1,000 cfs pumping scenario and a double vee was assumed for the 2,000 cfs scenario.

Following the original 1970 Appraisal Report parameters, the canal is earth lined with a trapezoidal section and 70-foot wide bottom, and riprap reinforced on both 2H:1V side slopes. The canal bottom slope is set at El. 4124.8 and the top banks at El. 4150.0, which result in a 25.2-foot deep canal. The original ground surface is assumed to be at El. 4138.0, so there will be 13.2 feet of excavation and 12 feet of fill for the compacted embankments. Since Upper Klamath Lake water surface elevation varies between El. 4136.0 and El. 4143.3, the assumed normal water surface in the canal is about El. 4140.0. Overall, the canal is approximately 19,000 feet long with paved, 25 foot wide service roads on each side of the canal. Both roads connect to Highway 140 and are approximately 3.5 miles long.

When water is released back into Upper Klamath Lake, the flow will be directed through a check structure located adjacent to the intake/fish screen structure. Redirecting these return flows will help protect the fish facility. The check structure has two radial gates with motor-operated hoists, similar to the ones constructed in the Tehama-Colusa Canal. For the 1,000 cfs flow, the two radial gates are sized for 14-foot wide by 14-foot high gate openings with a 7,500-lbs hoisting capacity, whereas the 2,000 cfs has openings of 18-foot wide by 15.5-foot high and 15,000-lbs capacity.

Improvements may be required to protect the existing Highway 140 crossing. Pump stations, turnouts and other infrastructure along the Caledonia Canal will require relocation or modification. Present conditions around and at the Highway 140 Bridge are unknown. This current reconnaissance estimate only includes a cost indexed values for the relocating the bridge piers and two nearby pumping stations identified in the 1970 report.

2.2. Intake Channel and Bypass Release Structures

Refer to Figure 5.

An intake channel will be constructed between the improved Caledonia Canal and the intake bays of the new pumping plant. Similar to the canal configuration, the channel sits at the same elevation, but with greater width. The 200-foot long and 200-foot wide intake channel (250-foot wide for 2000 cfs) is excavated and backfilled with 1-foot bedding and 2-foot thick riprap protection placed on each side. Water is diverted from the canal into the channel and is collected through the pumping plant units. The wide intake channel aids in dissipating energy when water released from Long Lake is bypassed around the pumping plant for release into the channel.

Water released from Long Lake will be directed through a bypass release structure incorporating a jet flow valve which will help in dissipating energy. The 1000 cfs pumping plant has only one bypass release structure, while the 2000 cfs pumping plant has two release structures located on each side of the pumping plant. Each bypass release structure has a 60-inch jet flow valve enclosed by concrete walls.

To ensure that water released from Long Lake into Caledonia Canal does not back up into the Wocus Drainage Canal a check structure will be constructed in the drainage canal and south of the pumping plant intake channel.

2.3. Pumping Plant

Refer to Figures 6, 7, and 8.

The 1000 cfs pumping plant consists of an indoor pumping plant with six pumping units of equal capacity discharging into 78-inch diameter steel pipes. Each pumping unit discharge line has a butterfly valve and a check valve. The discharge lines manifold into a

16-foot diameter pipeline installed above grade. The 16-foot diameter pipeline climbs approximately 120 feet vertically up the hillside to its junction with the 16-foot diameter tunnel. The pumping plant and switchyard are anticipated to be located near the base of the ridge at the same location identified in the 1970 study. A spread foundation for the plant is assumed to be adequate but will need to be verified with geologic investigations.

Discharges from the reservoir return down the hillside through the 16-foot diameter pipeline. At the pumping plant a 16-foot diameter bypass pipe diverges from the 16-foot diameter pipeline to one side of the pumping plant and reduces to a 5-foot pipe which discharges through a 60-inch jet flow valve. Energy not dissipated by the jet flow valve will be dissipated in the wide pumping plant intake channel before flowing into the Caledonia Canal.

Similar to the 1000 cfs schematic, the 2000 cfs pumping plant consists of nine pumping units discharging into 90-inch diameter steel pipes, then manifolds into a 22.5-foot diameter pipeline, and finally into the 23-foot diameter tunnel. Return flow is released into the tunnel and down the hillside through the 22.5-foot pipeline. The flow then bifurcates into two 16-foot pipelines located on each side of the pumping plant. The two bypass pipelines reduce to 5-foot pipes and discharge through 60-inch jet flow gates into the intake channel.

2.4. Tunnel and Surge Shaft

Refer to Figure 7.

The 3,000-foot long tunnel carries water from Caledonia Canal and discharges into the Long Lake Reservoir. The tunnel is lined with reinforced concrete and with a flat invert grade set at El. 4270.0. For the 1000 cfs flow the tunnel has a 16-foot finished diameter, while the 2000 cfs flow is sized at 23-foot. Rock excavation will be required to construct the tunnel and surge shaft, probably be means of blasting, perhaps supplemented with road header equipment. Use of a tunnel boring machine is not expected due to the relatively short length of the tunnel. The tunnel alignment selected for this reconnaissance study is north of the 1970 penstock alignment. This north alignment has the advantage of steeper terrain and better rock foundation which will reduce the length of the approach channel. However, it appears to be slightly longer. Selection of the final tunnel alignment will need to address these factors.

A 16-foot diameter (23 feet for 2000 cfs) surge shaft is placed about a third of the way from the tunnel entrance nearest to the pumping plant to provide relief from water hammer pressure commonly associated with pumping plant operations. It is 230 feet high with the top day-lighting at El. 4500.0.

2.5. Outlet Works Tower and Access Bridge

Refer to Figures 7 and 9.

The proposed outlet works tower and access bridge follow the same design as the San Luis Dam Outlet Works. The 200-foot high outlet works tower, also called trashrack structure, sits on an 8-foot thick concrete base and serves as a discharge, inlet, and gate structure. It consists of a rectangular semi-bellmouth-shaped entrance and a transition. The transition changes from a rectangular to a circular cross section and connects to the tunnel. A single 24-by 30-foot bulkhead gate is seated vertically in the entrance opening and 10 feet past the entrance is an 18.25-by 24-foot roller mounted gate. The roller mounted gate provides emergency closure of the outlet works tunnel, while the bulkhead gate permits for inspection, maintenance, and repair of the roller gate. The bulkhead gate is lowered and raised by a 60 ton capacity gantry crane. The trashrack is supported by columns and beams that extend about 100 feet high and 26 feet away from the opening. Access to the tower is provided by a 16 feet wide by 1,000 feet long bridge that connects from the Northwest Access Road.

2.6. Access Roads

Refer to Figures 1 and 6.

The Northwest Road, about 3 miles long, provides access to the outlet works bridge and tower. The road connects to the Caledonia Canal O&M road approximately 4,000 feet south of Highway 140. In the opposite direction and less than 6 miles long, the Southeast Road connects from Balsam Drive (1 mile north of West Klamath) and provides access to the pumping plant. Both access roads are paved, 25 feet wide, follow pre-existing alignments, and may require roadway clearing. Additional land acquisition may be necessary since the current alignments are on privately owned land and accesses to both ends of the valley are blocked by locked gates.

2.7. Reservoir Lining

Refer to Figure 10.

Geologic investigations of the water holding capability of Long Lake indicate that it may only be warranted to line less than 20 percent of the total 2,700-acre lake area. The minimum areas requiring lining are shown on Figure 10 and these locations were identified by MP-230 (Geology Branch). Reservoir lining may be accomplished by either a soil liner system or geomembrane liner system. MP-230 geologic investigations revealed borrow sources of material with relatively low permeability can be obtained locally within the valley or near the project site. In future evaluations, other suitable methods such as shotcrete lining should be explored.

2.8. Electrical Power

Electrical power will be required to operate the pumping plant, the new headworks and fish facility, and the outlet works tower. Smaller power demands may also exist at the penstock/tunnel junction and at the surge shaft.

Through a discussion with Pacific Power Company, the source of electrical power was estimated to be in the vicinity of Klamath Falls but could be as distant as 8 miles from the proposed pumping plant location. Pacific Power advised that an allowance be made for a longer transmission line route that may be dictated by environmental considerations. Specific electrical transmission components besides transmission lines include modifications to the Klamath Falls substation, a new breaker station, a new meter station, and a substation/switchyard at the pumping plant. Power to the canal intake, outlet works tunnel, surge tank, and trashrack tower is assumed to come from the pumping plant’s substation.

3. Cost Estimates Summary

Pumping Plant Capacities	1,000 cfs	2,000 cfs
Field Cost	$260	$374
Total Construction Cost	$367	$527

Costs are in million dollars

See Attachment 1-Worksheet Estimates for the cost breakdown of each design feature. In addition, Attachment 4 and 5 provide explanations for the percentage factors applied to calculate the mobilization, unlisted items, contingencies, and non-contract costs.

4. Uncertainties

Given the limited design data and information on the existing conditions of each feature site, the cost estimates and design assumptions are subject to some uncertainties. Some issues that need further exploration include:

1. The location of the pumping plant – We assumed the same location as the 1970 proposal. However this site has not been determined as the optimal location.
2. Caledonia Canal and Wocus Drainage Canal – Data available on these features was minimal. Information on the canal existing conditions, capacity, operations, dimensions, and geologic conditions are needed to determine the most suitable design of this feature. This reconnaissance study did not examine if the present canal can handle the proposed pumping flow rates or if other improvements are

necessary. A specific inventory of potentially affected infrastructure needs to be prepared.

3. Highway 140 modifications – Depending on the location of the canal intake structure other modifications/relocations to the Highway 140 bridge may be necessary.
4. The foundation conditions at all identified features (fish facilities, canal conveyance, pumping plant, tunnel, reservoir lining, etc). If adequate foundation materials are not present at relatively shallow depths then the cost estimates for the fish facility, canal, and pumping plant may be low.
5. Access roads – There may be other road alignments that are preferred to provide access to the pumping plant, tunnel, and outlet works tower. Available information on the proposed roads was limited. The extent of improvements needed for construction and long term operation and maintenance were estimated based on verbal descriptions of the existing roads.
6. Biological input on the proposed fish facilities – The intake structure (with fish facility) was patterned after the designs for A-Canal Fish Screen. However, the remote location of the Caledonia Canal inlet area may warrant a different arrangement of these facilities.
7. Dead storage elevation – The project water storage elevation 4430 has been cited as a 350,000 acre foot of storage. This is correct in one sense in that the Area-Capacity curve indicates this amount. However, this figure does not reflect the usable storage amount. We set the tunnel invert elevation (El. 4270) at 10 feet above the average valley bottom elevation. According to the Area-Capacity curve (dated 8-27-69) the amount of storage available between El. 4270 and El. 4430 is approximately 340,000. In the 1970 study scenario most similar to this reconnaissance study, a tunnel invert of El. 4271 was used. Also, the minimum water surface was identified as El. 4296. The amount of "usable" storage available between El. 4296 and El. 4430 is approximately 305,000. Apparently the cited 350,000 acre-feet of storage is a nominal figure. Care should be taken when indicating the actual usable capacity of the project.

5. Summary

According to this reconnaissance level study an estimated $367 million is required to construct Long Lake Valley into a 350,000 acre-feet offstream storage reservoir with a 1,000 cfs capacity pump plant; and $527 million with a 2,000 cfs capacity pumping plant. These two estimates represent the Total Construction Costs, which consisted of the Field Costs for all ten project features and the Non-Contract Costs. Even though this March 2006 study included some new re-formulations – such as installation of a fish-screen, elimination of a dam and dikes, construction of a pumping-only plant, and partial lining of the reservoir – further investigation is recommended, especially to address the uncertainties associated with the cost estimates and design assumptions.

6. List of Figures

7. References

1. Upper Klamath Pump Storage – Long and Round Lakes 1970 Design Files. Canals, Dams, and Mechanical design files were available for reference, but Electrical files were not found.

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3. Surface Geologic Investigations – Proposed Offstream Storage in Long Lake Valley, Klamath Project, Klamath Falls, Oregon. U.S. Department of the Interior, Bureau of Reclamation, 2004.

4. Long Lake Valley Offstream Storage Study – Geologic and Hydrologic Investigations in Long Lake Valley. Klamath Project, Klamath County, Oregon. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, MP-230, March 2006.

5. Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates. A component of Yakima River Basin Water Storage Feasibility Study, Washington. Technical Series No. TS-YSS-2. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center. Denver, Colorado. December 2004.

6. Appraisal Study - Raising Upper Klamath Lake. U.S. Department of the Interior, Bureau of Reclamation. November 2000.

7. Technical Record of Design and Construction: Central Valley Project – West San Joaquin Division – San Luis Unit – California. Volume II and III – *Design and Construction San Luis Dam and Pumping-Generating Plant, O'Neil Dam and Pumping Plant.* U.S. Department of the Interior, Bureau of Reclamation. Denver, Colorado. November 1974.

8. Specification No. DC-5855: San Luis Dam and Pumping-Generating Plant and Forebay Dam.

9. Specification No. DC-7296: Tehama-Colusa Canal, Reach 7.

10. Specification No. 20-C0569: A Canal Fish Screen.

11. Specification No. 20-C0648: Delta-Mendota Canal – California Aqueduct Intertie Pumping Plant

8. Attachments

1. Summary Cost Estimate Worksheets
   Summary of Field Costs for pumping plant capacities of 1,000 and 2,000 cfs.

2. Ten figures associated with the design features.

3. Initial transmittal letter dated September 29, 2003.
   Letter written by MP-200 for KBAO-1000, subjected “Updated Construction Cost – Appraisal Report, February 1987 – Upper Klamath Offstream Storage Project – Klamath Project – Oregon.”

4. Follow-up email dated October 17, 2003.
   From Jim Goodwin to Dave Sabo regarding clarifications of cost figures for the September 2003 transmittal letter.

5. Field Cost Estimates Explanation
   An excerpt from “Appraisal Assessment of Black Rock Alternative Facilities and Field Cost Estimates” explaining the field cost estimates for mobilization, unlisted items, and contingencies.

6. Area-Capacity Curve and Table, dated August 27, 1969.

ATTACHMENT 1

Bureau of Reclamation

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE		PROJECT
Long Lake Reservoir - with Pumping Capacity of 1,000 cfs		UPPER KLAMATH LAKE - Offstream Storage Study
		DIVISION MP-210

ITEM NUMBER	DESCRIPTION	MEANS ITEM NUMBER	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	SUMMARY SHEET					
1	Canal Conveyance System (3.6 miles)					$21,000,000
	Include canal, roads, and relocation of highway & pumping plants					
2	New Fish Facility and Check Structures					$15,000,000
	Trashracks, fish screen & facilities, headworks, and check structure d/s of Howard Bay					
3	Intake Channel and Bypass Release Structure					$1,000,000
	Include 200-ft long riprap channel with a 60" jet flow release structure					
4	Pump Storage Plant					$57,000,000
	Pump-storage plant with 6 pumping units					
5	Concrete Lined Tunnel					$16,000,000
	16-ft diameter and 3000-ft long at invert El.4270					
6	Surge Shaft					$3,000,000
	230-ft deep and 16-ft diameter concrete surge shaft					
7	Outlet Works Tower and Bridge					$12,000,000
	Include OW trashrack structure, bulkhead and roller-mounted gates, & access bridge					
8	Access Roads					$3,000,000
	Include northwest access to OW tower & southeast access to pumping plant					
9	Reservoir Lining					$27,000,000
	Geomembrane lining approx 20% of Long Lake Valley					
10	Electricity to Project Features					$25,000,000
	Include transmission line, substations, switchyard, & electric instlln to project features					
	Subtotal					**$180,000,000**
	Mobilization (+/- 5%)					$9,000,000
	Subtotal w/ Mobilization					**$189,000,000**
	Unlisted Items (+/- 10%)					$19,000,000
	Contract Costs					**$208,000,000**
	Contingencies (+/- 25%)					$52,000,000
	FIELD COSTS					**$260,000,000**
	Non-Contract Cost (+/- 41%)					$107,000,000
	CONSTRUCTION COSTS					**$367,000,000**

QUANTITIES		PRICES	
BY Trang Nguyen	CHECKED Jim Goodwin	BY Trang Nguyen	CHECKED Jim Goodwin
DATE PREPARED 3/1/2006	PEER REVIEW 3/1/2006	DATE 3/1/2006	PEER REVIEW 3/1/2006

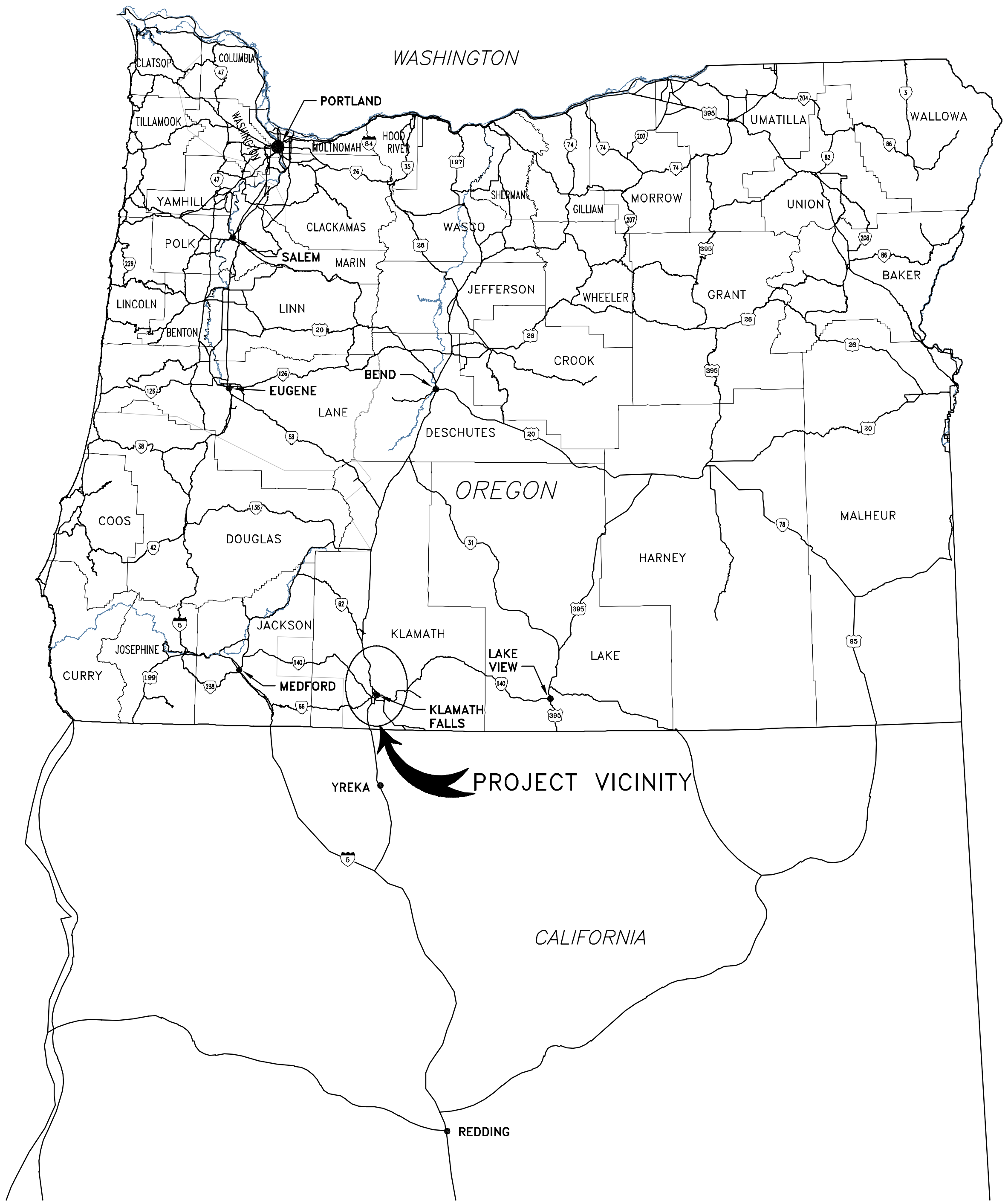
Bureau of Reclamation

ESTIMATE WORKSHEET

FEATURE	PROJECT
Long Lake Reservoir - with Pumping Capacity of 2,000 cfs	UPPER KLAMATH LAKE - Offstream Storage Study
	DIVISION: MP-210

