RECLAMATION

Managing Water in the West

Phase I Assessment Report
Storage Dam Fish Passage Study
Yakima Project, Washington

Technical Series No. PN-YDFP-001

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
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U.S. Department of the Interior

Mission Statement

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.

U.S. Bureau of Reclamation

Mission Statement

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.

Yakima Dams Fish Passage Assessment

Goal Statement

The goal of the Yakima Dams Fish Passage Assessment is to determine the feasibility of building fish passage facilities at Yakima Project storage dams, recommend construction where feasible, and develop and recommend alternatives at sites where passage is not feasible.

This document should be cited as follows:

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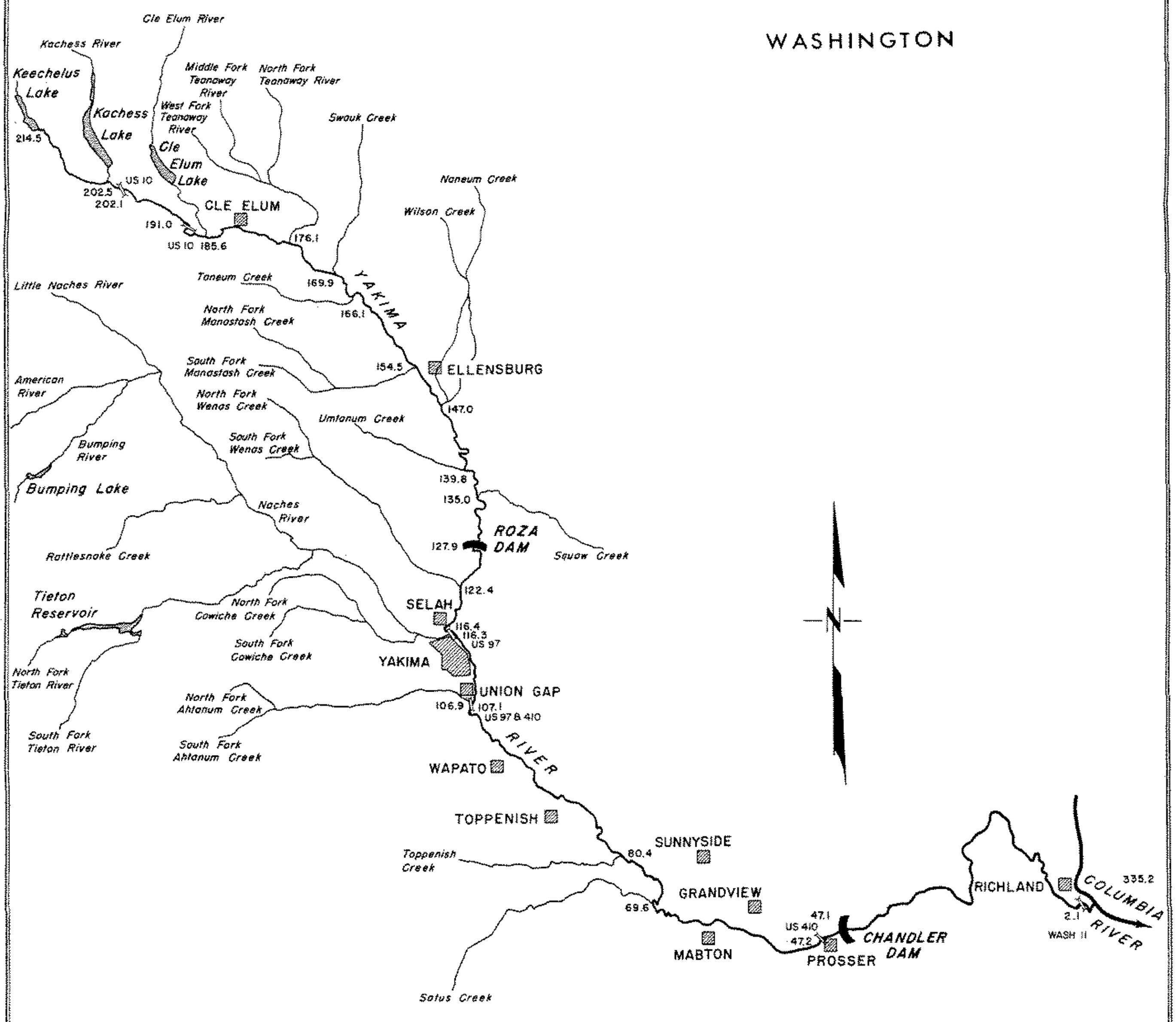
COLUMBIA RIVER BASIN

RIVER MILE INDEX
YAKIMA RIVER

WASHINGTON



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SUMMARY

PURPOSE AND BACKGROUND

The Bureau of Reclamation's Yakima Project provides irrigation water for a comparatively narrow strip of fertile land that extends for 175 miles on both sides of the Yakima river in south-central Washington. The irrigable lands eligible for service from Reclamation total about 465,000 acres. Major storage dams and reservoirs on the Project are Keechelus, Kachess, Cle Elum, Bumping Lake, and Tieton Dam (Rimrock Lake). There are no upstream or downstream fish passage facilities at any of these storage dams.

The historical lakes and tributaries upstream from these dams formerly supported runs of anadromous salmonids and resident species of fish. Varying amounts and quality of potential spawning and rearing habitat suitable for anadromous salmon and steelhead trout still exist above the dams. Two species listed under the Endangered Species Act (ESA) — bull trout and Middle Columbia River steelhead — would likely benefit from passage at the dams. Passage would also likely benefit chinook salmon and might allow reintroduction of extirpated sockeye salmon and coho salmon.

Early in 2001, many Yakima Basin interests viewed the proposed Keechelus Safety of Dams (SOD) construction as an opportunity to add fish passage at Keechelus Dam. These interests strongly urged Reclamation to incorporate fish passage features at Keechelus Dam as part of the SOD construction. Reclamation carefully considered this issue but was unable to build passage features as part of the Keechelus SOD construction. However, in response to the stated concerns, Reclamation negotiated a "mitigation agreement" with Washington Department of Fish and Wildlife (WDFW) and agreed to certain conditions contained in the Hydraulic Project Approval (HPA) permit for the Keechelus Safety of Dams construction.

To meet the requirements of the HPA, Reclamation began this preliminary assessment of fish passage at all the storage dams of the Yakima Project and is seeking funding for detailed feasibility studies that may eventually lead to implementation of fish passage features at the dams. The purpose of this "Phase I assessment" is to consolidate and document existing habitat information, evaluate preliminary passage concepts, prepare appraisal-level cost estimates for passage options, and identify uncertainties associated with fish passage at the dams where more data and modeling are needed to determine the relative merits of passage.

A core team of technical specialists from Reclamation's Pacific Northwest Regional Office and Upper Columbia Area Office prepared this assessment. Other technical specialists representing local, State, and Federal agencies, irrigation districts, and other entities provided extensive support for this effort and helped to shape the contents of this report. However, the opinions, assumptions, observations, conclusions, and recommendations are those of Reclamation and do not necessarily represent the opinions or thoughts of the other participants.

KEECHELUS SOD ANALYSIS

As required by the HPA, initial study efforts of the Phase I assessment were directed towards review and evaluation of potential fish passage features at Keechelus Dam and the relationship of those features to the on-going SOD reconstruction activities. This review and evaluation confirmed Reclamation's earlier decision to move ahead with the SOD reconstruction while continuing the investigation of the feasibility of providing fish passage features at Keechelus Dam and the other Project storage dams.

Through this review and evaluation, Reclamation determined that there would be no significant savings achieved by incorporating fish passage features into the SOD reconstruction as opposed to retrofitting fish passage at a later date. The SOD work will not adversely affect the options for constructing fish passage facilities, nor make the construction of fish passage facilities in the future more expensive or more difficult to construct. There would be no financial or operational advantage to starting passage construction during or in conjunction with current SOD work.

OPERATIONS AND STORAGE FACILITIES

Reclamation tailors its operations to ensure that public safety requirements are satisfied (flood control and recreational use), that water delivery contractual obligations are met (irrigation and M&I), and that instream flow targets (fish and wildlife habitat) are met. Maximizing flood control, irrigation water delivery, and meeting target streamflows requires continuous water management adjustments and includes many system operation considerations.

The five major Project reservoirs are operated in a coordinated manner to provide for the needs of the system as a whole. The releases from each reservoir are balanced to meet system-wide irrigation and water demands in conjunction with natural runoff and return flow available in the basin. No single reservoir is designated to supply the needs of one particular area, irrigation district, or Project division.

FISHERIES AND FISH PASSAGE CONSIDERATIONS

The four natural lakes (Tieton Dam was built on the open river) supported Native American fisheries for sockeye salmon and other anadromous and resident fish. Detailed information is not available for pre-Project fish populations in these lakes. However, available information suggests that all of the native species currently found in each lake — as well as those found in the river reach downstream from each dam — were historically present in the watersheds above the dams. In addition, sockeye salmon and coho salmon were present but are now extinct. Rimrock Reservoir was not a natural lake so the watershed upstream would not have supported sockeye salmon; however, it is likely the river and its tributaries would have been used by the other anadromous species.

There are peak migration periods for juvenile downstream migrants generally during the spring and fall. However, there is some movement of juveniles nearly year-round. The upstream migration period for the combination of different species of adult salmonids could extend from March through November. Because of the number of salmonid species that would eventually be involved in restoration and the different expressions of their life histories, it is reasonable to assume that fish would be present and trying to move past the dams nearly year-round at all five storage projects.

Providing fish passage at Yakima River basin storage projects could increase or enhance populations of Upper Yakima Basin steelhead, coho salmon, and spring chinook salmon by restoring access to historically occupied habitat; restoring life history and genetic diversity of salmonids; allowing reintroduction of sockeye salmon back into the watersheds where they occurred historically; and reconnecting isolated populations of bull trout and other resident fish species. Over time, anadromous salmonids would be expected to recolonize the watersheds upstream from the storage dams if fish passage were provided.

Bull trout abundance would be expected to expand due to enhanced connectivity and interaction among the presently isolated populations, and expanded foraging and overwintering habitat. Restoring connectivity among presently isolated populations of bull trout would allow for dispersal of fish among local populations, providing a mechanism for supporting weaker populations or refounding those that might become extirpated. It will also allow for gene flow among populations, which prevents the loss of genetic variation that insures survival in variable environments and thus decreases the probability of local extirpations.