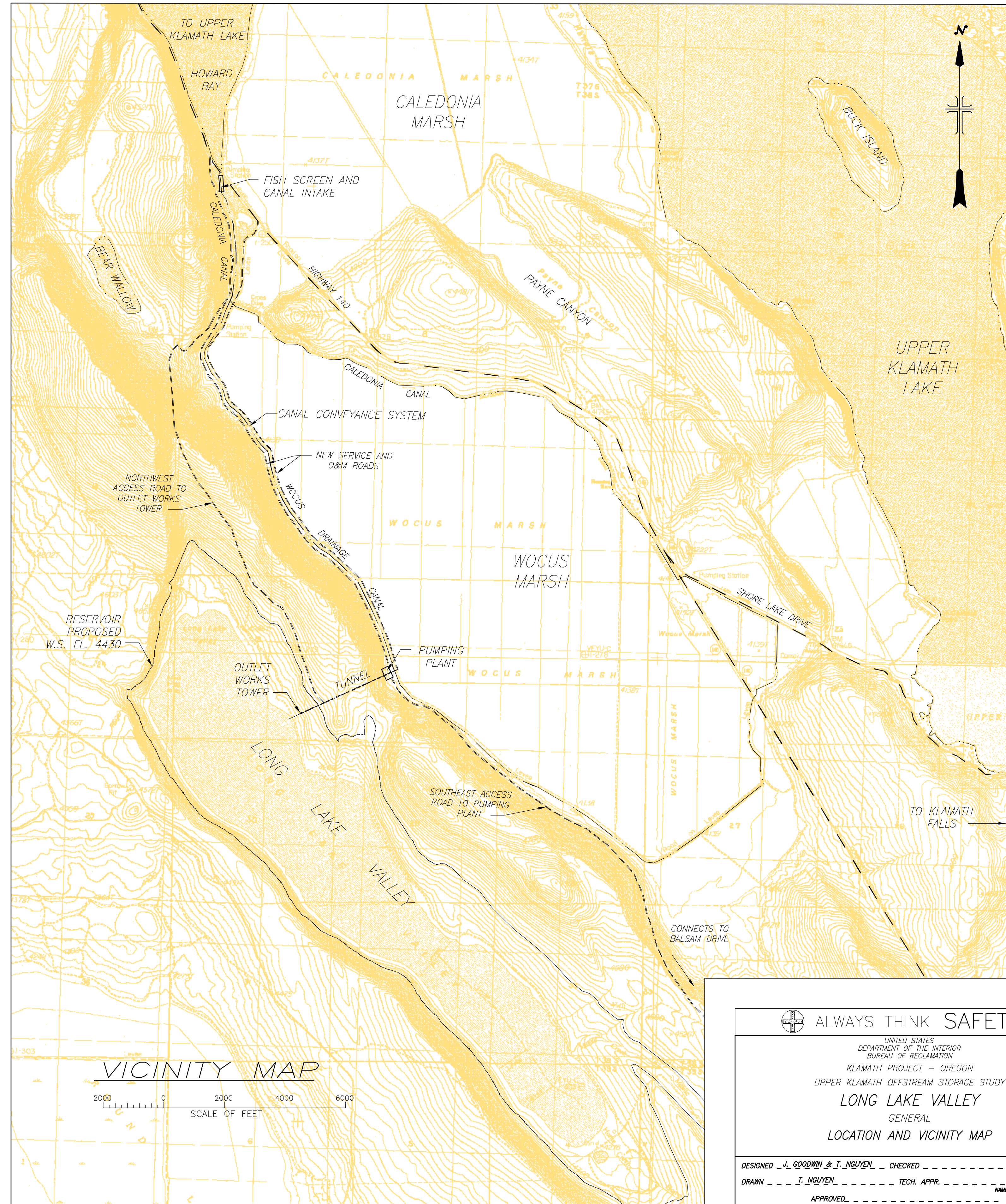
ITEM NUMBER	DESCRIPTION	MEANS ITEM NUMBER	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	SUMMARY SHEET					
1	Canal Conveyance System (3.6 miles)					$21,000,000
	Include canal, relocation of highway & pumping plants, roads					
2	New Fish Facility and Check Structures					$26,000,000
	Trashracks, fish screen & facilities, headworks, and check structure d/s of Howard Bay					
3	Intake Channel and Bypass Release Structures					$1,000,000
	Include 200-ft long riprap channel with two 60" jet flow release structures					
4	Pump Storage Plant					$115,000,000
	Pump-storage plant with 9 pumping units					
5	Concrete Lined Tunnel					$20,000,000
	23-ft diameter and 3000-ft long at invert El.4270					
6	Surge Shaft					$3,000,000
	230-ft deep and 23-ft diameter concrete surge shaft					
7	Outlet Works Tower and Bridge					$15,000,000
	Include OW trashrack structure, bulkhead and roller-mounted gates, & access bridge					
8	Access Roads					$3,000,000
	Include northwest access to OW tower & southeast access to pumping plant					
9	Reservoir Lining					$27,000,000
	Geomembrane lining approx 20% of Long Lake Valley					
10	Electricity to Project Features					$28,000,000
	Include transmission line, substations, switchyard, & electric instlln to project features					
	Subtotal					**$259,000,000**
	Mobilization (+/- 5%)					$13,000,000
	Subtotal w/ Mobilization					**$272,000,000**
	Unlisted Items (+/- 10%)					$27,000,000
	Contract Costs					**$299,000,000**
	Contingencies (+/- 25%)					$75,000,000
	FIELD COSTS					**$374,000,000**
	Non-Contract Cost (+/- 41%)					$153,000,000
	CONSTRUCTION COSTS					**$527,000,000**

QUANTITIES		PRICES	
BY: Trang Nguyen	CHECKED: Jim Goodwin	BY: Trang Nguyen	CHECKED: Jim Goodwin
DATE PREPARED: 3/1/2006	PEER REVIEW: 3/1/2006	DATE: 3/1/2006	PEER REVIEW: 3/1/2006



LOCATION MAP

N.T.S.



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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY

GENERAL
LOCATION AND VICINITY MAP

DESIGNED J. GOODWIN & T. NGUYEN CHECKED
DRAWN T. NGUYEN TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

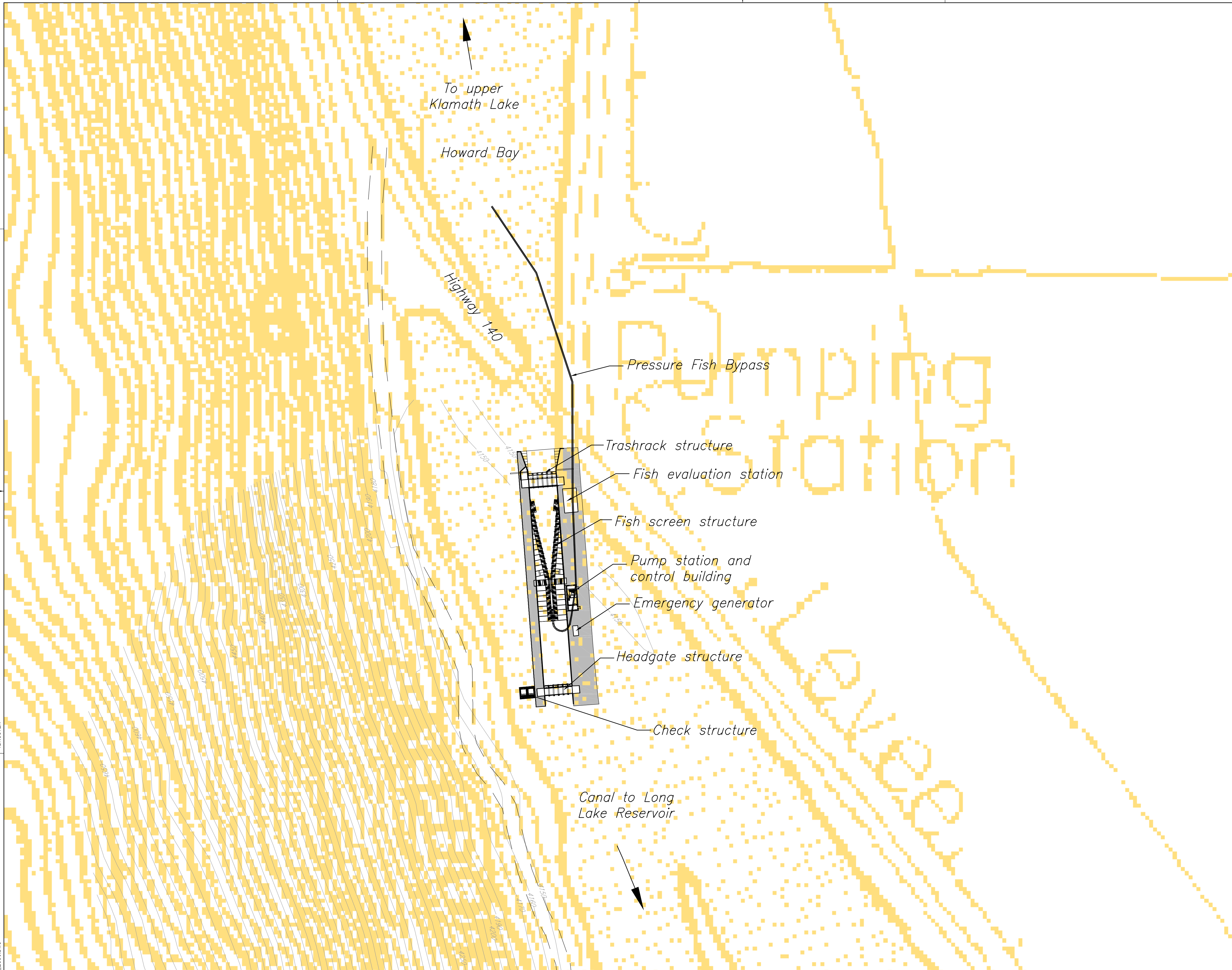
SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

DATE AND TIME PLOTTED APRIL 10, 2006 11:52
PLOTTED BY TDNGUYEN

CAD SYSTEM AutoCAD Rel. 16.1s
CAD FILENAME VIC LOC MAP.DWG

FIGURE 2

ATTACHMENT 2



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BUREAU OF RECLAMATION
KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY

CALEDONIA AND WOCUS DRAINAGE CANAL
FISH SCREEN AND HEADWORK
STRUCTURES FOR 1,000 CFS
PLAN VIEW

DESIGNED T. NGUYEN & J. GOODWIN CHECKED
DRAWN T. NGUYEN TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

FIGURE 2

FIGURE 3

ATTACHMENT 2

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KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY

CALEDONIA AND WOCUS DRAINAGE CANAL

FISH SCREENS AND HEADWORK STRUCTURES FOR 2,000 CFS PLAN VIEW

DESIGNED T. NGUYEN & J. GOODWIN CHECKED

DRAWN T. NGUYEN TECH. APPR. NAME – TITLE

APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

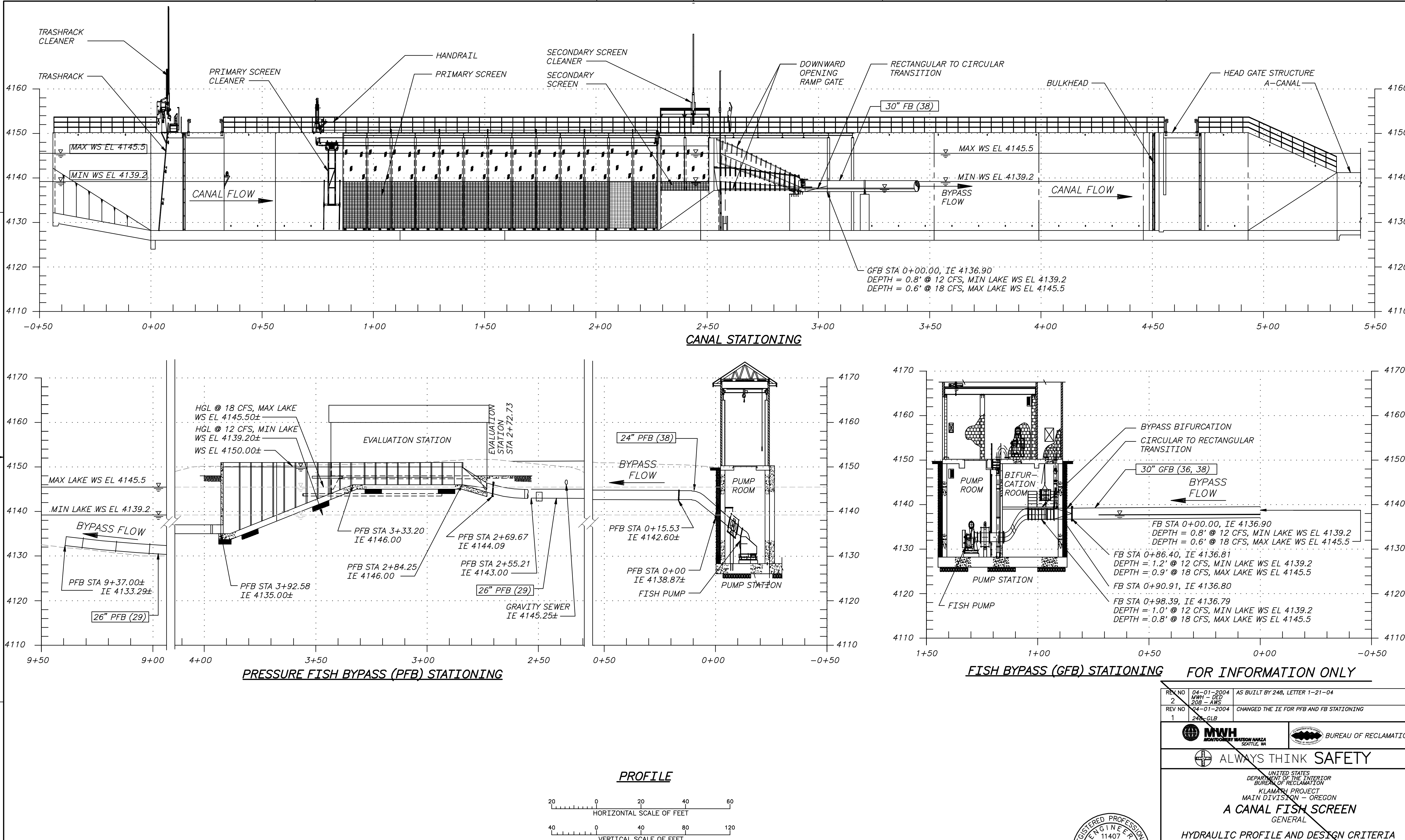
DATE AND TIME PLOTTED APRIL 4, 2006 07:59
PLOTTED BY TDNGUYEN

CAD SYSTEM AutoCAD Rel. 16.1s
CAD FILENAME LLV_2006.DWG

FIGURE 3

FIGURE 4

ATTACHMENT 2



FOR INFORMATION ONLY

REV NO	DATE	DESCRIPTION
2	04-01-2004 MWH - DED 208 - AWS	AS BUILT BY 248, LETTER 1-21-04
1	04-01-2004 248-GLB	CHANGED THE IE FOR PFB AND FB STATIONING

MWH MONTGOMERY WATSON HARZA SEATTLE, WA — BUREAU OF RECLAMATION

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KLAMATH PROJECT
MAIN DIVISION – OREGON

A CANAL FISH SCREEN
GENERAL

HYDRAULIC PROFILE AND DESIGN CRITERIA

REGISTERED PROFESSIONAL ENGINEER 11407 OREGON DENNIS E. DORRATCAGUE

MWH
DESIGNED C. GARRIC
DRAWN B. TAYLOR
CHECKED D. DORRATCAGUE
SUBMITTED TECHNICAL APPROVAL
CADD SYSTEM AutoCAD Rel. 16.1s
SACRAMENTO, CALIFORNIA JANUARY 9, 2002
DRAWINGS DESIGNED AND DRAWN BY MWH, SEATTLE, WA

BUREAU OF RECLAMATION
REVIEWED PROJECT MANAGER
RECEIVED CHIEF, ENGINEERING BRANCH
CADD FILENAME ACANAL PROFILE.DWG

12-208-853

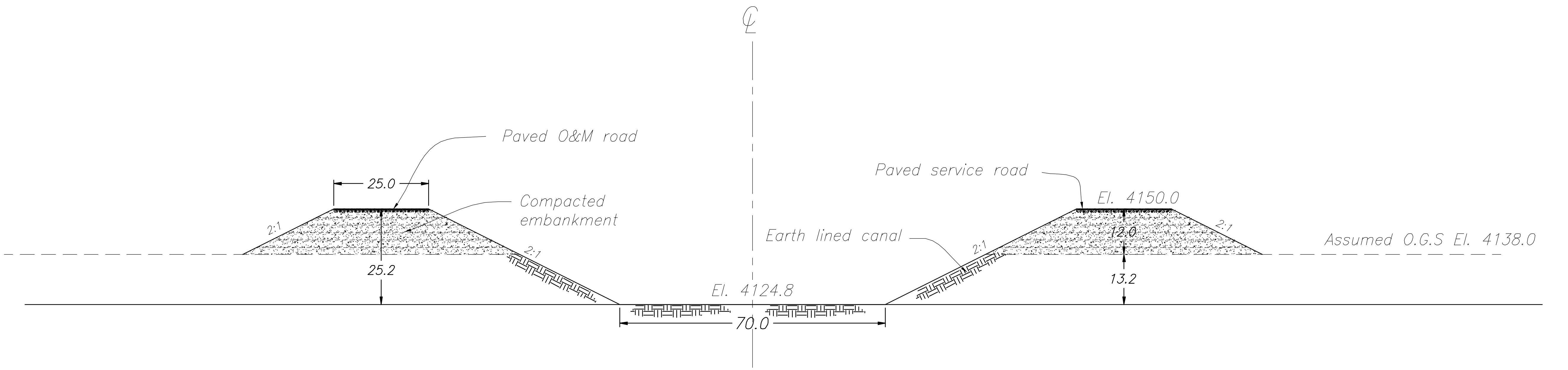
FIGURE 4

Specification No. 20-C0569

DATE AND TIME PLOTTED MARCH 15, 2006 16:20 PLOTTED BY TONGUYEN

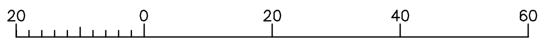
FIGURE 5

ATTACHMENT 2



TYPICAL CANAL CROSS SECTION

SECTION B–B (SEE FIGURE 6)



NOTE:

For both flows, canal height is approximately 25.2 ft, with an excavation depth of 13.2 ft and embankment fill height of 12.0 ft.