TRIBUTARY HABITAT CONDITIONS

The core team assessed tributary habitat conditions upstream of the storage reservoirs. The team also considered the potential for improving connectivity among populations of native fish. The team obtained tributary stream length in miles up to natural or manmade barriers from various published reports and USFS stream surveys. The team estimated, where possible, the additional length of tributary stream that might be available if manmade barriers to fish passage, such as improperly placed culverts or other obstructions, were replaced and/or improved to allow fish passage.

The fisheries subteam used existing data and information to assess tributary habitat. The subteam attempted a qualitative evaluation of the spawning and rearing habitat in the tributary streams. The data were collected from various agency reports and peer-reviewed papers, on-the-ground observations, and experiences of the team participants. Information relating to spawning and rearing habitat for anadromous salmonids was not uniform for all tributary streams, so comparison among tributary streams was not possible. For this preliminary assessment, the subteam assumed that on a scale of from excellent to poor, the newly accessible habitat would be "good" overall for successful spawning and rearing in all basins. The team did not attempt to calculate potential increases or changes in anadromous salmonid production as a result of habitat expansion upstream from reservoirs.

Estimated overall reservoir tributary stream length in miles of suitable spawning and rearing habitat that would be potentially accessible to anadromous salmonids if passage were provided at the several dams is shown in Table 5-1 in the main narrative of the report on page 32.

PASSAGE CONCEPTS AND COSTS

In general, fish passage at each of these dams is complicated by the large fluctuation of reservoir water surface elevations. Typically, the reservoirs begin to fill at the start of the water year (October), reach maximum water surface elevation in the spring (at the start of the irrigation season), and are drawn down through the remainder of the year. Depending on the reservoir, the annual difference in elevation can be as much as 120 feet. Under these conditions, a traditional gravity flow fish ladder would not function.

The passage concepts in this report describe means of providing fish passage that is exacerbated by the problem of high water surface elevation fluctuations. Some concepts would provide fish passage over the entire range of elevations. Others would be designed to operate over a specific and more limited range of elevations that would result in shorter time periods when passage could be provided.

In developing new fish passage operations and structures at Project storage reservoirs, the winter hydrology and/or conditions under which these facilities would need to operate must be carefully considered. All of the storage reservoirs have frozen-over solid at times in the past. In many years, this layer of ice will support light vehicle traffic and in most years the snowpack which can be as much as 8 feet deep in the early spring at some sites. The cold, snowy conditions will not necessarily preclude the development of fish passage at the dams; however, when designing and installing fish passage features, the winter conditions and associated impacts on operations and maintenance (O&M) activities must be taken into account.

The methods for providing upstream passage for anadromous salmonids examined in this report include trap-and-haul, fish ladder with pumped flow, and a traditional fish ladder. The **trap-and-haul** is a conventional but labor intensive method that has been used in the past. Fish swimming upstream are attracted into a collection facility where they can be captured and then transported over the dam, usually by trucks equipped with tanks and water-quality equipment. The **fish ladder with**

pumped flow concept uses a traditional fish ladder to the top of the dam and a flume (slide) that slopes down to the reservoir. Ladder flow is pumped from the river to the top of the dam. A **traditional fish ladder** concept, a series of stepped pools and gravity flow in the ladder, may be feasible at Bumping Lake Dam.

The methods for providing downstream fish passage examined in this Phase I assessment include surface spill with modification to the existing spillway, construction of new spillways, use of a fish collection barge, and construction of new outlet works.

Several concepts at each dam involve **spillway modification** for downstream passage through the use of "overshot gates," which operate by spill over the top. The **new fish spillway** concept operates under the same principle as the surface spill with overshot gates. The idea of this concept is to provide surface-spill releases at lower reservoir elevations than could be obtained by modifications to the existing spillways.

The **fish collection barge** concept consists of a barrier net (to guide fish), a collection (or "gulper") barge with pumps, an underwater bypass pipe, and a holding (or "trap") barge. The concept was modeled after existing facilities at Upper Baker Dam on the Baker River in western Washington (owned by Puget Sound Energy). The **new outlet works** concept is a stationary collection structure that provides an attraction flow to draw downstream migrants to the structure. Fish are separated from the attraction flow by a screen and are then transferred with a bypass flow that moves them into a collection chamber. From there, they are moved below the dam by one of two methods; either through a pipe or a trap-and-haul system.

The following estimated costs are typical for each site. Construction costs for upstream fish passage features are estimated at $7 million for the **trap-and-haul** concept, $8.5 million for the **fish ladder with pumped flow** concept, and $11 million for the traditional **fish ladder** concept. Annual O&M costs could range from$250,000 (trap-and-haul) to $380,000 (ladder with pumped flow). O&M costs for the traditional ladder would be relatively minor.

Construction costs for downstream passage features are estimated from $1.7 million to $5 million for the **spillway modifications** concept; $4.6 million to $42 million for the **new spillway** concept; $11 million for the **fish collection barge** concept; and $20 to $25 million for the **new outlet works** concept. Annual O&M costs for the surface spill concepts would be relatively minor. Annual O&M costs for the fish collection barge would be about $340,000 and for the new outlet works, about $320,000.

FINDINGS

During this Phase I assessment process, we determined that there are a range of options and opportunities for providing fish passage and eventually reestablishing populations of anadromous salmonids in some tributaries of the five Yakima River basin reservoirs. Some combinations of passage options and associated biological benefits are more feasible than others. Costs vary widely among options, especially for downstream passage of juvenile fish. All five reservoirs have some tributary habitat that would be available if passage were provided at the dams; the amount and quality of the habitat varies considerably from reservoir to reservoir.

From our initial assessment, it appears that some form of upstream and downstream passage for anadromous salmonids and bull trout connectivity is technically feasible at all the storage projects. Passage at some would be much more expensive in relation to available habitat than at other locations. Tables 8-1, 8-2, and 8-3 in the main body of the report on page 58 were developed to relate the number of stream miles of habitat to the cost of fish passage at each site. This provides a way to make a rough comparison of the relative merits of providing passage at each of the sites.

The estimated costs of the several upstream and downstream passage options were divided by the number of stream miles of newly accessible habitat. This determined the cost per mile of habitat for each upstream and downstream passage option at each storage project. These values were then combined to show the cost per mile of newly accessible habitat for the different combinations of upstream and downstream passage features. Costs per mile of stream habitat for upstream passage options range from $0.2 million to $3.6 million. Costs per mile of stream habitat for downstream passage options range from $0.1 million to $10.6 million.

Not reflected in the table is the downstream migrant passage window that each of the options would encompass. The hydrographs for the five reservoirs (figures 1 through 5 in appendix D) show that each option provides a different window of passage. For example, at Cle Elum Dam, a new spillway would provide a much broader window of passage than spillway modification, but at a higher cost. In drier years such as 2001, a new spillway still would not provide for season-long, volitional, juvenile fish passage.

Table 8-3 shows that for all storage projects, the lowest initial cost per mile of newly accessible habitat (that is, without considering passage window size or O&M costs) for anadromous salmonids is trap-and-haul for adult upstream passage and spillway modification for juvenile downstream passage.

ADDITIONAL ISSUES AND CONCERNS

The team encountered numerous issues and concerns that were beyond the scope of this Phase I assessment. These issues and concerns as well as identified data gaps will need to be addressed in later phases of this effort. As a followup to this final Phase I report, Reclamation will draft a Phase II proposal to provide the context for discussion by the entire assessment team in early spring 2003.

CONCLUSIONS

- **There are definite benefits to restoring fish passage at Yakima Project storage dams.**
- **It is technically feasible to construct fish passage facilities at all five Yakima Project storage dams.**
- **Longer passage windows would provide the greatest biological benefits for migratory species.**
- **Suitable habitat is available for anadromous and resident salmonids in the tributaries above the dams.**
- **It is likely that self-sustaining populations of anadromous salmonids and bull trout connectivity could be restored if passage is provided.**

RECOMMENDATIONS

- **Contingent upon available funding, evaluate two reservoirs in greater detail in Phase II.**
- **Contingent upon funding, continue in Phase II to evaluate tributary habitat initiated in Phase I.**
- **Plan for operational adjustments**
- **Evaluate potential operational changes, including new basin storage, to determine possible benefits to fish passage.**
- **Monitor results of passage and restoration activities and institute an adaptive management approach as part of Phase III.**
- **As part of Phase II efforts, develop a detailed scope of work for Phase III and later stages of the feasibility study in collaboration with other entities and organizations involved with fish passage and recovery issues in the Yakima River basin.**

1. INTRODUCTION — PURPOSE AND BACKGROUND

1.1 PURPOSE

There are no upstream or downstream fish passage facilities at any of the five major Yakima Project storage dams in the Yakima River basin.[1/] The lakes and tributaries upstream from these dams formerly supported large runs of anadromous salmonids, and varying amounts and quality of potential spawning and rearing habitat suitable for anadromous salmon and steelhead exist above the dams. Prior to construction of the dams, non-anadromous fish species traveled back and forth between natural lakes and the river below. Two species listed under the Endangered Species Act (ESA), bull trout *(Salvelinus confluentus)* and Middle Columbia River steelhead *(Oncorhynchus mykiss)* would likely benefit from passage at the dams. Passage would also likely benefit chinook salmon *(O. tshawytscha)* amd might allow reintroduction of extirpated sockeye salmon *(O. nerka)* and coho salmon *(O. kisutch).*

The Yakama Nation, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (FWS), and others have urged the Bureau of Reclamation (Reclamation) to build fish passage facilities at Yakima Project storage dams. Recommendations contained in the *Habitat Limiting Factors, Yakima River Watershed, Water Resource Inventory Areas 37-39, Final Report* (WSCC 2001) included restoring passage at the dams. Early in 2001, many Yakima River basin interests saw the proposed Keechelus Safety of Dams (SOD) construction as an opportunity to add fish passage at Keechelus Dam. These interests strongly urged Reclamation to incorporate fish passage features at Keechelus Dam as part of the SOD construction.

Reclamation was unable to build passage features as part of the Keechelus SOD construction. However, in response to the stated concerns, Reclamation negotiated a “mitigation agreement” with Washington Department of Fish and Wildlife (WDFW) and agreed to certain conditions contained in the Hydraulic Project Approval (HPA) permit for the Keechelus Safety of Dams construction. To meet the requirements of the HPA, Reclamation launched this preliminary assessment of fish passage at all the storage dams of the Yakima Project and is seeking funding for detailed feasibility studies that may eventually lead to implementation of fish passage features at the dams.