Canal side slopes will be reinforced with 1.5 ft thick of riprap and bedding, up to El. 4146.0

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BUREAU OF RECLAMATION
KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY

CALEDONIA AND WOCUS DRAINAGE CANAL

TYPICAL CANAL CROSS SECTION
SECTION B–B

DESIGNED T. NGUYEN & J. GOODWIN CHECKED
DRAWN T. NGUYEN TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

DATE AND TIME PLOTTED APRIL 10, 2006 11:51
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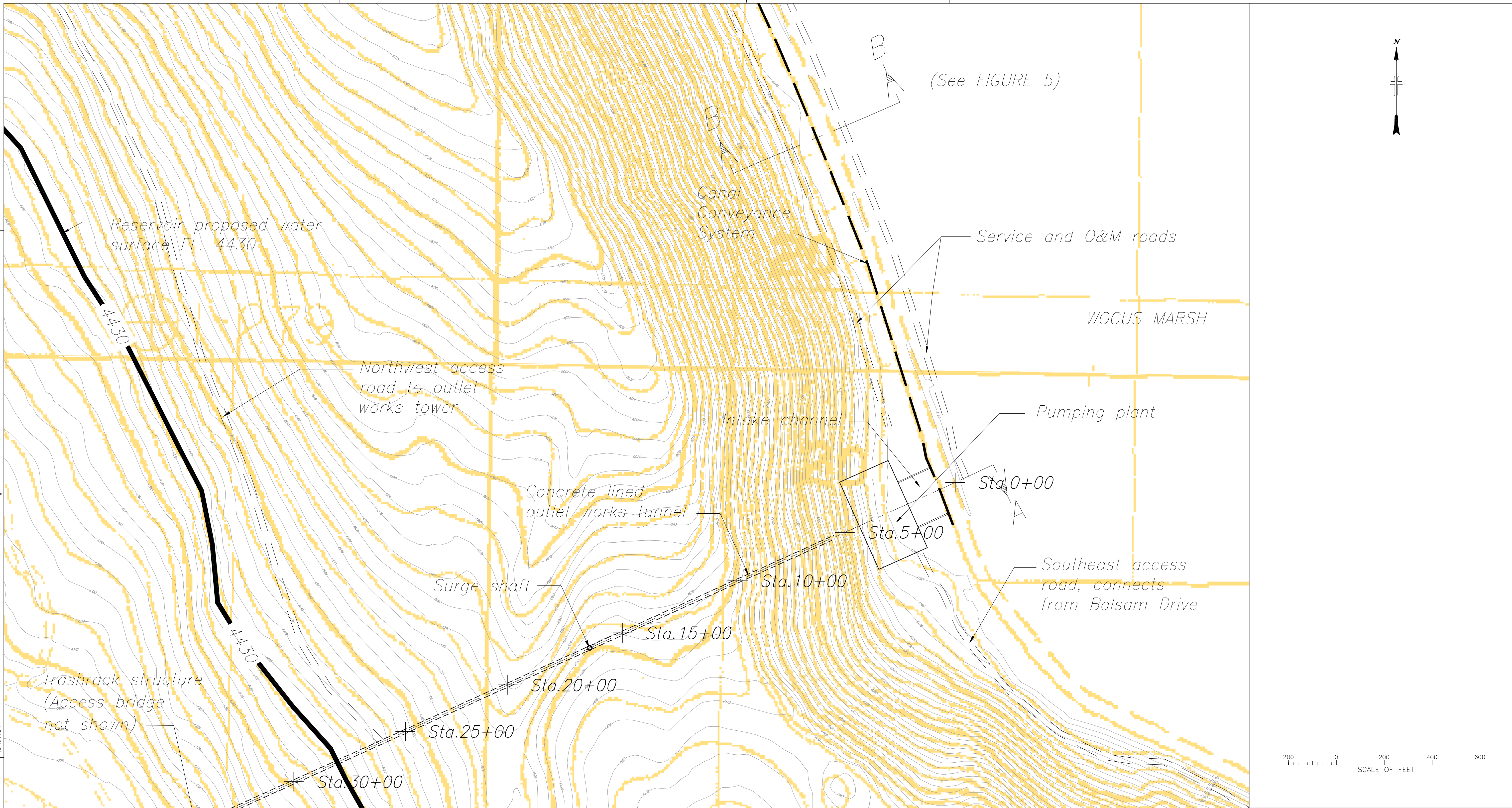
CAD SYSTEM AutoCAD Rel. 16.1s
CAD FILENAME LLV_2006.DWG

FIGURE 6

ATTACHMENT 2



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BUREAU OF RECLAMATION
KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY

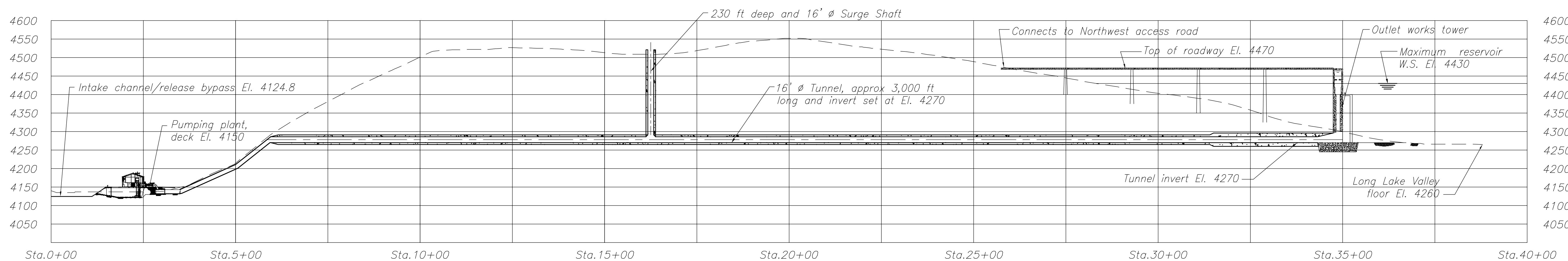
PUMPING PLANT FEATURES

ACCESS ROADS, INTAKE CHANNEL, PUMPING PLANT, AND OUTLET WORKS FEATURES
PLAN VIEW

DESIGNED T. NGUYEN & J. GOODWIN CHECKED
DRAWN T. NGUYEN TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

FIGURE 6



OUTLET WORKS TUNNEL

SECTION A–A (SEE FIGURE 6)

150 0 150 300 450
SCALE OF FEET

DATE AND TIME PLOTTED APRIL 10, 2006 11:50 PLOTTED BY TDNGUYEN

CAD SYSTEM AutoCAD Rel. 16.1s CAD FILENAME LLV_2006.DWG

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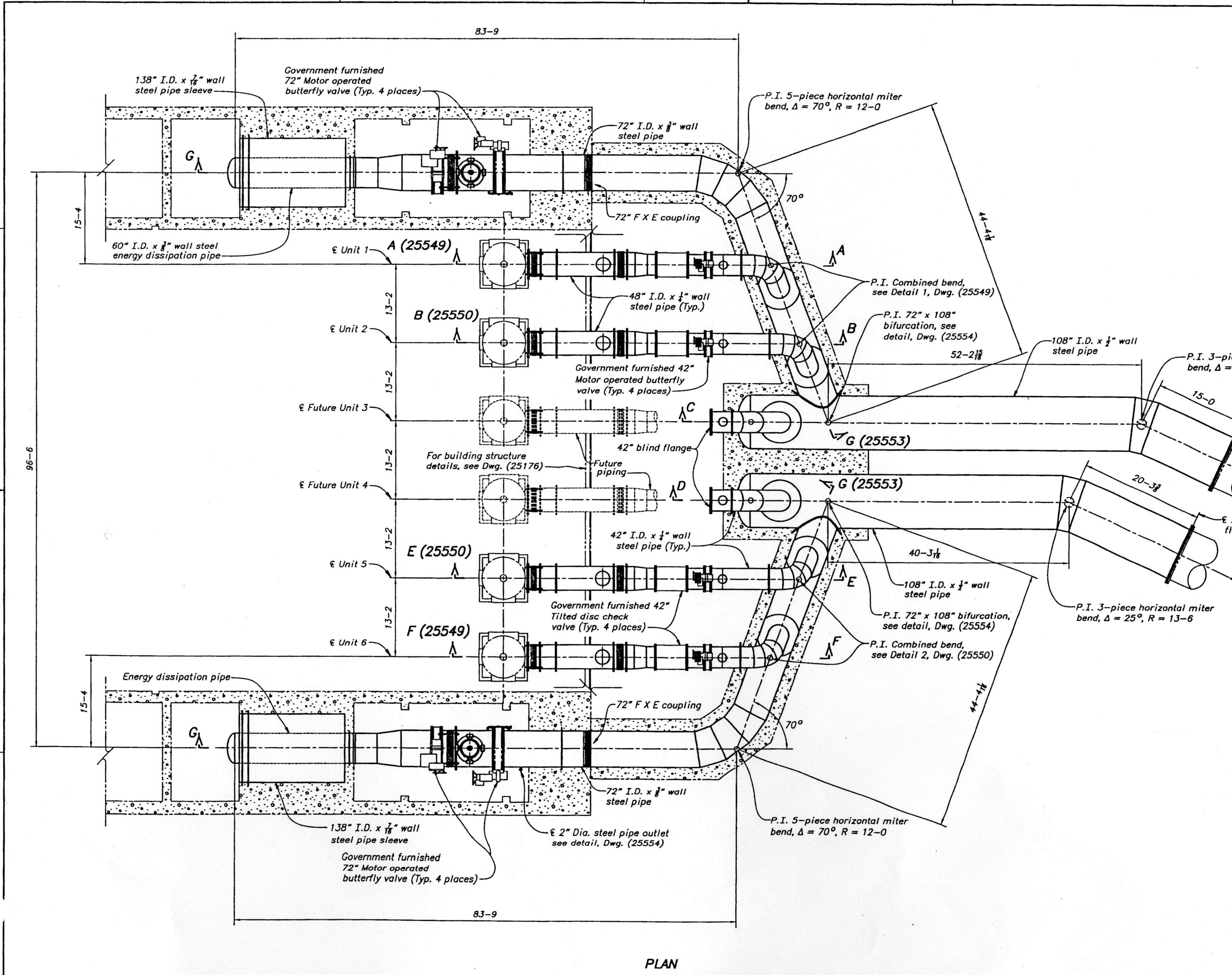
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY
PUMPING PLANT FEATURES
OUTLET WORKS TUNNEL, SURGE SHAFT, AND TRASHRACK TOWER
SECTION A–A

DESIGNED T. NGUYEN & J. GOODWIN CHECKED
DRAWN T. NGUYEN TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1



PLAN

REFERENCE DRAWING

GENERAL ARRANGEMENT ________________ 214-D-25169

FOR INFORMATION ONLY

NOTES

Provide bolts, nuts and gaskets for cold-water service.

All flanges shall be AWWA Class B or D as shown.

Additional fittings, flanges, or welded joints added by the contractor to facilitate installation of the manifold piping are subject to Government approval.

Miter bends may not be used in lieu of welding elbows.

Hydrostatic test pressure shall be 50 psig for the steel piping.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
DELTA DIVISION

DMC-CA INTERTIE PUMPING PLANT

STEEL MANIFOLDS
PLAN

DESIGNED R.V. Fain CHECKED K.R. Smith P.E.
DRAWN N. Nakamoto TECH. APPR. R.V. Fain P.E.
APPROVED [signature] P.E.
MANAGER, HYDRAULIC EQUIPMENT GROUP

CADD SYSTEM AutoCAD Rel. 16.0s | CADD FILENAME 214D25548.DWG | DATE AND TIME PLOTTED AUGUST 23, 2005 08:33
DENVER, COLORADO AUGUST 24, 2005 SHEET 1 OF 10 | 214-D-25548

SPECIFICATION NO. 20-C0648
1

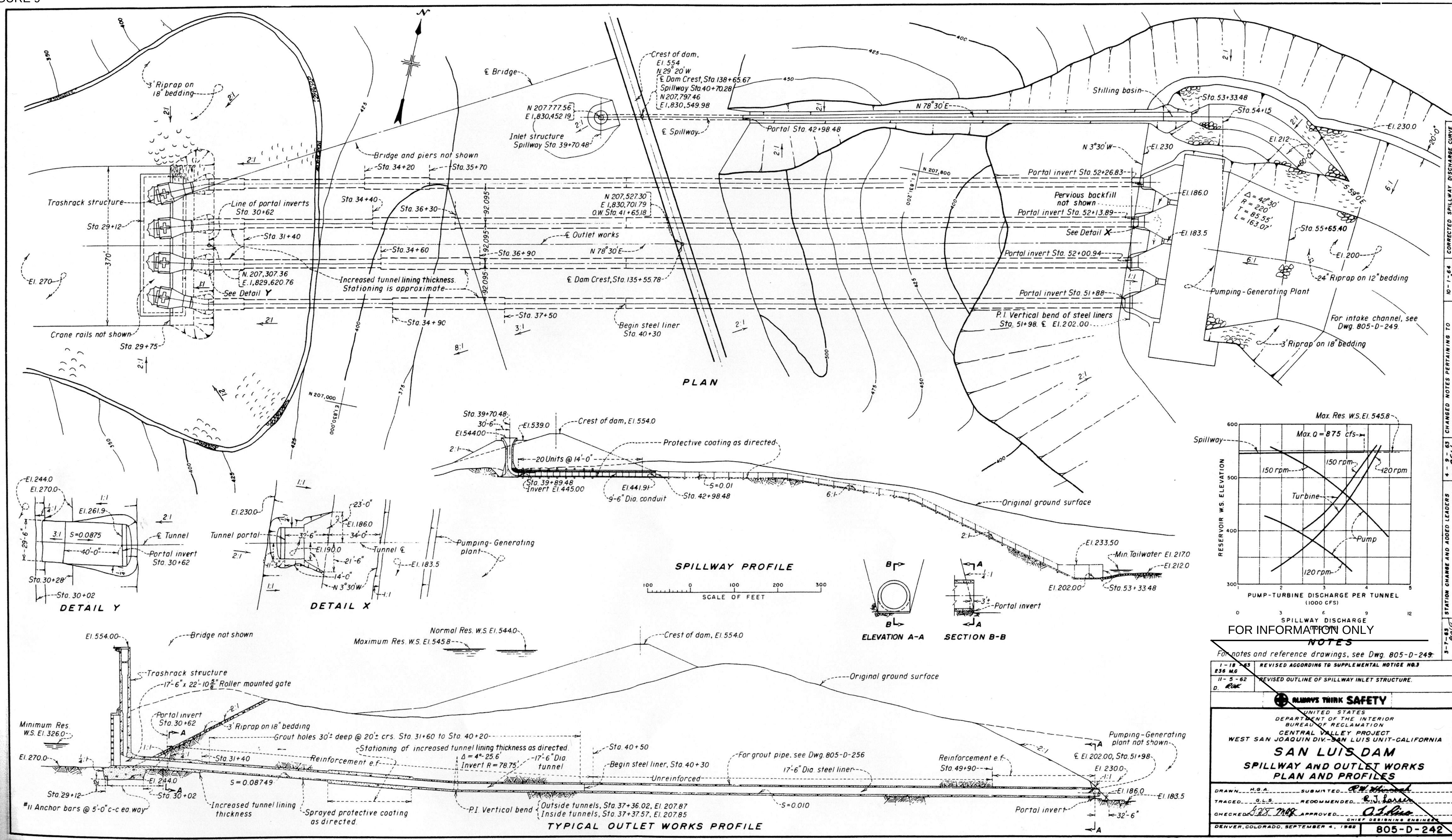
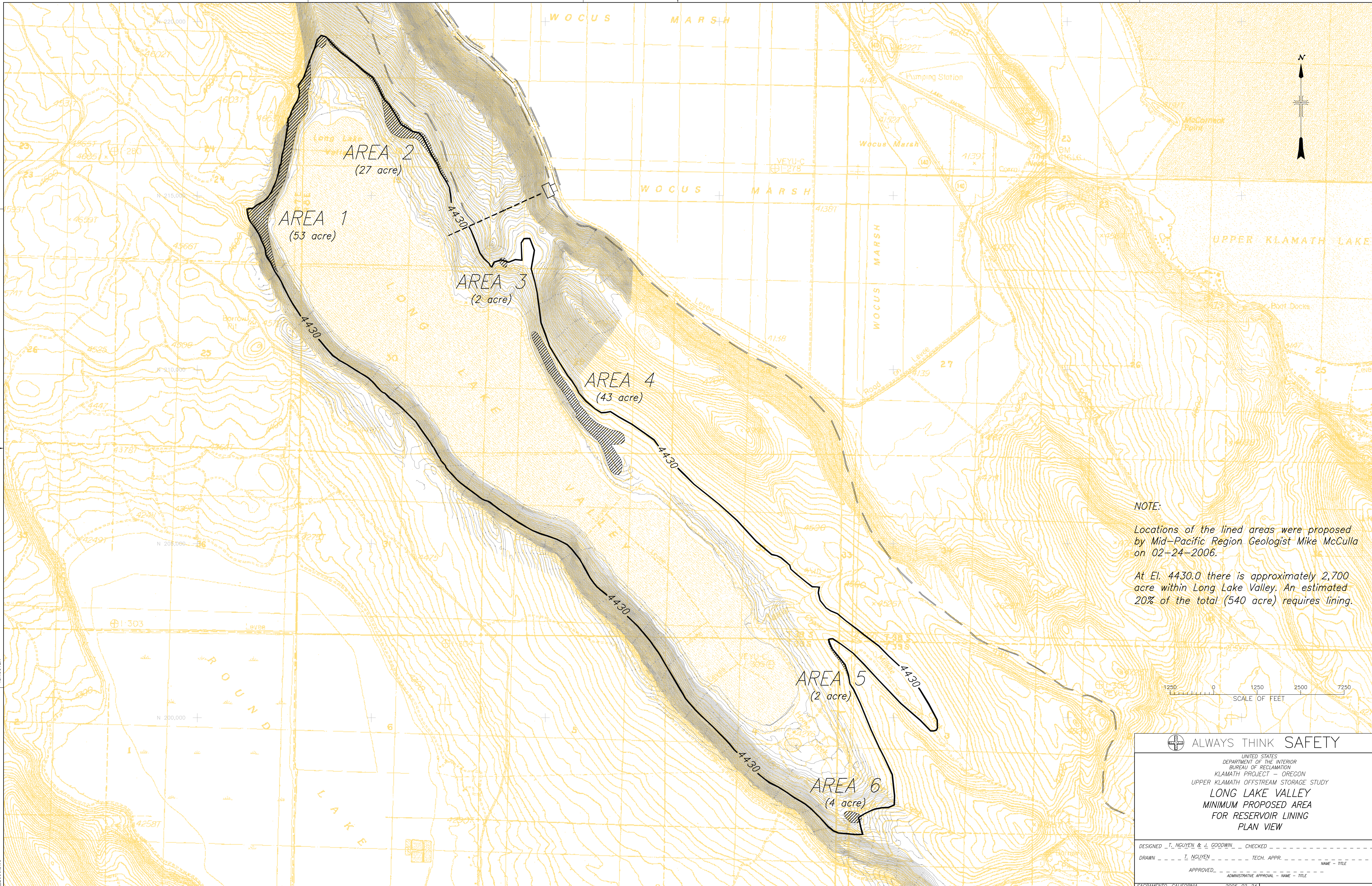


Figure 36.—San Luis Dam—Spillway and outlet works—Plan and profiles.

FIGURE 9

FIGURE 10

ATTACHMENT 2



NOTE:

Locations of the lined areas were proposed by Mid-Pacific Region Geologist Mike McCulla on 02-24-2006.

At El. 4430.0 there is approximately 2,700 acre within Long Lake Valley. An estimated 20% of the total (540 acre) requires lining.

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BUREAU OF RECLAMATION
KLAMATH PROJECT – OREGON
UPPER KLAMATH OFFSTREAM STORAGE STUDY

LONG LAKE VALLEY
MINIMUM PROPOSED AREA
FOR RESERVOIR LINING
PLAN VIEW

DESIGNED T. NGUYEN & J. GOODWIN CHECKED

DRAWN T. NGUYEN TECH. APPR. NAME – TITLE

APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

SACRAMENTO, CALIFORNIA 2006-02-24
SHEET 1 OF 1

DATE AND TIME PLOTTED APRIL 4, 2006 08:02 PLOTTED BY TDNGUYEN

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FIGURE 10

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

ATTACHMENT 3

~~210 PM~~ ~~24-7~~ 210 File

IN REPLY
REFER TO:

MP-210
PRJ-1.00

SEP 29 2003

To: Area Manager, Klamath Basin Area Office
Attn: KBAO-100

From: David W. Gore (sgd) David W. Gore
Regional Engineer

Subject: Updated Construction Costs – Appraisal Report, February 1987 – Upper Klamath Offstream Storage Project – Klamath Project – Oregon

As requested via email on August 1, 2003, we reviewed the subject February 1987 report, and a revision of the Table 15 Construction Costs shown on page 35 of that report is attached. This revised table presents construction costs updated from the January 1984 price level to a July 2003 price level. The estimates we have presented should be considered as order of magnitude cost figures. The original 1987 appraisal level cost figures have been cost indexed approximately 20 years to July 2003 cost levels. This approach is subject to a lot of uncertainties. Also, we were not able to find the original engineering and geology study files, so educated estimates of quantities and costs were made based on available information. Please note that in 1987 the pump-generating plant costs were only developed for the Aspen Lake scenario, but were thought to be applicable to the Long-Round Lake scenario. Due to recent developments for complying with fishery issues on the Upper Klamath Lake, a fish screen structure was assumed to be required on any new pumping plant intake. The cost of the new fish screen with a design flow rate of 2,000 cfs was estimated at $22M. This estimate is based on the 1,100 cfs fish screen facility recently constructed at A-Canal headworks at an approximate cost of $12M.

Two estimate worksheets are attached which show the breakdown of costs for the "Long Lake Only" and the "Long-Round Lake" scenarios. A "Long Lake Only" scenario was not considered in the 1987 study. However, due to the recent interest, we also estimated the cost of this concept. The Field Costs are $490M and $900M, respectively. Adding Non-Contract costs associated with real estate actions (temporary and permanent), utilities relocations, environmental compliance (EIS/EIR investigations, reports, permits and mitigation), and staff costs for design, procurement and contract administration results in Total Construction Costs of approximately $690M and $1,270M, respectively.

As part of your request to us, we also reviewed the 1987 report geologic considerations used in developing the construction costs. The potential for significant reservoir seepage to occur was a major consideration in the development and assessment of these offstream storage sites. The

MP-210

original 1987 cost estimates assumed that 90 percent of the reservoir area up to the maximum water surface would require lining. The 1987 estimates identified the costs for accomplishing the reservoir lining with three alternative soil materials: a 3-foot-thick compacted clay liner, a 1-foot-thick soil-cement layer, and a 1-foot-thick compacted clay layer with bentonite added to reduce permeability. These soil systems would be applied in flatter terrain. Steep slopes would probably not be lined, and outcrops would be spot treated with shotcrete or bentonite slurry. Because of advances in technology in the past two decades, we investigated using a geomembrane liner system as an alternative to the soil liner systems. A likely impermeable system would consist of a 45 mil PVC liner covered by 1.5 feet of common soil to protect the liner from weathering. The cost of a geomembrane liner system appears to be similar to the lowest priced option of the 3 foot compacted clay liner and would cost approximately $1 per square foot (about $30M per square mile, or about $96M for Long Lake alone). However, a geomembrane liner system would not be used on steep slopes either.

Our review of the previous geologic assessments of reservoir water holding capability conducted by USBR and others in the 1980s also identified other points worthy of consideration in the present assessment of offstream storage potential. Statements made in previous reports regarding project area geologic and hydrologic conditions (see February 1987 report page 20, Items 1 and 2), and a cursory review of archival data by Reclamation's Mid Pacific Region Geology Branch indicate that, at present, the geology and hydrogeology of the project area are not fully characterized or understood and are subject to differing interpretations. Serious concerns as to the water holding capability and potential for excessive leakage of the proposed reservoirs have been raised. However, in contrast to these concerns, two existing Reclamation reservoirs, Clear Lake and Gerber, located in similar geologic and hydrologic environments within 50 miles of the project area have performed satisfactorily for over 80 years. Although not always the case, in regard to this project, differing geologic interpretations can lead to variations in construction cost estimates of hundreds of millions of dollars. For this reason, further geologic and hydrogeologic studies may be warranted before making a final assessment of the viability of this project and prior to developing a realistic cost estimate. To quantify the effect of reservoir lining costs on the viability of the project, an estimate worksheet is attached which shows the cost of the "Long Lake Only" scenario assuming no reservoir lining. The approximate Field Cost and Total Construction Costs are $360M and $510M respectively. Compare these costs to the "with lining" estimates: $490M and $690M. Using the Total Construction Costs for the two scenarios (unlined and lined), and an assumed storage of 350,000 acre-feet, the unit cost of water ranges from approximately $1,460 to $1,970 per acre-foot.

As explained in the 1987 report, faulting within the area is quite extensive. The reservoir sites are structural depressions which have been faulted downward along youthful zones. The area is seismically active. Two earthquakes of Richter magnitude 5.9 and 6.0 occurred on September 20, 1993. Most recently, a Richter magnitude 4.3 earthquake occurred near Long Lake on May 15, 2002. The earthquakes are thought to have occurred along the West Klamath Lake Fault zone. The attached plot shows the location of the 1993 and 2002 earthquakes as well as the numerous aftershocks which have occurred since 1993. It is estimated that future earthquakes along the West Klamath Lake Fault Zone could be as high as M_w 7.25. The proposed tunnels and penstocks must cross probable active faults which will require special design provisions, and would likely result in interruptions to service during larger magnitude events. Other concrete and earth structures (dams, canals, pump/generating plants) would need to be designed for close proximity earthquakes of moderately high magnitude. These conditions would increase construction costs as well as increase the possibility of interruptions.

If you have any questions or require further assistance, please contact Jim Goodwin at 916-978-5316.

Attachments - 5

cc: MP-210, -230 (w/att to each)

WBR:JGoodwin:dburney:09/29/2003: 916-978-5316
(I:\Jim Goodwin\KlamathProject\UpperKlamathOffstreamProject.doc

ATTACHMENT 4

From: Jim Goodwin
To: Dave Sabo
Date: 10/17/03 6:55PM
Subject: Re: Long Lake study

Dave,

I appreciate your concerns about the accuracy of the cost figures I presented in the letter and I offer the following clarifications:

Your email is referring to the estimate worksheet for the Long Lake Only, Max WS 4500, No reservoir lining.

1. The first 5 items that comprise the Contract Cost are the 1987 costs indexed up to current date. The multiplier is about 1.6. As I mentioned in the letter we were unable to locate the original studies and indexing over a 20 year period is subject to uncertainties. We consider the costs as "order of magnitude."

2. The 25% allowance for contingency seems to be a common practice even in private sector. However, the USBR definition may be different than private sector. We use contingency to allow for unforseen costs due to overruns or changed conditions that can happen during construction. It is statistical in nature. Some jobs come in on budget while others overrun much more. The 25% is an average in our experience. I am concerned that private sector employs this amount as an allowance for something such as unlisted items.

3. I list 3 separate costs under the category of Non-Contract Costs: real estate 1% ($4M), environmental 10% ($36M), design/procure/construct staff 30% ($108M) for a total multiplier of 41% of the Field Cost (total $148M).

The 1% allowance for real estate is a guess on my part based on past projects. Your office might have a better feel of local conditions for what this category might cost. The area of Long Lake affected is about 2000 acres. Add to this the area affected by the dams, canals and pump/generating plant. If assume a total of 2100 acres at $1000 per acre = $2.1M.

The 10% allowance for environmental compliance is based on recent experience with the Battle Creek Restoration Project - approx $65M project cost. The cost for EIS/EIR investigations and prepartion, environmental permitting, and mitigation for disturbed habitat was actually around 15%. BCR is a complex project covering 8 distinct sites, inpacts a number of wetlands and oaklands, and there was a setback with having to get a second environmental contractor on board. So we thought it reasonable to reduce the percentage to 10%. The "rim" of the Long Lake area we understand is heavily forested. There would seem to be the potential for a significant impact to species of concern such as spotted owl, and perhaps other species. The delivery canal is quite long and is adjacent to a marshy area. I would guess (sight unseen) that there would be wetlands affected. Same with the pump/generating and dam sites. I would suggest that your environmental officer conduct a preliminary assessment of the potentially affected areas. Perhaps there are fewer concerns than I envision. Mary Marshall is our environmental specialist and is available for consultation.

The $108M allowance for staff costs for the design and construction contracting must seem high. We concede that there may be justification for lowering the total estimated dollars. I researched a few sources to get some perspective. I am currently reviewing a water supply reliability report (subappraisl level study) prepared by MWH (Montgomery Watson Harza) for 4 municipal water companies in Sacramento area. The project is in the $500M range. MWH is using a 25% allowance for "Engineering, Environmental, Administration, and Legal Services" but no further breakdown except to mention that the percent does not include real estate items. This MWH 25% would therefore compare to USBR 40%. On recent subappraisal level estimates the California DWR used a 35% allowance as follows: engineering

ATTACHMENT 4

15%, environmental 5%, construction inspection 10%, and contract administration 5%. I contacted Lauren Carly of our construction office in Willows and she advised to use a 10% allowance for construction administration after award of a contract for this appraisal level of estimate. If we can estimate that design staff cost would be 10% it might be reasonable to estimate a total non-contract percentage of about 30% (10 design, 10% construct, 5%environmental, and 5% other). However, planning costs are not included in these figures. Reviewing appraisal and feasibility studies conducted in the 1970's indicate non-contract allowances range from 27% to 33%. Using a 30% total allowance for non-contract costs reduces the $148M (41%) to $108M (30%). A minimum of 25% would be $90M (148-90) - a reduction of $58M. The Total Constriction cost could therefore be reduced, at the most, from $508M to $450M.

4. In my letter I offered a simplified calculation of cost per acre foot based on a 350,000 acre-foot storage. The 350,000 af figure comes from the Klamath Commissioner report. But the project cost I presented is for a higher dam and storage scenario. The estimated storages for the various lakes and maximum water surface elevations are presented in the 1987 report Table 14. The project costs I presented should be applied to a 570,000 af volume not the 350,000 af. I apologize for this oversight. Revising this calculation using the total project costs I proposed in the letter of $510M to $690M, and 570,000 af of storage then the unit cost of water ranges from $895 to $1,211 per acre foot. Reducing the non-contract cost by $58M (reduce to a 25% allowance) reduces the unit costs by about $100 per acre foot ($58M/570,000 = $102/af) or $793 to $1,109 per acre foot.

The 1987 report did not present a cost for a pump station for the lower maximum water surface of El. 4440. So we did not prepare an estimate for this lower storage scenario (USBR 382,000 af vs Klamath Commiss 350,000 af). I prepared (attached) a rough estimate of construction cost for the lower storage scenario 382,000 acre feet. I reduced the Dams and apurtenances to zero, and reduced the pump/generating plant cost by 10% to account for the lower head (300 foot vs 360 foot lift). Other construction costs and non-contract percentages are assumed the same as in the letter. The Total Construction Cost is $432M. The unit price of water would then be $1,131 per acre foot ($432M/382,000). If the non-contract allowance is reduced from 41% to 25% then the Total Construction Cost is $382M and the unit price is $1,000 per acre foot.

I reiterate that the costs presented are "order of magnitude" and should be applied with considerable judgement. The best use of the cost figures is for comparing between alternatives and for understanding the order of magnitude cost of the project. These costs should not be used to support a funding request for a project.

Please contact me if I can provide any further clarification.
Thanks, Jim Goodwin 916-978-5316

>>> Dave Sabo 10/14/03 07:30AM >>>
Hi Jim et al-
I was wondering about some of the numbers in your revised cost estimate. For example environmental compliance at 10%, $36 million and staff costs at 30 %, 106 million seem a bit high. Also the storage amounts I have heard touted for the project were more on the order of 380,000 acre-feet. Would that make a difference?
We have to be extremely careful about our estimates, Reclamation has taken some hugh hits to its credibility lately. Could you let me know about these numbers at your earliest?
Thanks
>>> Jim Goodwin 09/30/03 12:58PM >>>
Dave,

I am attaching 6 pdf files. These can be opened in Adobe Acrobat reader which hopefully should be accessible by your audience. Dave Gore did not want the Word and Excel files released. I know Bob

ATTACHMENT 4

Davis can open these as he sent me the Klamath Commissioner letter in pdf.

1. the MP-200 letter
2. revised Table 15 Evaluation of Alts
3. Long-Round estimate
4. Long Only - with liner estimate
5. Long Only - no liner
6. earthquake plot

Please advise if you have needs or questions.

Jim Goodwin 916-978-5316

Dave Sabo
Area Manager
Klamath Basin Irrigation Project

>>> Dave Sabo 09/30/03 12:46PM >>>
Hey Jim
Thanks for the quick work on the long lake review.
Could you e-mail me a version of your letter? I need to distribute it and would rather not fax it around.
Thanks

Dave Sabo
Area Manager
Klamath Basin Irrigation Project

CC: Bud Cook; David Gore; Mary Marshall; Ponce Marquez

ATTACHMENT 5: An excerpt from the "Appraisal Assessment of Black Rock Alternative Facilities and Field Cost Estimates".

foot-diameter corrugated metal pipes between the cofferdams would permit canal operation during construction.

XII. Field Cost Estimates

Field cost estimates were prepared for the major features identified for each option. Field cost estimates include construction contract costs and contingencies. Construction contract costs include itemized pay items and mobilization, plus an allowance for unlisted items. Field cost estimates do not include non-contract distributive-type costs (environmental studies, site investigations, design, construction management, ...) and non-contract corollary-type costs. Field cost estimates do not include land acquisition, relocation, or right-of-way costs that may be required for construction of the project features. Operation, maintenance, and replacement costs are also not included in field cost estimates.

Cost estimates were prepared using available existing design data from past work accomplished by WIS and Reclamation. Aerial topography developed by Reclamation and limited geologic explorations conducted near the proposed damsites were also used to better define features. The amount of data collection is not considered to be at the level required for feasibility-level assessment of project features. Design data collected for future studies can cause future cost estimates to significantly deviate from the cost estimates presented in this report.

Field costs prepared for this study were generated using industry-wide accepted cost estimating methodology, standards, and practices. Major features were broken down into pay items and approximate quantities were calculated for these items based on preliminary general designs and drawings. Unit prices, adjusted for location and current construction cost trends, were determined for the identified pay items.