1 “Yakima River basin” designates the entire Yakima River watershed, from the Columbia River to the headwaters of the mainstem and all its tributaries;
“Lower Yakima Basin” is the area downstream from Parker gage (RM 107.1) to the Columbia River;
“Upper Yakima Basin” is the area upstream from Parker gage to the headwaters of the mainstem and all tributaries;

The study is being conducted in phases. The purpose of this "Phase I Assessment" is to consolidate and document existing habitat information, evaluate preliminary passage concepts, prepare appraisal-level cost estimates for passage options, and identify uncertainties associated with fish passage at the dams where more data and modeling are needed to determine the relative merits of passage. Because of its interest in passage at the storage dams, the state of Washington has provided some funding to assist Reclamation in other program areas so that Reclamation funds can be reallocated for this study.

A core team of technical specialists from Reclamation's Pacific Northwest Regional Office and Upper Columbia Area Office prepared this assessment. Other technical specialists representing local, State, and Federal agencies, irrigation districts, and other entities provided extensive support for this effort and helped to shape the contents of this report. However, the opinions, assumptions, observations, conclusions, and recommendations are those of Reclamation and do not necessarily represent the opinions or thoughts of the other participants (see Chapter 11).

1.2 BACKGROUND

During review of the *Keechelus Safety of Dams Draft Environmental Impact Statement* (USBR 2000b), a large number of comments were received that dealt with the issue of fish passage at Keechelus Dam. All of the fish passage comments were addressed in "Attachment A, Fish Passage Issues" of the *Keechelus Safety of Dams Modification, Final Environmental Impact Statement* (USBR 2001b). *Attachment A* discussed authority for fish passage, design constraints, cost considerations, and biological information. After carefully considering the comments received and the information developed for *Attachment A*, Reclamation decided to proceed with the Keechelus Safety of Dams (SOD) work without providing fish passage features concurrent with the SOD reconstruction.

In the January 2002, *Record of Decision* [ROD] *for Keechelus Dam Modification* (USBR 2002a), Reclamation committed to seek funding under existing authorities to conduct a feasibility study for fish passage at all of the storage dams that are part of the Yakima Project (the Project). Further discussion and negotiations with the fisheries agencies subsequent to the ROD culminated in two documents — the "Mitigation Agreement" and the "Hydraulic Project Approval" — that summarize the fish passage issues related to Keechelus SOD reconstruction and impose certain requirements on Reclamation in order to proceed with the SOD work. These documents provide the structure for the present assessment of fish passage at the Yakima Project storage dams and are briefly summarized here. The complete text of each is included in Appendix A.

1.2.1 Mitigation Agreement — The *Mitigation Agreement between the USDI Bureau of Reclamation and Washington Department of Fish and Wildlife regarding Keechelus Dam Construction Issues Including Fish Passage* was signed on April 8, 2002. The major provisions of the *Mitigation Agreement* are shown below.

(1) The assessment shall include consideration of the potential fish production and likelihood of sustainability above each dam using a mutually acceptable assessment tool.

(2) Where fish passage is determined to be desirable and practicable, based on this assessment, Reclamation shall examine engineering feasibility.

(3) Where fish passage is determined to be impracticable or infeasible, Reclamation shall negotiate with WDFW to provide an alternative to fish passage.

(4) Reclamation shall seek appropriate funding to ensure timely implementation of:
- Fish passage facilities, where passage is determined desirable and practicable by the Project-wide assessment.
- Alternative fish restoration measures for locations where fish passage is determined by the Project-wide assessment to be biologically beneficial but impractical or infeasible.

(5) Until construction of fish passage facilities at each of the Yakima Project storage reservoirs where fish passage has been determined as necessary as per item (2) above, and such fish passage facilities are in operation, [Reclamation is] to provide interim fish passage (that is, a trap-and-haul program) in collaboration with WDFW at each of those reservoirs.

1.2.2 Hydraulic Project Approval — The second document is the *Hydraulic Project Approval* [HPA] *for Safety of Dams Reconstruction of Keechelus Dam* issued by the Washington Department of Fish and Wildlife (WDFW) on April 17, 2002. The *HPA* covers the same provisions as the *Mitigation Agreement* but adds timelines for completion of different phases of the project. The *HPA* requires Reclamation to conduct a Project-wide assessment of fish passage at all Yakima Project reservoirs with Keechelus Dam to be the first facility to be considered (provision 56). The other requirements in provisions 56, 57, and 58 of the *HPA* are summarized below.

Phase I (January 2003) — The assessment shall include investigations as to the engineering, constructability and biological considerations of fish passage at each facility.

Phase II (January 2004) —

1) Prioritize where fish passage is determined to be desirable and practicable, based upon the results of the Phase I assessment.
2) Focus on engineering feasibility, cost, water management implications, and biological parameters for restoring specific stocks.

Phase III (January 2005)[2] —

1) Provide interim fish passage (that is, a trap-and-haul program) in collaboration with WDFW at facilities where fish passage is desirable based upon the results of the Project-wide passage assessment.

Phase IV (to be determined)[3] —

1) Where fish passage is determined to be both desirable and feasible, seek funding and complete design and construction of fish passage facilities in a timely manner.
2) Where fish passage is determined to be undesirable or impractical, based upon the results of this assessment, negotiate with WDFW an alternative to providing fish passage.