The appraisal-level field cost estimates developed for this assessment study are for the purpose of evaluating which options should be investigated in greater detail as the Storage Study progresses. **The cost estimates in this report are not intended to be at the feasibility-level required to request project authorization for construction and construction appropriations by Congress.** All field costs are in **June 2004** price level dollars and include mobilization, unlisted items, and contingencies as explained below:

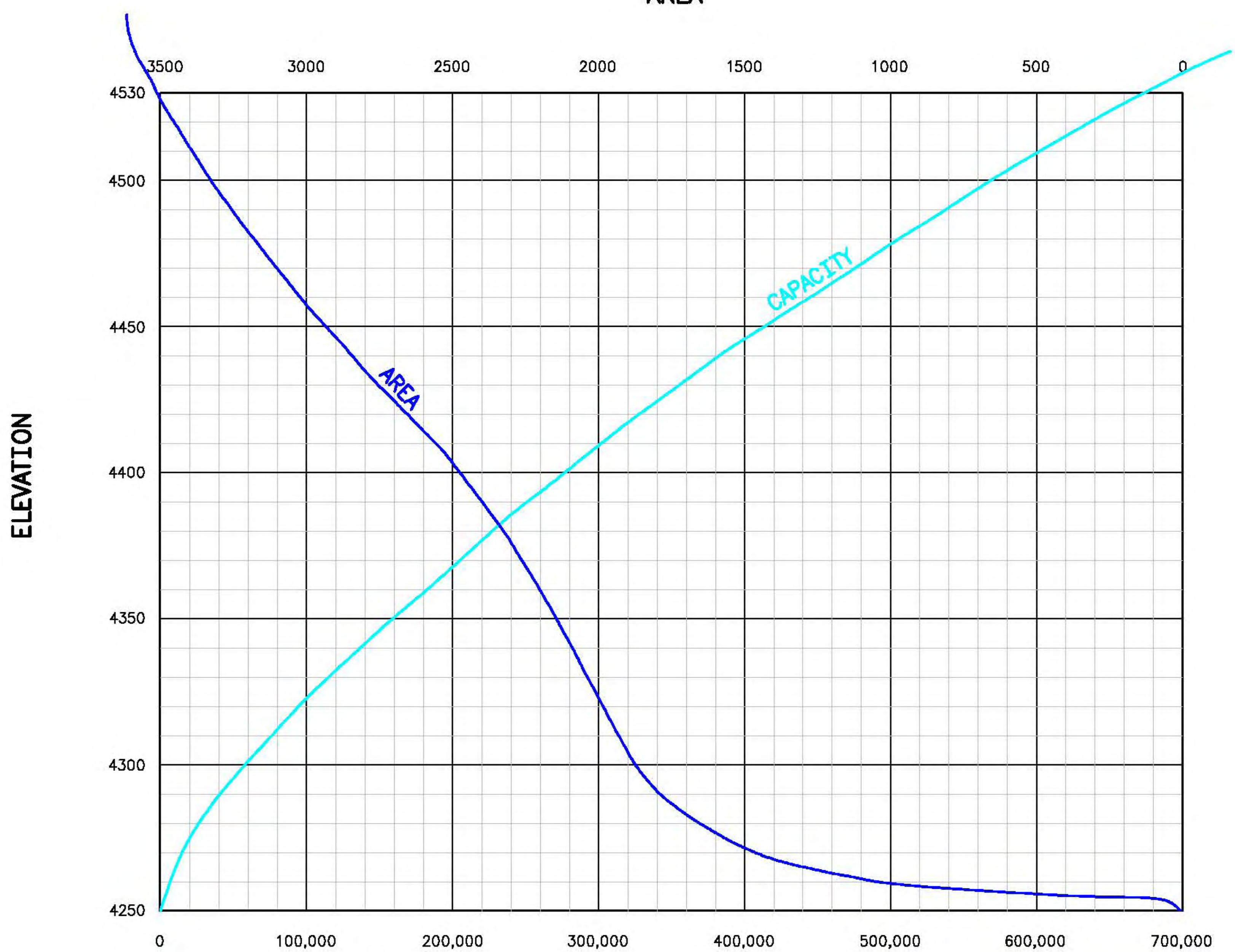
• Mobilization - Mobilization costs include mobilizing contractor personnel and equipment to the project site during initial project start-up. The assumed 5 (+/-) percent of the subtotal cost used in the cost estimates contained in this report is based on past experience of similar projects. The mobilization line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

• <u>Unlisted Items</u> - Unlisted items are a means to recognize the confidence level in the estimate and the level of detail and knowledge that was used to develop the estimated cost. This line item may be considered as a contingency for minor design changes and also as an allowance to cover minor pay items that have not been itemized, but will have some influence on the total cost. As per Reclamation Cost Estimating Handbook guidelines, the allowance for unlisted items in appraisal estimates should be at least 10 (+/-) percent of the listed items. Typically a value of 15 (+/-) percent is used. Based on the level of detail provided for this study's cost estimates, the unlisted items line item was set at 10 (+/-) percent of the subtotal cost plus mobilization for all features. The unlisted items line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

• <u>Contingencies</u> - Contingencies are considered funds to be used after construction starts and not for design changes during project planning. The purpose of contingencies is to identify funds to pay contractors for overruns on quantities, changed site conditions, change orders, etc. As per Reclamation Cost Estimating Handbook guidelines, appraisal-level estimates should have 25 (+/-) percent added for contingencies. Based on the current level of design data, geologic information, and general knowledge of the conditions at the various sites, the contingency line item was set at 25 (+/-) percent of the contract cost for all features. The contingency line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

Table 19 is a summary table of the appraisal-level field cost estimates that were prepared for this Assessment. Estimate worksheets showing a detailed breakdown of these field cost estimates are shown in Appendix D. Table 20 shows a comparison of itemized costs (pay items only) for the major features between the Columbia River and MP22.6 of the Roza Canal. Costs shown in Table 20 do not include mobilization, unlisted items, and contingencies. From Table 20, preferred options based on cost can be assembled for the Large Reservoir – Pump Only Option (Option 1), Large Reservoir – Pump-Generating Option (Option 2), and Small Reservoir – Pump Only Option (Option 3). Table 21 compares the combined field cost estimates for each preferred Storage-Pump Option. Tables 20 and 21 do not include costs for the Sunnyside Powerplant and Bypass Structure located at the end of the Sunnyside Delivery System.

LONG LAKE A/C CURVE



By:
Date: August 27, 1969

Project: Upper Klamath Basin
Feature: Long Lake
Detail: A/C Curves

ATTACHMENT 6

LONG LAKE

RESERVOIR AREA–CAPACITY CALCULATIONS

Elevation	Increment of depth	Total Depth	Area (mi^2)	Area (acres)	Total	Total / 2	Total / 2 + inc. of D	Accum. Total (acre–feet)
4520		270	5.41	3460				632,900
	40				6590	3295	131,800	
4480		230	4.89	3130				501,100
	40				5990	2995	119,800	
4440		190	4.39	2860				381,300
	40				5310	2655	106,200	
4400		150	3.83	2450				275,100
	40				4670	2335	93,400	
4360		110	3.46	2220				181,700
	40				4200	2100	84,000	
4320		70	3.09	1980				97,700
	40				3640	1820	72,800	
4280		30	2.59	1660				24,900
	30				1660	830	24,900	
		0	0	0				0

By:
Date: August 27, 1969

Project: Upper Klamath Basin
Feature: Long Lake
Detail: A/C table to elev. 4520

ATTACHMENT 6

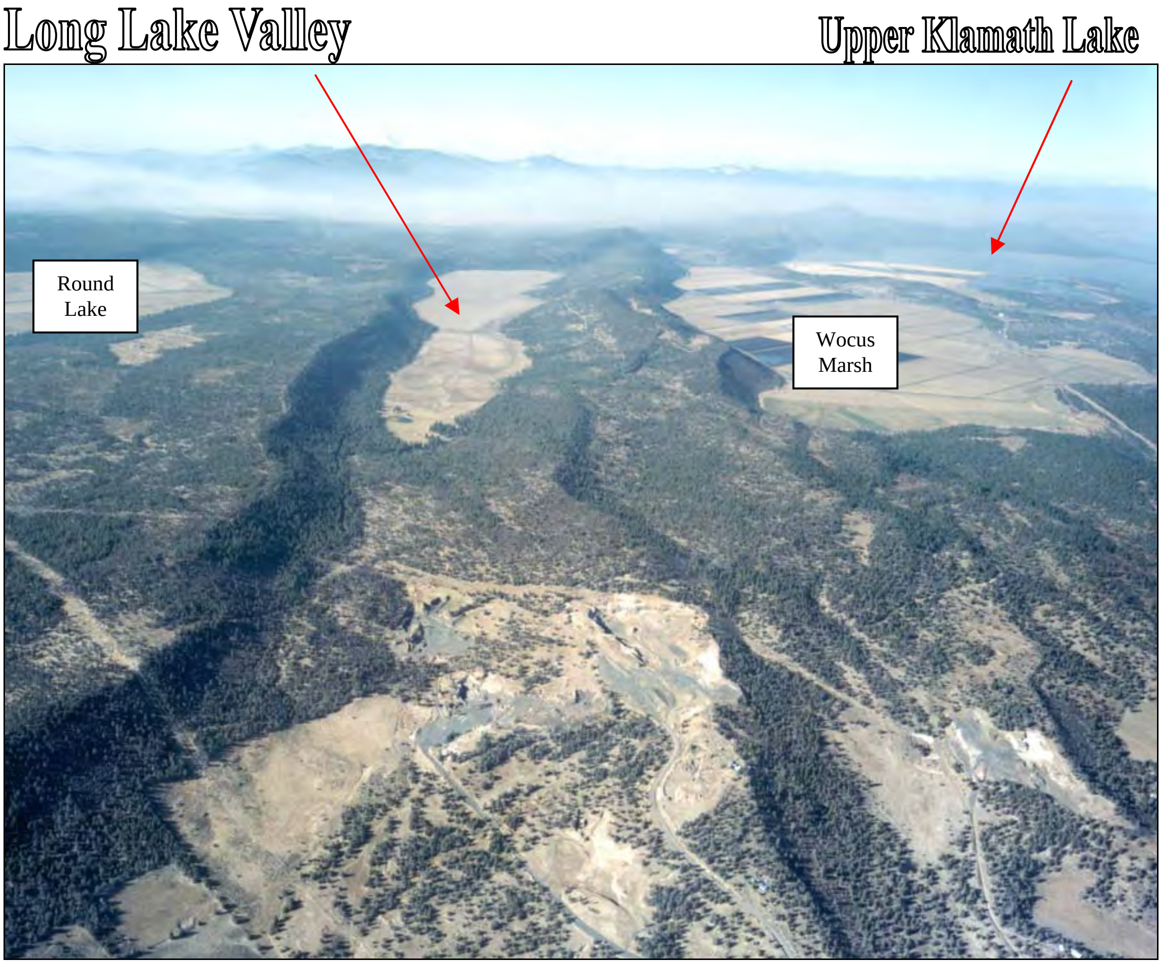
Appendix J—*Long Lake Valley Offstream Storage Study—Geologic and Hydrologic Investigations in Long Lake Valley*, March 2006

RECLAMATION

Managing Water in the West

Long Lake Valley Offstream Storage Study

Geologic and Hydrologic Investigations in Long Lake Valley



Klamath Project, Klamath County, Oregon

March 2006

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region, MP-230

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APPENDICES

Long Lake Valley Offstream Storage Study

Geologic and Hydrologic Investigations in Long Lake Valley

March 2006

Prepared by M. McCulla, Ph.D.; Project Geologist

PART 1 – Introduction

The following report includes terms and units commonly used by groundwater geoscientists such as "**hydraulic conductivity**" to indicate flow of water through rock or soil in **units of feet/day** (cubic feet of water / per square foot of area / per day). Technical reports, memos, and manuals by Reclamation geoscientists and engineering geologists commonly refer to the flow of groundwater through rock or soil as "**permeability**" and use **units of feet/year** or **centimeters/second**.

The non-technical reader of this report can use the terms "hydraulic conductivity" and "permeability" interchangeably, meaning approximately the same thing. The technical reader of the report will note that hydraulic conductivity is expressed in a "**K-value**" and **ranges of K-values** are defined by four categories of relative permeability (high, medium, low, and very low). These relative permeability terms are from Figure 5.5 of Reclamation's Groundwater Manuel [Ref. 3]. Permeability of these units is correlated with the hydraulic conductivity (K) test data shown on Charts 3 and 4 of the following report.

High relative permeability rock/soil has a K-value greater than 10 ft/day.
Medium relative permeability rock/soil has a K-value range of 10^{1} to $1x10^{-1}$ ft/day.
Low relative permeability rock/soil has a K-value range of $1x10^{-1}$ to $1x10^{-4}$ ft/day.
Very Low relative permeability rock/soil has a K-value less than $1x10^{-4}$ ft/day.

Scope of Work

In the fall of 2003, the U.S. Bureau of Reclamation (Reclamation), Mid-Pacific Region, Division of Design and Construction, Geology Branch (MP-230) was requested by Reclamation's Klamath Basin Area Office (KBAO) to conduct a geologic investigation within the Long Lake Valley area and surrounding environs (Figure 1 and Photographs 1 and 2). The purpose of this investigation was to provide the KBAO with geologic data relevant to determining the suitability of Long Lake Valley for use as an offstream storage site with a capacity of 350,000 to 500,000 acre-feet of water.

Long Lake Valley is a naturally closed basin. The valley floor (el 4,264 feet) is about 125 feet above the regional groundwater table, and the walls surrounding the valley are composed of a series of lava flows interbedded with volcaniclastic sediment. The main question being asked is "Are the hydrologic properties of the volcanic rocks/sediments comprising Long Lake Valley suitable for the retention of a large volume of offstream storage water?". Following data compilation and review, the first step in answering this question was to map local surface geology.

Area reconnaissance and geologic mapping in the fall of 2003 revealed the presence of several rock units within Long Lake Valley believed to have hydrologic characteristics favorable for the project. Based on this initial field mapping it was recommended that the study continue and a plan for surface and subsurface hydraulic conductivity investigations be initiated [Ref. 4].

From mid-August through October 2004 and from mid-July through August 2005 a drilling program was carried out in Long Lake Valley to determine the local geologic stratigraphy, and to perform hydrologic conductivity tests on the various rock types present throughout the basin.

Location, Access, and Description of the Project Area

Long Lake Valley is located in Klamath County, Oregon about 4.5 miles west of the city of Klamath Falls (Figure 1). Three major land owners control most of the property within the area of investigation. It was with their permission and cooperation that the present investigations were allowed to take place.

Access to the site is via well established, privately owned and maintained roads leading into the valley from both the southern and northern ends. Both ends of the valley are blocked by locked gates, and access to the valley can only be gained with the landowners' permission.

The valley is about 5.5-miles long and up to 1.5-miles wide with a floor elevation of about 4,264-ft. (Photographs 2 and 3). A dry to seasonally-wet lakebed covers the valley floor, with several hundred acres of the land providing pasture for cattle ranching.

The western and northern walls of the valley are bounded by sheer cliff faces and steep talus slopes that rise about 260 feet to greater than 500 feet above the valley floor. From the western rim of the valley volcanic rocks slope gently towards Round Lake, about 1 mile to the southwest. The floor of Round Lake is at about the same elevation as that at Long Lake Valley. The northern rim of Long Lake Valley is a high, plateau composed of gently rolling hills.

The eastern and southern sides of the valley are mostly bounded by gentle slopes and rolling hills, capped by cliff-forming lava flows (Photographs 1, 2, and 3). The eastern rim of Long Lake Valley drops off several hundred feet to Wocus Marsh (Photographs 4 and 5). Wocus Marsh and Upper Klamath Lake to the east and northeast of Long Lake Valley form a base-level of the regional groundwater table. The southern rim of Long

Lake Valley slopes moderately towards the Klamath River, about 5 miles and 400 feet lower in elevation to the south.

Along the rim of Long Lake Valley there are three low spots that are near or below elevation 4,510 feet, the elevation necessary to allow the storage of ½-million acre-feet of water. These low spots are designated as the proposed Dam site, Dike-1, and Dike-2. If the proposed offstream storage reservoir uses a maximum water elevation of 4,430-ft., allowing for storage of about 350,000 acre-feet of water, construction of the dam and dikes would be unnecessary.

Previous Investigations

Upper Klamath Lake Area Offstream Storage Studies

Offstream storage studies around the Upper Klamath Lake area have been conducted by several organizations, both private and governmental. A review of these studies is presented in Reclamation's Upper Klamath Offstream Storage Study, Appraisal Report (February 1987) and a listing of these reports is included in the References section.

In 1959 and 1960 Dames and Moore, under contract to California - Oregon Power Company, conducted geotechnical investigations for offstream storage in the greater Aspen-Round-Long Lake area. The investigations included 13 drill holes located at Aspen Lake to determine subsurface geology and hydraulic conductivity of individual lithologic units. The results of these investigations were incorporated into a report by Shannon and Wilson [Ref. 7].

In 1982, Shannon and Wilson Inc. was contracted by Pacific Power & Light Co. to conduct an independent geotechnical review of offstream storage in the greater Aspen-Round-Long Lake area. Building on previous investigations, Shannon and Wilson drilled 10 additional holes and excavated several test pits to better determine subsurface geology and hydraulic conductivity of individual units. Like their predecessors, they focused most of their drilling and test pit work in the Aspen Lake area located about 4-mi. northwest of Long Lake Valley, with less work in Round and Long Lake valleys.

Findings from their 1982 investigations are presented in "Shannon and Wilson, 1983, Report to Pacific Power & Light Co., Independent Geotechnical Review Upper Klamath Offstream Storage Study, Klamath Falls, Oregon" [Ref. 7].

Many of the lava flow and airfall tuff units extending through the greater Long Lake, Round Lake, and Aspen Lake area have similar geotechnical properties. For this reason the geologic and hydraulic conductivity test data presented in Dames and Moore 1959-1960 and Shannon & Wilson 1982 & 1983 are largely applicable to the current study in Long Lake Valley.

Work within Long Lake Valley

Prior to Reclamation's present study, there have been no significant geologic or hydrologic investigations within Long Lake Valley to determine its suitability as an offstream storage reservoir site. The only investigations within the valley were by

Shannon & Wilson Inc. in 1982. The 1982 investigations included two shallow drill holes and falling head permeability tests. Based on the falling head permeability tests hydraulic conductivity values (K values) were assigned to lakebed sediment (Qlb) and Tertiary basaltic andesite (Tba_1). The hole drilled in lakebed sediment (Qlb) was 26.3 feet deep, and the hole drilled in basaltic andesite (Tba_1) was 9-feet deep. A third hole was drilled on the southwestern rim of the valley in soil derived from Basalt of Wocus Marsh (QTwb) to a depth of only 3.7 feet.

Two water wells are presently in use within Long Lake Valley; one is a domestic well (W-10) 162 feet deep and the second (W-9) is a 604-foot-deep water well used for irrigation of ranch land (well driller's logs in Appendix D).

DOGAMI Geologic Mapping

Oregon State Department of Geology and Mining Industry (DOGAMI) geologists have, within the past four years, completed geologic mapping of both the Keno and Klamath Falls 7.5-minute quadrangles. This work covers all but the northern part of Long Lake Valley and provides a sound geologic understanding for the current, more detailed, investigations.

Seismicity Data

A review of available seismic data, although pertinent to a feasibility level report, was not necessary for the current level of investigation. Long Lake Valley, and the greater Klamath Falls region is seismically active. A large number of small to medium magnitude earthquakes have taken place throughout the area in historical times, and the largest earthquake (Richter magnitude 6.0) to take place in Oregon in historical time was centered in Mountain Lakes Wilderness about 12- to 15- miles northwest of Long Lake Valley in 1933.

Water Well Data

Drill hole information having a bearing on stratigraphy in the Long Lake Valley area are predominantly from local water wells. The location of these wells has been plotted on the plan geologic plan map (Figure 3) and the well drillers logs are in Appendix D.

Although the information on these logs is of general use, there is often a question with regards to the location of these wells. The location stated on driller reports is not always correct, and some wells are known to be several miles from the stated location in the indicated drill report. The locations of many of the water well shown on Figure 3 still need to be verified. Although the location of water wells W9 and W10, within Long Lake Valley, are known to be accurate.

Shannon and Wilson studied water well data throughout the area. This data, and their geologic and hydrologic interpretations of the data are also presented in their 1983 report [Ref. 7].

Soil Maps - U.S.D.A. Soil Conservation Service

U.S. Department of Agriculture, Soil Conservation Service maps for the Long Lake Valley area were reviewed as part of this study. Pertinent data on soil classification and engineering properties was compiled and correlated with current investigations.

Reclamation (2003)

Work completed by MP-230 (geology) during the 2003 field season included:

- Research existing data for:
  - Previous Geologic Mapping
  - Drill Hole Logs
  - U.S.D.A. Soil Maps
- Compilation of existing water well data.
- Original field geologic mapping, focusing on an eight square-mile area within and around the proposed reservoir site.
- Identification of soil types and generation of an estimated depth-to-bedrock map.
- Research of regional groundwater conditions and incorporating that data with new geologic mapping to help provide an assessment of the potential use of Long Lake Valley as an offstream storage site.

Findings of this study are presented in Reclamation report "Proposed Offstream Storage in Long Lake Valley, Klamath Project, Klamath Falls, Oregon - Surface Geologic Investigations, March 2004" [Ref. 4]

PART 2 – Current Geologic Investigations

The current investigations took place over two field seasons (August through October 2004 and mid-July through August 2005) as funding, weather, personnel, and drilling equipment availability allowed.

Exploratory Work Completed

- Finalization of geologic mapping of the Long Lake Valley area (Figure 3).
- Subsurface investigations in 44 drill holes, including 10 diamond-core holes, 14 hollow-stem flight-auger holes, and 20 cone penetrometer test holes (Figure 3).
- Well permeameter field testing of lakebed sediment (Qlb) in two drill holes.
- Pressure hydraulic conductivity testing (packer permeability tests) in diamond core holes.
- Unsaturated falling head hydraulic conductivity testing in flight auger drill holes.
- Saturated constant head and falling head hydraulic conductivity testing in both diamond-core and flight-auger drill holes.
- Laboratory testing for hydraulic conductivity of both lakebed sediment (Qlb) and airfall tuff (Qt).
- Laboratory Analysis of 81 samples for physical properties and gradations, and two in-place density tests (Appendix C).

Geology

Surface geologic mapping within and around Long Lake Valley was a primary component of determining the local stratigraphic section. Mapping was particularly challenging as much of the area is covered with dense vegetation, soil derived from tuff, and colluvium. Talus slopes cover bedrock along most of the eastern side of the valley. A geologic map was constructed showing the location of rock outcrops upon which much of the geologic map was based (Figures 4). This figure also shows an estimated depth to bedrock below the tuff/colluvium (Qt/Qc) cover. The plan geologic map (Figure 3) and cross sections A-A' through G-G' (Figures 5 - 11) are the product of combining existing DOGAMI mapping with Reclamation's current project geologic mapping, and subsurface drill hole data.

Long Lake Valley is part of a constructional volcanic terrain characterized by basin and range topography that has been dissected by local and regional-scale faulting and erosion. Volcanic flows forming the sides of the valley range in composition from basalt to basaltic andesite. Most of the proposed reservoir site is surrounded by flows of basaltic andesite composition.

The predominance of lavas with basaltic andesite, rather than basalt, composition is important because basaltic andesite lava flows forming the sides of the proposed reservoir are generally thicker, more massive, and have much wider spaced joints than most basalt flows. Additionally, the basaltic andesite sides of Long Lake Valley do not host lava tubes common to basaltic terrains.

Stratigraphy
DOGAMI geologists have recently completed mapping both the Keno and Klamath Falls 7.5-minute quadrangles, which cover all but the northern part of Long Lake Valley. Their knowledge of the local volcanic units, backed up with petrography, geochemistry, and age determinations has produced a coherent geologic framework for the Long Lake Valley area. Reclamation's project geologist used DOGAMI's geologic maps and made changes based on current field observations and data from 44 drill holes to better understand the Long Lake Valley stratigraphy (Figure 3).

In the proposed reservoir area, much of the eastern and southern sides Long Lake Valley are covered by deposits of colluvium and airfall tuff that form a natural low permeability lining. The colluvium is primarily Clayey Gravel with Sand, Cobbles, and Boulders (GC)scb and is generally less than about 10 feet thick.

Beneath the colluvium or exposed at the surface, are two thicker deposits of airfall tuff. Airfall tuff forms thin to moderately thick deposits along the gentler side slopes of the valley, and comprises most of the lakebed sediment that covers the entire valley floor. As shown by drill holes and water wells, lakebed sediment attains depths of at least 80 feet across most of the valley floor, and locally may attain a depth of over 200 feet.

The upper unit of brown to red-brown airfall tuff formed from mafic volcanic eruptions of ash that are now moderately consolidated and generally weather to a Lean to Fat Clay (CL/CH) with some sand (Photographs 6, 7, and 8). The mafic airfall tuff unit (Qtm) is generally up to about 10 feet thick, but in drill hole DH-04-4A is 30 feet thick.

Underlying the mafic airfall tuff is a thicker buff colored unit of felsic airfall tuff (Qtf) that weathers to Elastic Silt (MH). Felsic airfall tuff is often up to about 20 feet thick, and in drill hole DH-04-4A is 48 feet thick. Unlike the mafic tuff, much of the felsic airfall tuff is moderately lithified to a soft rock, and locally has developed fractures.

Dense lava flows are the principal volcanic rocks cropping out within Long Lake Valley and the surrounding area. They form blocky cliff faces along the western, northern and eastern rim of the valley (Photograph 9), and locally cap fault-block hills along the southeastern end of the valley. Most of these flows are fine grained, dark gray in color, and very difficult or impossible to distinguish from one another without the aid of laboratory petrographic thin sections and geochemistry.

Below the lava flows is a volcaniclastic unit composed of lapilli tuff, water-lain sandstone, and tuff breccia that are interbedded with relatively thin lava flows.

<u>Long Lake Valley Stratigraphic Section</u>
QUATERNARY

Qtc Tuff / Colluvium – Undifferentiated – Various percentages of tuff and colluvium with a thin soil cover.

Qc Colluvium (Holocene) - Although present throughout the area it was not mapped as an individual unit. It is composed of various percentages of Clayey Gravel with Sand, Cobbles, and Boulders (GC)scb. Generally a few feet to less than 10 feet thick.

Qt Tuff, Lapilli Tuff, and Older Alluvium (Holocene to Pleistocene) – Undifferentiated, includes brown, loose to moderately indurated airfall tuff. Locally beneath the brown tuff is buff colored, moderately indurated to lithified lapilli tuff. Both weather to Silt, Lean to Fat Clay, or Elastic Silt (ML, CL, CH, or MH) with various percentages of sand and gravel size lapilli. Generally 10- to 30-ft. thick.

Qtm – Mafic tuff and lapilli tuff, red-brown, loose to moderately indurated.

Qtf – Felsic tuff and lapilli tuff, buff, moderately indurated to lithified.

Qal – Older alluvial gravel deposits between Qtm and Qtf, and also between Qtf and Tba_1, up to 2 feet thick, only noted in drill holes DH-05-9 and FA/DH-04-6.

Qlb Lakebed Sediment (Holocene to Pleistocene) – Lacustrine and fluviolacustrine, dark gray to tan, non-lithified, locally organic rich, Lean to Fat Clay, Elastic Silt, Silt (CL, CH, MH, or ML), and Sand with thin layers of tephra. Drilled to a depth of 83.9 feet in Long Lake Valley and locally could be much deeper.

Qbpb Basaltic Andesite of Porter Butte (Pleistocene) – Gray basaltic andesite described by Hladky and Mertzman (2002) in the Keno quadrangle as fine grained, aphanitic basaltic andesite with an age of 1.42 $\pm$0.08 Ma. Forms the northeastern rim of the valley, with exposures several hundred feet thick.

QTwb Basalt of Wocus Marsh (Pleistocene) – Gray basalt described by Priest, et al. (2002) in the Klamath Falls quadrangle, and Hladky and Mertzman (2002) in the Keno quadrangle as diktytaxitic olivine basalt with an irregular blocky fracture, and having a probable age of about 1.8 Ma. Forms the western rim of the valley and is up to several hundred feet thick.

TERTIARY

Tbv Basaltic Andesite Vent Complex (Pliocene) – Silt, sand, and fine gravel size cinder, ash, and breccia deposits with trace thin lava flows or dikes. Diamond core drilling to 310.1 feet in DH-05-2 encountered predominantly homogeneous and massively bedded cinder and ash, with minor well-bedded layers.

Tba Basaltic Andesite – Undifferentiated (Pliocene) – Includes sub-units Tba_1, Tba_i, and Tba_2 described below, with an age range of 4.08 $\pm$0.12 to 4.47 $\pm$0.28 (Hladky and Mertzman 2002; and Priest et al. 2002).

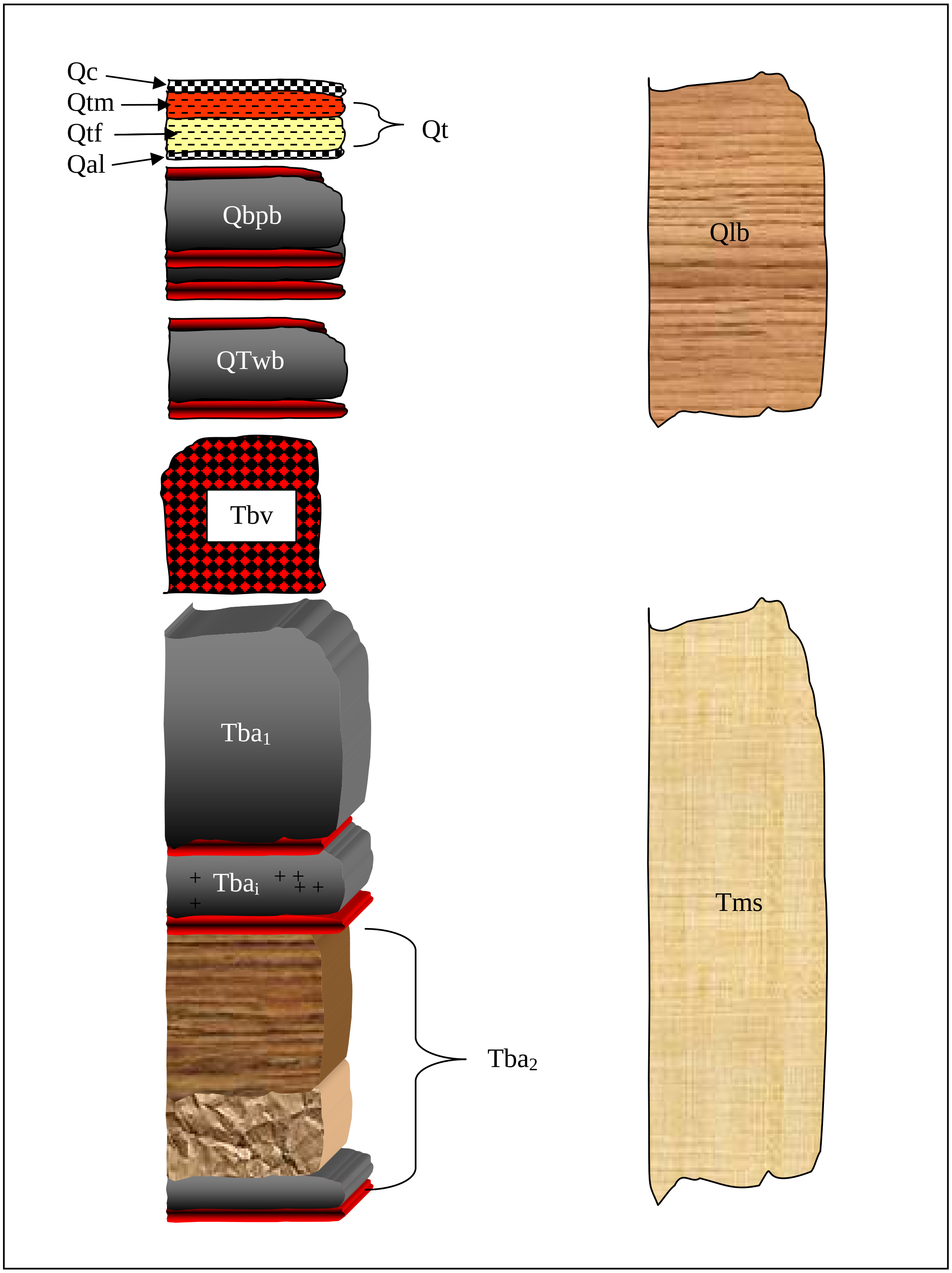
Tba_1 – Several flows of gray to dark brown basaltic andesite with massive, slightly to very-slightly jointed central cooling units 5 to 30-feet thick and rubble flow tops and bottoms. These lava flows overlie volcaniclastic rocks of Tba_2.

Tba_i – Large sill-like intrusive bodies and smaller dikes of basaltic andesite cutting older mudstone (Tms) outside the southern end of Long Lake Valley. Sills have well developed columnar jointing.

Tba_2 – Thick deposits of fine to coarse grained volcaniclastic sediment and tuff breccia interbedded with thin, discontinuous, lava flows of basaltic andesite.

Tms Mudstone (Pliocene and Upper Miocene) - Lithified diatomaceous and tuffaceous mudstone, sandstone, and volcaniclastic sedimentary rock deposited in lacustrine and fluviolacustrine environments outside of Long Lake Valley. Fines weather to CL, CH, ML, or MH.

Long Lake Valley Stratigraphic Section (continued)



Basin Development

Faulting

Long Lake Valley, Round Lake, and Wocus Marsh basins are all part of the larger Klamath Lake Graben. Most of the fault systems associated with this graben are normal or reverse faults, with minor oblique movement. However, one large strike-slip fault mapped within the Long Lake Valley project area provides clear evidence of significant transpressional tectonic activity (Photographs 10 and 11). Although Long Lake Valley has been mapped previously as a simple trap door, asymmetric basin [Ref. 5 & 6], there may be a significant strike-slip or oblique-slip component to faulting beneath the valley and throughout the surrounding area.

Young Volcanism

In addition to basin formation through faulting, the role of young volcanism also needs to be considered when explaining the presence Long Lake Valley as a closed basin. Age determinations of tephra deposits indicate that basins adjacent to Long Lake Valley were developing by <1.45 million years (Ma) [Ref. 1 & 2]. Assuming that Long Lake Valley similarly was forming about this time, then the presence of thick flows of basaltic andesite (Qbpb) along the northern and northeastern sides of Long Lake age dated at 1.42$\pm$0.08 Ma [Ref. 5](Hladky and Mertzman, 2002) may have significantly shaped the morphology of Long Lake Valley by closing off the northern and northeastern sides of the valley.

Basin Depth and Age

Detailed work has been completed by the U.S. Geological Survey (USGS) on the stratigraphy of unconsolidated sediments within the upper 165-ft. of Round Lake and Wocus Marsh [Ref. 1 & 2]. Core drilling by the USGS in Round Lake and Wocus Marsh intersected several layers of coarse airfall lapilli and ash (tephra) within lakebed sediment. Age determinations of several of these layers were conducted. Core drilling was completed to a depth of 49 to 50-meters (about 160- to 165-ft.) and deposits of tephra were present at this depth in both Round Lake and Wocus Marsh. These deposits correlated to tephra from Tule Lake dated at 1.36 Ma [Ref. 1 & 2] (Adams et al, 1994 & 1995), who list the ages of the 160- to 165-ft. deep tephra deposits in Round Lake and Wocus Marsh as <1.45 Ma.

Well logs in Round Lake and Wocus Marsh show the presence of unconsolidated lakebed deposits up to about 250-ft. thick. This thickness of lakebed sediment, along with an age of up to 1.45 Ma, indicate that the Round Lake and Wocus Marsh basins were at least starting to form by this time. It is reasonable to conclude that Long Lake Valley was also similarly developing more than a million years ago, and that within the deeper parts of the basin, lakebed sediment may exceed 200-feet thick.

The deepest drilling conducted in lakebed sediment in Long Lake Valley was a depth of 83.9 feet in FA/DH-04-7A. This drill hole was entirely within lakebed sediment, mostly composed of fat clay (CH) and elastic silt (MH) derived from weathering of airfall tuff

(Photographs 12 and 13. Abundant tephra clasts are present throughout the lakebed sediment, but age dating was not deemed necessary (Photo 14).

Cone Penetrometer Test Holes in Long Lake Valley

A total of 20 cone penetrometer test holes (CPT's) collected data in lakebed sediment (Qlb) across most of the valley floor. Most CPT's were to a depth of 35 to 50 feet. In the upper 20 feet most CPT holes encountered material interpreted as clay with a LOW TO VERY LOW relative permeability (Chart 5). A description log of each CPT hole is in Appendix B.

CPT holes augmented flight auger drilling and confirmed the presence of deep lakebed sediment even adjacent to the sides of the valley.

Structures

Long Lake Valley is a structural basin formed by Pleistocene to Holocene faulting similar to the other major basins throughout the Klamath Falls area. Both strike-slip and normal faulting have helped form the present morphology of Long Lake Valley.

Faults in Long Lake Valley are presently covered by either lakebed sediment or young airfall tuff and rarely crop out. At present, the complex structural pattern of the valley is very poorly understood. However, most faults in the valley floor and sides of the proposed reservoir are covered by significant layers of lakebed sediment or airfall tuff, and these covered faults will have little effect on the water retention characteristics of the valley.

Seismicity

The entire region surrounding Klamath Falls is presently seismically active (Zone 3). During historic times several large magnitude earthquakes have shaken the region, including magnitudes 5.9 and 6.0, both in 1993 within 15 miles of Long Lake Valley. Engineers designing structures will have to take into consideration the active seismicity of the region.

PART 3 – Hydrologic Investigations

Hydrogeology

The goal of this investigation is to establish a reasonable geologic understanding of rock units surrounding and underlying the potential offstream storage site in Long Lake Valley, and to determine hydraulic conductivity data for individual units. This combined data set can then be incorporated into a groundwater model that can be used to predict water loss for the valley if it is used as an offstream pump storage reservoir site.

Hydraulic conductivity data for several of rock types in different geologic units was determined by testing drill holes for water loss, as well as collecting samples for laboratory analysis. Down-hole methods included constant head well permeameter testing, Packer tests in diamond-core drill holes, unsaturated falling head tests in flight auger drill holes, saturated constant head and falling head tests in both diamond-core and flight-auger drill holes, and laboratory testing of undisturbed flight auger drill hole samples collected in lexan liners. Tables 1, 2, 3, 4, 5, and 6 are a compilation of the hydraulic conductivity data collected from drill holes and surface samples during the 2004 and 2005 field investigations.

Hydraulic Conductivity and Description of Principle Geologic Units

Rock and sediment in Long Lake Valley have been separated into units with similar relative permeability values. The terms HIGH, MODERATE, LOW, AND VERY LOW permeability were taken from Figure 5.5 of Reclamation's Groundwater Manuel [Ref. 3]. Permeability of these units is correlated with the hydraulic conductivity (K) test data shown on Charts 3 and 4.

<u>Lakebed Sediment</u> – Qlb

This unit consists of dark gray, olive green, to tan non-lithified organic rich mud, clay, silt, and sand with thin layers of tephra. Data on the unit comes from water well drill holes in Round Lake, Long Lake, and Wocus Marsh; USGS core drilling in Round Lake (1995) and Wocus Marsh (1994); drilling by Shannon and Wilson Inc. in Long Lake Valley (1982); and Reclamation's current investigations, which include four hollow stem flight auger holes and twenty cone penetrometer test holes (Photographs 15 – 21)..

Erosion has stripped much of the ash from the higher slopes and walls of Long Lake Valley and deposited it in the lake bottom. Reclamation drilling in the valley floor was relatively shallow, penetrating the upper 83.9 feet of the lakebed sediment (Photographs 12 - 17). The hydraulic conductivity of this unit is expected to be largely isotropic, but with horizontal conductivity slightly higher than vertical conductivity. Based on down-hole well permeameter test data and laboratory testing of undisturbed drill samples collected in lexan liners, **the relative permeability of the lakebed sediment is LOW to VERY LOW with a hydraulic conductivity (K) range of $1x10^{-2}$ and $1x10^{-6}$ ft/day, and a best overall estimate of $1x10^{-4}$ ft/day (Tables 3 & 5 and Chart 3).**

Table 1. Summary of hydraulic conductivity test data obtained from vadose zone testing in holes drilled during the 2004 and 2005 investigations in Long Lake Valley.