2 Not identified as a phase in the *HPA*

3 Not identified as a phase in the *HPA*

1.3 FISH PASSAGE AND KEECHELUS SAFETY OF DAMS CONSTRUCTION

In the *Mitigation Agreement* (paragraph II-8), Reclamation agreed to ensure that SOD reconstruction-related actions at Keechelus Dam would not result in significant additional costs for retrofitting fish passage facilities at the dam nor require future significant modification of the portions of the dam being reconstructed as part of the SOD work.

Correspondingly, Provision 57 of the *HPA* requires Reclamation to:

- Determine whether the proposed design and construction of the SOD project will adversely affect the feasibility, cost, or effectiveness of fish passage facilities at the dam.
- Modify the SOD work if necessary to ensure that SOD reconstruction actions will not cause significant additional costs for retrofitting fish passage facilities nor require future modification of the portions of the dam being reconstructed as part of the SOD work.

As required by the HPA, initial study efforts of the Phase I assessment were directed towards review and evaluation of potential fish passage features at Keechelus Dam and the relationship of those features to the on-going SOD reconstruction activities. This review and evaluation confirmed Reclamation's earlier decision to move ahead with the SOD reconstruction while continuing the investigation of the feasibility of providing future fish passage features at Keechelus and the other Yakima Project storage dams.

Through this review and evaluation, Reclamation determined that:

- There would be no significant savings achieved by incorporating fish passage features into the SOD reconstruction as opposed to retrofitting fish passage at a later date. The estimated cost of remobilization and excavation of newly replaced embankment is not substantial enough to warrant modifying existing SOD contracts. The opening of the embankment for retrofitting fish passage features is not expected to require significant changes in operations. Thus, there would be no significant advantage to doing the work in conjunction with SOD construction as opposed to any year in the future.
- The SOD work will not adversely affect the options for constructing fish passage facilities, nor make the construction of fish passage facilities in the future more expensive or more difficult to construct.
- There is no financial or operational advantage to starting passage construction during or in conjunction with current SOD work.

Therefore, considering that passage options have not been narrowed to a single preferred design, and investigations into fish passage strategy and specific design feasibility are still on-going, Reclamation has concluded that it would be unwise to initiate construction of Keechelus Dam fish passage features prior to completion of ongoing studies. More information on the initial assessment of fish passage and Keechelus SOD issues can be found in Appendix E.

1.4 PROJECT-WIDE ASSESSMENT

Reclamation has launched a preliminary assessment of fish passage at all of the storage dams of the Yakima Project and is seeking funding for detailed feasibility studies that may lead to implementation of fish passage features at the dams. Reclamation is proceeding with the preliminary assessment in phases as directed by the *HPA*. The *HPA* requires completion of Phase I of the assessment by January 2003 and of Phase II by January 2004. The *HPA* also requires that interim passage (in collaboration with WDFW) be provided at selected sites not later than within a year of completing Phase II.

Reclamation began its assessment of the feasibility of providing fish passage at five dams in the spring of 2002. The first interagency meeting was held in April 2002. Initial efforts were directed towards evaluation of potential fish passage features at Keechelus Dam and the relationship of those features to the on-going SOD reconstruction activities. The interagency core team was comprised of biologists, engineers, and other appropriate specialists from Reclamation, WDFW, National Marine Fisheries Service (NMFS or NOAA Fisheries), U.S. Fish and Wildlife Service (FWS), U.S. Forest Service (USFS), irrigation interests, local governments, and others. A list of participants is provided in Chapter 11. The core team met monthly, and subteams met on several occasions to work through biological, engineering, and operational issues associated with fish passage at the storage dams.

The engineering subteam developed and analyzed various passage options for both upstream and downstream passage of anadromous salmonids and bull trout. The fisheries subteam compiled existing information on habitat conditions in tributaries upstream from the five Project reservoirs to evaluate the potential for restoration of anadromous salmonids in these five watersheds.

This assessment was limited to a compilation and analysis of existing information. Although the team used some limited field observations, systematic collection of new data was beyond the funding and time limitations of this study. Requirements for fish passage and the feasibility and likelihood of restoring sustainable populations of anadromous salmonids is based on existing literature, work in progress on other studies, and professional knowledge.

Miles of tributary habitat potentially available for adult spawning and juvenile rearing is used as an indicator of fish production potential of a watershed. No credible modeling of potential fish production could be done within the limitations of this study, because of the lack of quantified information and the many variables involved.

The team worked with several key assumptions:

- There would be no changes to current operations;
- Fish passage facilities could be designed and operated within the exiting operational considerations and constraints (CCs);
- There would be no impacts to “total water supply available” (TWSA);
- Operations would continue to serve existing Reclamation contracts;
- Potential operation changes that might enhance passage without impacting service to existing contracts or TWSA would be considered in the Phase II study.