Packer Pressure Hydraulic Conductivity Tests Drill Hole DH-04-1							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type / Fracture Density
10	20	5	9.6	10	4.57	282	Qtm, Qtf, Qal
10	20	10	27.4	10	9.10	282	"
10	20	15	58.8	10	$1.5x10^{1}$	282	"
10	20	10	38.8	10	$1.3x10^{1}$	282	"
49.6	56.6	20	0.0	7	0.0	244	Tba_1 flow center FD1-3
49.6	56.6	25	0.0	7	0.0	244	"
49.6	56.6	30	0.0	7	0.0	244	"
49.6	56.6	40	5.8	7	$6.6x10^{-1}$	244	"
49.6	56.6	35	5.4	7	$6.7x10^{-1}$	244	"
49.6	56.6	30	5.0	7	$6.8x10^{-1}$	244	"
49.6	56.6	25	4.3	7	$6.4x10^{-1}$	244	"
90	100	45	0.0	10	0.0	202	Tba_1 flow center FD1-3
90	100	50	2.7	10	$1.6x10^{-1}$	202	"
90	100	55	6.8	10	$3.9x10^{-1}$	202	"
90	100	50	6.8	10	$3.9x10^{-1}$	202	"
90	100	45	6.7	10	$4.3x10^{-1}$	202	"
119.7	129.7	65	16.6	10	$7.6x10^{-1}$	172	Tba_1 flow center FD1
119.7	129.7	70	32.7	10	1.44	172	"
119.7	129.7	60	19.0	10	$9.1x10^{-1}$	172	"
119.7	129.7	55	11.4	10	$5.7x10^{-1}$	172	"
119.7	129.7	45	8.1	10	$4.5x10^{-1}$	172	"
Drill Hole DH-04-3							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type / Fracture Density
39.9	45.9	25	25.2	6	4.65	307	Tba_1 flow center FD5
39.9	45.9	30	33.8	6	5.60	307	"
39.9	45.9	35	49.2	6	7.39	307	"
39.9	45.9	30	36.6	6	6.06	307	"
39.9	45.9	25	41.6	6	7.68	307	"

Packer Pressure Hydraulic Conductivity Tests Drill Hole DH-04-3 (continued)							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type / Fracture Density
60.9	65.9	25	26.2	5	4.51	287	Tba_1 flow center FD3
60.9	65.9	30	29.4	5	4.62	287	"
60.9	65.9	35	30.6	5	4.42	287	"
60.9	65.9	30	31.6	5	4.97	287	"
60.9	65.9	25	29.2	5	5.03	287	"
70.0	75.9	25	0	5.9	0.0	277	Tba_1 flow center FD2
70.0	75.9	30	0	5.9	0.0	277	"
70.0	75.9	35	0	5.9	0.0	277	"
70.0	75.9	30	0	5.9	0.0	277	"
70.0	75.9	25	0	5.9	0.0	277	"
Drill Hole DH-04-4B							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type
18.7	28.7	10	1.6	10	$4.3x10^{-1}$	297	Qtm
18.7	28.7	15	0.0	10	0.0	297	"'
18.7	28.7	20	0.0	10	0.0	297	"
18.7	28.7	25	0.0	10	0.0	297	"
18.7	28.7	30	2.6	10	$3.5x10^{-1}$	297	"
18.7	28.7	25	2.2	10	$3.4x10^{-1}$	297	"
18.7	28.7	20	0.2	10	$3.6x10^{-2}$	297	"
42.0	52.0	25	0.6	10	$7.1x10^{-2}$	273	Qtf
42.0	52.0	30	0.0	10	0.0	273	"
Drill Hole DH-05-6							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type / Fracture Density
65.5	80.3	15	*	14.8	$6.1x10^{-1}$	179	Tba_1 flow top/bottom FD5
Drill Hole DH-05-9							
Depth feet	Bottom feet	Pressure psi	Loss gpm	Test Length	K Value ft/day	Depth to groundwater	Rock Type / Fracture Density
52.0	62.0	15	*	10.0	1.48	140	Tba_1 flow top/center FD4

*Didricksen (Appendix A)

Table 2. Saturated constant head and falling head test data obtained from vadose zone testing in holes drilled during the 2004 and 2005 investigations in Long Lake Valley.

Saturated Constant Head and Falling Head Tests					
DH-05-2A					
Depth feet	Bottom feet	Depth to groundwater	Constant Head K Value (ft/day)	Falling Head K Value (ft/day)	Rock Type
60.0	80.0	372	$2.2x10^{-2}$	$1.5x10^{-3}$	Qtf
130.0	160.0	297	$4.0x10^{-2}$	$3.2x10^{-3}$	Tbv
DH-05-3A					
Depth feet	Bottom feet	Depth to groundwater	Constant Head K Value (ft/day)	Falling Head K Value (ft/day)	Rock Type / Fracture Density
197.0	215.3	251	$1.4x10^{-1}$	$1.5x10^{-2}$	Tba_2 Vitrophyre FD1 to FD3
DH-05-6					
Depth feet	Bottom feet	Depth to groundwater	Constant Head K Value (ft/day)	Falling Head K Value (ft/day)	Rock Type / Fracture Density
5.0	40.0	229	$6.4x10^{-3}$	$4.7x10^{-4}$	Qc, Tba_1 FD5 TO FD9
5.0	53.0	223	$7.8x10^{-1}$	$3.2x10^{-1}$	Qc, Tba_1 FD5 to FD9
80.0	89.2	167	$4.7x10^{-1}$	$3.3x10^{-2}$	Tba_1 FD5 to FD9
DH-05-9					
Depth feet	Bottom feet	Depth to groundwater	Constant Head K Value (ft/day)	Falling Head K Value (ft/day)	Rock Type / Fracture Density
16.2	42.4	168	$4.9x10^{-1}$	$7.2x10^{-2}$	Qtm; Qtf; Qal

Table 3. Unsaturated constant head well permeameter d test data obtained from vadose zone testing in holes drilled during the 2004 - 2005 investigations in Long Lake Valley.

Well Permeameter Tests (BOR Method 7300-89)							
Drill Hole FA/DH-04-7A							
Depth feet	Bottom feet	Test Duration		Test Length	K Value fe/day	Depth to groundwater	Rock Type
55.5	65.5	29 hrs		10.0	$1.04x10^{-2}$	264	Qlb (CH to MH)
Drill Hole FA/DH-04-7B							
Depth feet	Bottom feet	Test Duration		Test Length	K Value fe/day	Depth to groundwater	Rock Type
28.9	38.9	9 hrs		10.0	$1.38x10^{-2}$	290	Qlb (CH)

Table 4. Unsaturated falling head well permeameter test data obtained from vadose zone testing in holes drilled during the 2004 - 2005 investigations in Long Lake Valley.

Unsaturated Falling Head Tests				
Drill Hole FA/DH-04-1B				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
10.0	20.0	273	$5.1x10^{-2}$	Qtm & Qtf
Drill Hole FA/DH-04-2B				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
14.5	24.5	190	$8.4x10^{-2}$	Qtm & Qal
Drill Hole FA/DH-04-3A				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
5.0	10.0	302	$6.0x10^{-2}$	Qc
Drill Hole FA/DH-04-3B				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
15.0	20.0	293	$3.1x10^{-2}$	Tba_1 flow top intensely weathered
Drill Hole FA/DH-04-4				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
14.3	19.3	236	$1.4x10^{-2}$	Qc & Tba_1 flow top intensely weathered
Drill Hole FA/DH-04-5				
Test Interval depth below ground (feet)		Depth to groundwater	Falling Head K Value (ft/day)	Rock Type
6.2	11.2	236	$7.6x10^{-2}$	Qtm & Tba_1 flow top intensely weathered

Table 5. Laboratory hydraulic conductivity tests of undisturbed drill hole samples collected in lexan liners from the vadose zone in lakebed sediment at Long Lake Valley.

Flexible Membrane Laboratory Tests (ASTM Method D5084) Drill Hole FA/DH-04-7A				
Depth feet	Bottom feet	Test Length	Average K Value ft/day	Rock Type
9.6	10.0	0.4	$2.7x10^{-6}$	Qlb (MH)
31.1	31.6	0.5	$1.4x10^{-6}$	Qlb (MH)
70.5	70.9	0.4	$1.7x10^{-4}$	Qlb (MH)

Table 6.

Remolded Laboratory Tests (ASTM Method D5084 – 3 inch) Drill Hole FA/DH-05-2					
Depth feet	Bottom feet	Pressure psi	Average Hydraulic Gradient	Average K Value ft/day	Rock Type
10.0	15.0	10	8.5	$7.9x10^{-5}$	Qtm s(ML)
10.0	15.0	20	8	$4.3x10^{-5}$	"
10.0	15.0	30	8.6	$3.4x10^{-5}$	"
Surface Sample (D-2) from the Western Rim					
		Pressure psi	Average Hydraulic Gradient	Average K Value ft/day	Rock Type
		10	2.0	1.6×10^{-3}	Tuff Qtf
		20	3.6	1.5×10^{-3}	"
		30	6.2	1.2×10^{-3}	"

Hydraulic Conductivity and Description of Principle Geologic Units (continued)
<u>Airfall Tuff and Lapilli Tuff</u> - (Qtm/Qtf and Qc)
Over the past 1.5 million years (Ma) eruptions from volcanoes have deposited multiple layers of volcanic ash and lapilli (gravel size ash) throughout the greater Long Lake Valley, Round Lake Valley, Wocus Marsh area. These surface and near-surface deposits of ash vary from poorly consolidated (Qtm)to moderately lithified (Qtf) (Photographs 6, 7, and 8A & 8B) and are generally thickest (10- to 20 feet) near the valley floor and thin going up the sides of the valley. In some locations ash is mixed with colluvium.

Hydraulic conductivity of these units is expected to be largely isotropic, with similar vertical and horizontal conductivity. Based on packer pressure test data, saturated and unsaturated constant head and falling head tests, and laboratory testing of surface samples, **both the deposits of ash and ash/colluvium have a LOW relative permeability with a Hydraulic Conductivity (K) range of $5x10^{-1}$ to $5x10^{-5}$ ft/day, and a best estimate of $5.0x10^{-2}$ ft/day (Tables 1, 2, 4, & 6 and Charts 3 & 4)**.

<u>Basaltic Andesite Vent Complex</u> – Tbv
At least three vent complexes are present outside of the rim of Long Lake Valley, two the north-northeast and one to the northwest. The basaltic vent on the northwestern rim of Long Lake Valley will have a direct impact on groundwater adjacent to the proposed reservoir site and was diamond-core drilled to a depth of 310.1 feet (Figures 3 and 11). The material encountered was moderately consolidated to slightly lithified accumulations of silt, sand, and fine gravel size cinder, ash, and breccia deposits with trace thin lava flows or dikes. The unit is predominantly homogeneous and massively bedded cinder and ash, with minor well-bedded layers.

The hydraulic conductivity of this unit is expected to be largely isotropic. It was tested using saturated constant head and falling head tests at two depths, from 60 to 80 feet and from 130 to 160 feet. These tests indicate that **the vent complex has a LOW relative permeability with a hydraulic conductivity (K) ranging between K= $4x10^{-2}$ and $3x10^{-3}$ ft/day, and a best estimate of about K= $5x10^{-2}$ ft/day (Table 2 and Chart 3).**

<u>Tertiary to Quaternary age Lava Flows</u> - Tba_1, QTwb, and Qbpb
The rim and high walls of Long Lake Valley are composed of a thick series of lava flows including: Tertiary Basaltic Andesite (Tba_1), Quaternary to Tertiary Basalt of Wocus Marsh (QTwb), and Quaternary age Basaltic Andesite of Porter Butte Qbpb) [Ref. 5 & 6]. These flows are generally 10 to 15-ft. thick, and up to 50 feet thick (see drill logs in Appendix B). This sequence of lava flows crops out boldly forming steep to vertical walls on the western and northern sides of the valley (Figures 3 and 4).

Hydraulic conductivity of these lava flows is anisotropic. Vertical hydraulic conductivity is largely controlled by regularly spaced near-vertical cooling joints, often spaced 3 to 8 feet apart, through massive central cooling units of each flow (Photographs 9, 22A, and 22B). Horizontal hydraulic conductivity is largely controlled by the presence of near-horizontal flow tops and flow bottoms comprised mostly of moderately weathered to decomposed ash, scoria, and breccia (Photographs 23A and 23B).

Hydraulic conductivity through these units has likely been modified over time. Many of the near-vertical joints in the central cooling units of individual flows have been filled or partially filled with tan to red-brown clay (Photographs 24 and 25; and drill logs, Appendix B). Tan to red-brown clay is also present in varying percentages partially filling void spaces in several of the flow tops and bottoms encountered during drilling (Photo 26). The presence of clay infillings in many void spaces has likely reduced the hydraulic conductivity of the lava flows within and surrounding Long Lake Valley. This clay is the same color and consistency as the overlying tuff units, which may have provided a source for much of it.

Test data indicates **that lava flows comprising the Tertiary Basaltic Andesite (Tab_1) unit have a MODERATE relative permeability with a hydraulic conductivity (K) ranging between K= 2 and $1x10^{-2}$ ft/day, and a best estimate of about K= $5x10^{-}1$ ft/day (Tables 1 & 2 and Charts 3 & 4)**.

The other lava units (QTwb and Qbpb) are mostly above the proposed reservoir elevation and were not penetrated by drill holes. It is expected that if tested, these lava flows would have a hydraulic conductivity in a similar range as found in Tba_1 lavas.

Volcaniclastic Sediment (Tba_2)

Beneath the lava flows are relatively thick deposits of volcaniclastic sediment and tuff breccia interbedded with thin, relatively discontinuous lava flows (Tba_2). This unit has been encountered in drill holes on both the eastern and western flanks of the valley, but because it is relatively soft it only crops out at one place uphill from Wocus Marsh (Photographs 27A, 27B, 28A, and 28B).

Only a few hydraulic conductivity tests were successfully conducted in the volcaniclastic sediment. Several packer pressure tests were attempted that failed for one reason or another, and it wasn't until the 2005 drilling season that a Hermit 3000 data logger with transducers was brought in for falling head testing.

The test data collected is consistent with visual observations of the core, which shows several beds of tightly packed sandstone and tuff breccia (Photographs 27A, 27B, 28A, and 28B). The hydraulic conductivity of this unit is expected to be isotropic in some beds and anisotropic in other beds.

The volcaniclastic sediment in Tba_2 is expected to have a broad range of permeability, but overall classified as MODERATE to LOW relative permeability with a Hydraulic Conductivity (K) between 1 and $1x10^{-2}$ ft/day, and a best estimate of about $1x10^{-1}$ ft/day (Table 2 and Chart 3).

Table 7. Comparison of hydraulic conductivity test data (best estimate) for major rock units in the greater Aspen, Round, and Long Lake Valley areas [Ref. 7].

Comparison of Data Sets		
Rock Unit	**Reclamation 2004/2005** Hydraulic Conductivity (/ft/day)	**Shannon & Wilson 1983** Hydraulic Conductivity (/ft/day)
Lakebed Sediment	$1x10^{-4}$	$4.8x10^{-3}$
Airfall Tuff & Colluvium	$5x10^{-2}$	$1.4x10^{-2}$
Jointed Vesicular Basalt	$5x10^{-1}$	$2.9x10^{-1}$

Exposed Surface Area of Major Rock Units within Long Lake Valley

The use of aerial photography was key in determining the actual area of exposed rock units within the basin. Based on 2003 geologic mapping, the area of each exposed rock unit below the 4,510-ft. and 4,430-ft. elevations was determined by using "Terramodel" software to drape aerial photography over the basin and calculate actual surface areas (Table 8). This software allowed the area of rock units with steep to vertical outcrops to be calculated much more accurately than a method using vertical projection of contacts to a horizontal plane.

The three major rock units comprising the surface of Long Lake Valley basin are Lakebed Sediment (Qlb), Airfall Tuff and Colluvium (Qtc), and jointed vesicular basalt (Tba_1, QTwb, and Qbpb). The greatest percentage of rock units cropping out within the basin have low to very-low relative permeability (Charts 1 and 2).

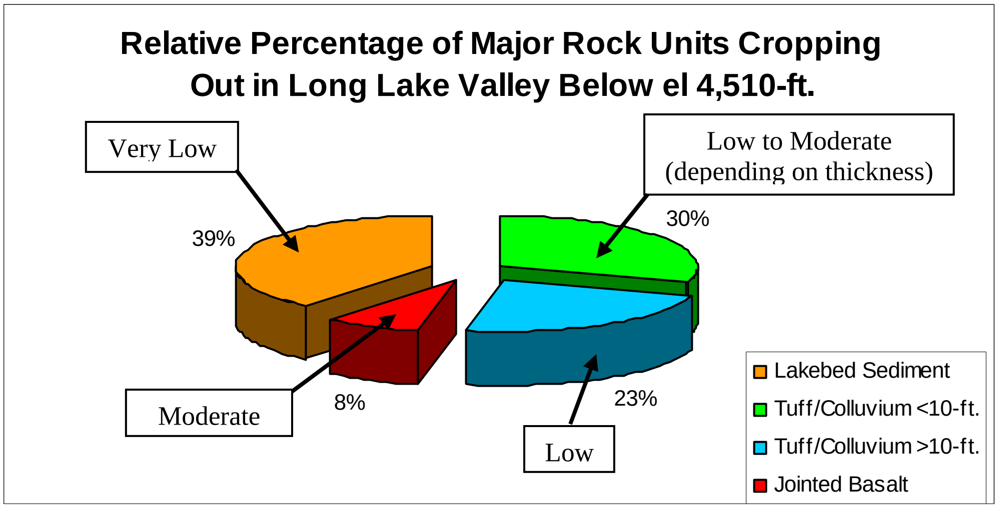


Chart 1. Percentage of major rock units cropping out below el 4,510 feet in Long Lake Valley and their assigned relative permeability.

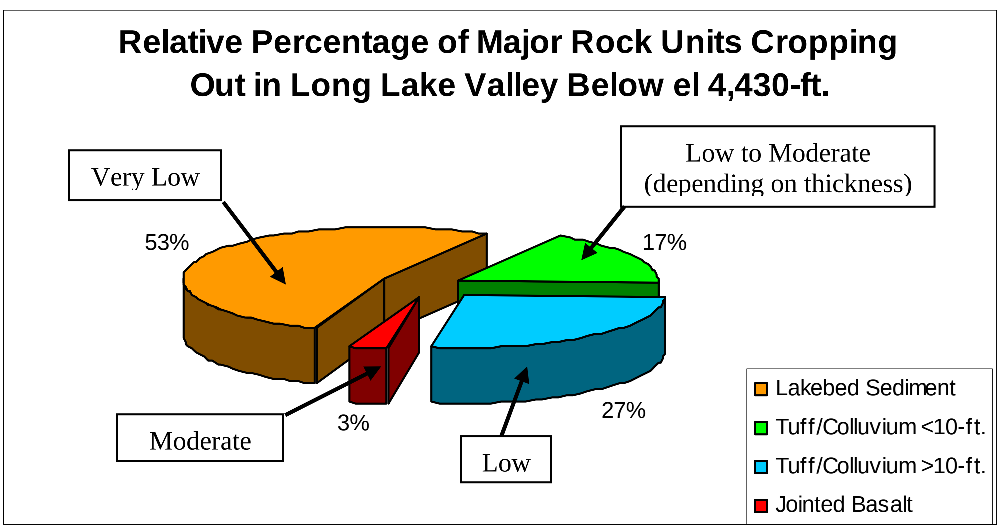


Chart 2. Percentage of major rock units cropping out below el 4,430 feet in Long Lake Valley and their assigned relative permeability.

Table 8A. Area of various major rock units exposed in Long Lake Valley at or below elevation 4,510 feet. Calculations were made using "Terramodel" software.

Exposed Area in Long Lake Valley Below Elevation 4,510 feet	
Rock Unit	Acreage
Lakebed Sediment (Qlb)	1,455
Airfall Tuff <10 feet deep (estimated)	1114
Airfall Tuff ≥10 feet deep (estimated)	855
Jointed Basalt, mostly Tba_1	292
Total = 3,716	

Table 8B. Area of various major rock units exposed in Long Lake Valley at or below elevation 4,430 feet. Calculations were made using "Terramodel" software.

Exposed Area in Long Lake Valley Below Elevation 4,430 feet	
Rock Unit	Acreage
Lakebed Sediment (Qlb)	1,455
Airfall Tuff <10 feet deep (estimated)	476
Airfall Tuff ≥10 feet deep (estimated)	722
Jointed Basalt, mostly Tba_1	76
Total = 2,729	

Findings

1. The bottom of Long Lake Valley is at an elevation of 4,264 feet, which is about 125 feet above the regional groundwater table, as recorded at Wocus Marsh to the east and about 105 feet above the regional groundwater table below Round Lake Valley to the west.

2. To explain the present day lack of a significant volume of lake water in Long Lake Valley, Shannon and Wilson (1983) completed a water balance study and from this concluded that at present the annual evaporation rate (51.5 in/yr) is more than double the annual precipitation rate (23.0 in/yr) [Ref. 7].

3. In addition to evaporation, movement of groundwater out of Long Lake Valley appears to be taking place primarily where water is in contact with fractured basaltic lava flows, which crop out in abundance along the northern end of the valley.

4. Long Lake Valley is surrounded and underlain by a complex assemblage of volcanic rocks and sediments. Drilling confirmed the presence of rock units with favorably low to moderate permeability underlying surface outcrops of jointed vesicular lava flows. The hydraulic conductivity of major rock units cropping out at the surface in Long Lake Valley are listed in Table 7.

5. Hydraulic conductivity data collected by Reclamation (2004 – 2005) in Long Lake Valley is overall similar to data collected over the greater Aspen-Round-Long Lake Valley area by Dames and Moore (1959 – 1960) and Shannon and Wilson (1982) [Ref. 7].

Conclusions

I. There is a basic disconnect between expected hydraulic conductivity of major rock units in the Long Lake Valley basin, based on casual surface observations, versus data collected using a variety of hydraulic conductivity test methods. Seeing the basin rim and northern end of the valley composed primarily of jointed basaltic lava flows, and the lack of ancient lake strand lines, suggests a potentially high water loss.

When studied in detail, outcrops of jointed basalt comprise only 3% to 8% of rock units cropping out below the proposed reservoir surface elevations. Hydraulic conductivity tests indicate that these lava flows have an overall MODERATE relative permeability, and other rock units exposed throughout the basin have MODERATE TO VERY LOW relative permeability.

II. The maximum water surface elevation of the proposed reservoir has a direct bearing on the potential water loss due to infiltration into rock units, as well as the project cost. The higher the maximum water surface of the proposed reservoir, the greater contact the water has with jointed basalt flows and the higher the potential water loss. Additionally, a reservoir surface at el 4,510-ft. (storing up to 500,000 acre-feet) requires the construction of at least one embankment dam (up to 2,400-ft. long) and possibly two dikes, adding considerably to the project cost.

Constructing a reservoir with a maximum water surface at el 4,430-ft. (storing up to 350,000 acre-feet) would not require the construction of any dams or dikes, and reduces the area of the reservoir that may potentially require lining.

III. Rock types in the valley can be characterized by their hydraulic conductivity into four major groups with the following relative permeability (Charts 3 and 4):

Low to Very Low Permeability (K = 10^{-2} to 10^{-6}ft/day) – Lakebed Sediment

Low Permeability (K = 10^{-1} to $1\text{x}10^{-4}$ ft/day) – Airfall Tuff / Lapilli Tuff, Colluvium, and Tertiary basaltic vent deposits of cinder and ash.

Moderate to mostly Low Permeability (K = 1 to $1\text{x}10^{-2}$ ft/day) – Volcaniclastic Sediment interbedded with thin basalt flows.

Moderate Permeability (K = 2 to $1\text{x}10^{-2}$, mostly $5\text{x}10^{-1}$ ft/day) – Lava Flows of intensely to slightly fractured Tertiary age Basaltic Andesite, Tertiary to Quaternary age Basalt of Wocus Marsh, and Quaternary age Basalt of Porter Butte.

IV. Long Lake Valley hosts several geologic characteristics favorable for its use as an offstream pump storage reservoir site.

- Its area/capacity curves show that it can contain a large volume (Figure 2).

- It is a closed basin with a natural low to very low relative permeability lining covering 80% to 95% of the area likely to be inundated by offstream storage of 350,000 to 500,000 acre-feet of water.
- For areas that require lining, borrow sources of material with relatively low permeability can be obtained locally, within the valley or within one to two miles of the project area.
- Faults within Long Lake Valley are covered by low to very low permeability lakebed sediment and airfall tuff. Because of this, the locations and geometry of faults within the basin are unclear. However, earthquake epicenter maps of the Klamath Falls area do not show the presence of active faulting within Long Lake Valley. Active faulting along the western side of Wocus Marsh and Klamath Lake is an entirely different issue and will need to be looked at in detail for engineered structures.
- It is unlikely that faults within Long Lake Valley will act as conduits for migration of significant volumes of reservoir water out of the Long Lake Valley basin. Although engineered structures will need to take into consideration the potential for faulting within the present-day valley floor.

V. Reclamation's 2003 – 2005 geologic and hydrogeologic investigations of Long Lake Valley have provided a level of understanding of the geology and hydraulic conductivity of major rock/sedimentary units sufficient for a reasonable groundwater model to be developed.

A skilled groundwater modeler, using the correct software, should be able to determine potential water loss from a proposed reservoir at various levels of operation, the major directions of seepage, and the effects of placing additional lining.

Chart 3. Plot of hydraulic conductivity data for 40 tests in Long Lake Valley.

Long Lake Valley

Relative Permeability

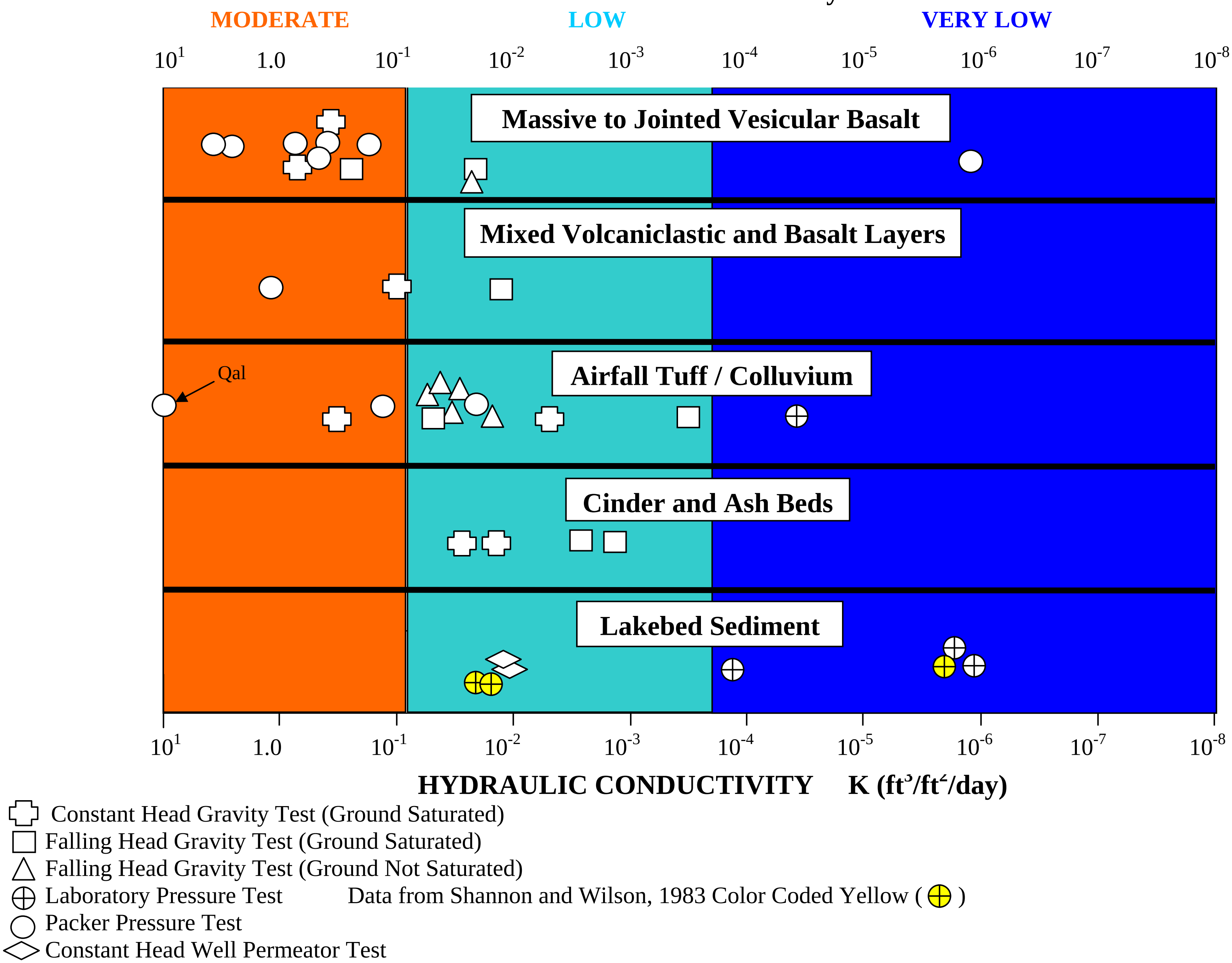
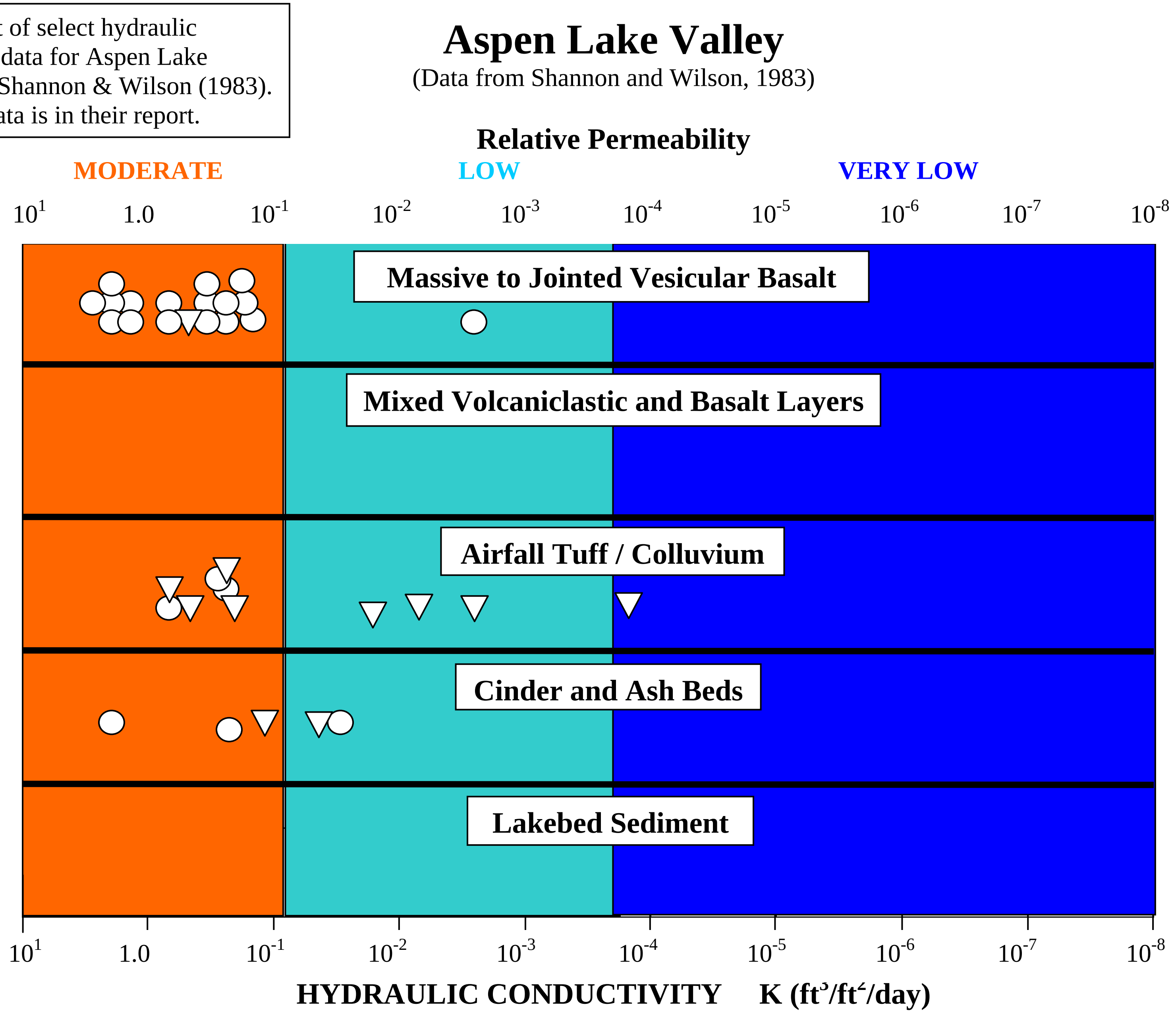


Chart 4. Plot of select hydraulic conductivity data for Aspen Lake Valley from Shannon & Wilson (1983). Additional data is in their report.



▽ Falling Head Gravity Test (Ground Saturation Unknown)
⊕ Laboratory Pressure Test
○ Packer Pressure Test

Discussion

Rock Permeability and Variability

Volcanic rocks often exhibit rapid changes in depositional environments over short distances. This is certainly the case in Long Lake Valley where there is a mixture of lava flows, airfall fragmental deposits, and lacustrine/fluvial sediment.

Currently there is a moderate understanding of the complex geology of the Long Lake Valley. Major rock units have been identified, and their relative stratigraphic positions determined. Through a series of subsurface investigations, data has been collected indicating the general range of hydraulic conductivity (K) values in various rock types. Additionally, there is a significantly large amount of hydraulic conductivity data on similar rock types within the surrounding area (Aspen Lake and Round Lake valleys) in the Shannon & Wilson (1982) report [Ref. 7].

Combining the currently understood geology of Long Lake Valley with the hydraulic conductivity data provides a moderate understanding of the range of relative permeability of major rock units comprising the basin.

Geologic investigations integrated with hydraulic conductivity data collected by Reclamation during the 2004 – 2005 drilling program, combined with data collected by Dames and Moore (1959 – 1960) and by Shannon and Wilson (1982) can be used to establish a reasonable accurate groundwater model. Potential water loss can then be modeled for the presence of a pump storage reservoir in Long Lake Valley.

Based on very limited hydraulic conductivity in Long Lake Valley, but a significantly large data base for the greater Aspen-Round-Long Lake Valley area, Shannon and Wilson [Ref. 7] estimated water loss for a reservoir in Long Lake Valley of 23cfs. This estimate was based on a reservoir maximum water surface of el 4,400 feet, and after initially high water losses during initial filling had stabilized (several years).

Lakebed Sediment (Qlb)

The greatest favorable hydrologic characteristic of Long Lake Valley is that more than 90% of the rock potentially exposed to reservoir water has a low to very low hydraulic conductivity (Charts 1, 2, and 3). The two units most responsible for this are Lakebed Sediment (Qlb) and Airfall Tuff / Colluvium (Qtc).

The Lakebed Sediment is mostly composed of thick to very thick deposits of volcanic ash and lapilli that have weathered to clay, generally has a hydraulic conductivity of 10^{-2} to 10^{-6} ft/day, and should form an excellent reservoir bottom.

Airfall Tuff / Colluvium (Qtc)

Thick deposits of airfall tuff and colluvium with a hydraulic conductivity (K) generally between 10^{-1} and 10^{-4} ft/day cover most of the side slopes of the valley. Near the valley bottom these deposits are often 10 to 20 feet thick, and as they go uphill they thin. To be reasonably certain that reservoir water is in contact with material that has a hydraulic conductivity of tuff and colluvium (10^{-1} and 10^{-4} ft/day) the deposit should be at least ten feet deep.

For this reason the outcrop map (Figure 4) shows areas of tuff/colluvium estimated to be greater than 10 feet deep and less than 10 feet deep. The total aerial extent of the tuff/colluvium (Qtc) in Long Lake Valley at a reservoir elevation of 4,430-ft. (hosting about 350,000 acre-feet of water) is 1,198 acres or about 44% of the total volume (Table 8B.). Of this, about 476 acres (17%) is tuff/colluvium deposits that are less than or equal to 10 feet thick. Because of this, either this 17% of Qtc that is less than 10 feet thick needs to be covered by additional lining, or the water loss in this area should be calculated using the hydraulic conductivity of the underlying bedrock units.

Reservoir Lining

The amount of reservoir lining will be a function of project economics, water availability, and acceptable water loss. Some portions of the proposed reservoir area are anticipated to exhibit higher than acceptable water loss and should be lined.

Lining will likely be limited to areas of outcropping basalt that appear to exhibit significant potential for high water loss, and possibly beds of tuff/colluvium that are relatively thin or where reservoir wave action is expected to be high. Modeling of the potential water loss will help determine lining requirements of the basin.

Recommendations

I. Construct a groundwater model to determine potential water loss issues for the proposed reservoir in Long Lake Valley. George Matanga, Ph.D. Groundwater Modeler MP-700 recommends using the HydroGeoSphere groundwater modeling program for work in Long Lake Valley. HydroGeoSphere is a groundwater modeling program jointly developed by Reclamation, the University of Waterloo, Laval University, and HydroGeoLogic Inc.

HydroGeoSphere is an acknowledged state-of-the-art coupled surface water – groundwater model that can conduct a 3-D water loss analysis, and is well suited for modeling groundwater passing through fractured volcanic rock as well as surface evaporation. This model can be run for various scenarios of reservoir operation and lining elevations, i.e. rapid or slow pumping into the reservoir, rapid or slow draw-down of the reservoir, various maximum water surface levels of the reservoir.

II. Additional Geologic Investigations – The geologic and hydrologic investigations completed to date within and around Long Lake Valley should be adequate to construct a groundwater model that will address water loss issues.

Should the project go into feasibility, additional site specific geologic and geotechnical investigations will be needed to collect design data at proposed engineered structure sites, including a pumping plant site, fish screen site, along the water conveyance tunnel alignment, at a bridge relocation site, and along the canal.

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