2. CURRENT PROJECT OPERATIONS

This chapter describes and summarizes the general parameters and functions — physical, contractual, environmental, political and social constraints — that affect current Yakima Project operations. The chapter's purpose is to provide insight into current operations and hydrology of the Project as managed by Reclamation's Yakima Field Office. In any given year the Project, with regard to current "considerations and constraints" (see section 2.4), develops an operation scheme to manage the Yakima River basin water supply and to provide maximum benefit for each of the varied water demands in the river system within the considerations and constraints. In this section, a typical operational "water year" (October through September) with four seasons is shown, with the considerations, constraints, and thought processes necessary for defining a year's operations. Detailed information is provided in Section 5 of the *Interim Comprehensive Basin Operating Plan for the Yakima Project, Washington* (*IOP*) of November 2002, published by Reclamation's Upper Columbia Area Office.[4/]

2.1 YAKIMA PROJECT DESCRIPTION

The Yakima Project provides irrigation water for a comparatively narrow strip of fertile land that extends for 175 miles on both sides of the Yakima River in south-central Washington. The irrigable lands eligible for service from Reclamation total about 465,000 acres. There are seven "divisions" (physical and administrative units) in the Project; "Storage" is one of the divisions. Storage dams and reservoirs on the Project are Keechelus, Kachess, Cle Elum, Bumping Lake, Tieton, and Clear Creek. There are six water-delivery divisions: Kittitas, Tieton, Sunnyside, Roza, Kennewick, and Wapato, totaling about 418,000 acres. In addition, Reclamation has water supply contracts with private interests who irrigate over 45,000 acres not included in the six water-delivery divisions.

Reclamation considers the entire river basin outflow when calculating "total water supply available" (TWSA) for all demands (see section 2.4 below) but only physically operates the Storage Division of the Project.

2.2 PROJECT PURPOSES

Reclamation operates the Project to meet four specified purposes: irrigation water supply, municipal and industrial (M&I), instream flows for fish, and flood control. Irrigation operations and flood control management have been the historic priorities for reservoir operations. Instream flows and satisfying some of the requirements of anadromous salmonids have been incorporated as part of the

4 Text and tables in this chapter have been extracted and modified from the *IOP* (Reclamation 2002b); the material has been edited to conform with the format of this Phase I assessment report.

current routine operation of the system and take primary status at certain times of the water year based on legislation, judicial order, and water supply available.

Hydroelectric power is produced incidentally to other Project purposes. Reservoir storage releases are not made to meet hydroelectric power demand; sometimes power is subordinated to meet instream flow requirements. This includes the Wapatox Power Plant (owned by PacifiCorp) which is currently not operated. Reclamation is concluding purchase of the water rights from this plant for use as instream flow.

Recreational needs are considered but are incidental to other Project purposes. The Yakima River Basin Water Enhancement Project (YRBWEP) Act was enacted in 1994 as Title XII of Public Law 103–434. Section 1205(e) of the law authorized fish, wildlife, and recreation as "an additional purpose" of the Yakima Project and said the existing storage rights "shall include storage for the purposes of fish, wildlife, and recreation." However, "the above specified purposes shall not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts."

Reclamation tailors its operations to ensure that public safety requirements are satisfied (flood control and recreational use), that water delivery contractual obligations are met (irrigation and M&I), and that instream flow targets (fish and wildlife habitat) are met. Maximizing flood control, irrigation water delivery, and meeting target streamflows requires continuous water management adjustments and includes many system operation considerations.

2.3 WATER SUPPLIES AND DEMANDS

The five major Project reservoirs are Bumping (1910), Kachess (1912), Keechelus (1917), Rimrock at Tieton Dam (1925), and Cle Elum (1933). They provide most of the system's ability to store and release irrigation water, to meet flood control needs, and to meet instream flow requirements. Clear Creek Reservoir is operated primarily to maintain maximum pool elevation for recreation opportunities.

For the purpose of the general development of this Phase I assessment, there are adequate data and hydrology information currently available on Hydromet and the Internet. The *IOP* (Reclamation 2002b) has detailed information on the current operations, hydrology, and yearly operational "considerations and constraints."

Parker gage, downstream from Union Gap at RM 103.7, marks the division between the Lower Yakima Basin and Upper Yakima Basin. As measured at Parker gage, the average annual "unregulated" (natural) flow of the Upper Yakima Basin is about 3.4 million acre-feet (MAF). Annual natural flows have ranged from a high of 5.6 MAF (1972) to a low of 1.5 MAF (1977). Average annual irrigation diversions by entities recognized in the "1945 Consent Decree" [see Glossary] total about 2.2 MAF (1961-1990). This does not include the other water demands that must be satisfied in the Yakima River basin, including instream flows, hydroelectric generation (Wapatox Powerplant natural flow right), and M&I uses.

The Yakima Field Office Manager (FOM) is responsible for Reclamation's operational control and management of the "total water supply available" (TWSA) for the Yakima River basin. TWSA is

> "…that amount of water available in any year from natural flow of the Yakima River, and its tributaries, from storage in the various Government reservoirs on the Yakima watershed and from other sources, to supply the contract obligations of the United States to deliver water and to supply claimed rights to the use of water on the Yakima River and its tributaries, heretofore recognized by the United States."[5/]

Note that the April 1-September 30 TWSA water entitlements total 2.31 MAF for irrigation; in order to maintain YRBWEP target flows, an additional 0.13 to 0.23 MAF is needed. These combine to a total entitlement of 2.44 to 2.54 MAF during the 183-day period, plus 76,000 acre-feet carryover storage water to meet October's demands. As a rule, the water year needs to supply natural runoff of 2.77 MAF to 2.87 MAF of water to meet and support current entitlements; this also allows for minimum winter flows, which require 0.33 MAF.

The "total demand" is supplied through a combination of stored water releases, unregulated (natural) flows, bypassed reservoir inflows,[6/] and return flows. Total storage in the basin is a little over 1 MAF. Currently, Reclamation services storage contracts totaling 1.74 MAF, whereas the total yearly runoff passing through the storage reservoir system averages only 1.71 MAF. The total storage contract amount is not called for every year by all of the storage contract holders. However, Reclamation must carefully manage the runoff passing through the storage reservoir system (requires exacting reservoir operations) each year to ensure the annual demand is satisfied.

Demands cannot always be met in years of below-average runoff. Project operations make use of a monthly forecasting process to provide advance indication of water availability to supply total system demands for the current water year. On a daily basis, the Project must take into account varying weather conditions, water demands, "travel time" of the flow from the reservoirs to the point of use, inflow from unregulated tributaries, return flows, and other factors to maintain appropriate flow levels at selected control points (generally, gaging station locations) in the Yakima River basin.

Reclamation makes efforts to reduce impacts of Project operations on the fishery resource and to provide for appropriate water flows, while at the same time providing water for irrigation purposes. Reclamation implements three atypical operation strategies beginning in late August each year. These are "Flip-Flop," "Mini Flip-Flop," and "KRD Canal Bypass." Each of these operational schemes is designed to balance the need for irrigation water delivery with the protection of spring chinook salmon redds in the upper arm of the Yakima River above Roza Dam.

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5 A detailed explanation of the 1945 Consent Decree may be found in Section 4.5.1 of the *IOP*.

6 "Bypassed reservoir inflows" are streamflows into the reservoirs that are released rather than stored.

2.3.1 Flip-Flop— Flip-Flop operation meets Lower Yakima Basin irrigation demands (below Parker gage) primarily from upper mainstem Yakima River (the arm above Roza Dam) storage during the summer months and then reduces flows in the upper mainstem Yakima River during the latter part of the irrigation season. Late-season Lower Yakima Basin demands are then met primarily from Rimrock Lake on the Naches River arm. The purpose of the Flip-Flop operation is to encourage spring chinook salmon in the upper mainstem Yakima River above Roza Dam to spawn at lower river stage levels. This minimizes the river flows (and storage releases) required to keep the redds watered and protected during the subsequent incubation period (November through March.)

2.3.2 Mini Flip-Flop — In years of sufficient water supply, heavier releases are made from Keechelus during June, July, and August to meet upper mainstem Yakima River above Roza Dam demands; Keechelus releases are reduced to provide suitable spawning flow in the Yakima River reach from Keechelus to the upper end of Lake Easton. This minimizes the river flows (and Keechelus storage releases) required to keep the redds watered and protected during the subsequent incubation period (November through March).

2.3.3 KRD Canal Bypass — The operation uses storage upstream from Easton Diversion Dam to supply some of the irrigation diversion demands in the lower Kittitas/Ellensburg valley, Roza Irrigation District, and flow demands below Roza Diversion Dam while maintaining target spawning flows in the Easton reach of the Yakima River. Flows are bypassed through the Kittitas Reclamation District KRD canal beginning about September 1 and continuing to about mid-October when KRD's irrigation season ends. This allows the target flow below Easton Diversion Dam (about 200 cfs) to be maintained while releases from Keechelus Lake and Kachess Lake totaling about 1,450 cfs are continued for downstream demand.

There may be some room for changes in reservoir operations for fish passage enhancement. However, any proposed changes would require an in-depth review of the individual operation adjustment and accounting of the total effect on basin storage as a whole. With experience as an indicator, some changes in operation (such as flood control) could require several years of negotiations among the Yakima River basin's clientele.

2.4 OPERATIONAL CONSIDERATIONS AND CONSTRAINTS (CCs)

Each year, in light of the annual prevailing conditions and all current legal considerations, the Yakima FOM will ensure that the concerned parties are involved as part of the consultation process used to make decisions for basin operation. To maintain continuity on the development of the year's operation, the Yakima FOM will maintain contact with the different groups on a monthly or as needed basis via meetings or other forms of communication.

At these meetings, issues of significant concern to the Project operations in the river basin may be addressed with the Yakima FOM and others, allowing public input for possible inclusion into the strategy for the upcoming operational season. If consensus of operation cannot be reached, the

Yakima FOM, after review of available science and data, will make the decision for the seasonal operations. These meetings could include

- the monthly "SOAC" (System Operations Advisory Committee) meetings for fishery-related issues;
- the monthly "River Operations" meetings concerning future months' plans for operations (for all interested parties);
- "Managers" meetings (irrigation district managers and other interested parties) for discussion of the water supply for the on-going year which normally starts in March or earlier if a shortfall is foreseen.

2.5 OPERATING SEASONS

Each irrigation operating season, from mid-March through October of each year, is affected by factors spanning a 15-month time period. Reservoir and diversion operations occurring in August through October of one irrigation season can influence operations during the following irrigation season. System operations must include continual planning and adjustments to successfully satisfy the multiple demands on the Yakima River. System operations can be divided into four general time periods during the year and these correspond in general to the seasons of the year. These time periods and their relationships to the irrigation season and water measurement period (the water year) are shown below.

Table 2-1. Operating Periods and Seasons; Yakima River Basin 15-Month Operation Year (USBR 2002b)

Fall			**Winter**				**Spring/Summer**				**Summer/Fall**			
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
							Average Irrigation Season (mid-March–October 21)							
		Water Year (October 1-September 30)												

Table 2-2 at the end of this chapter demonstrates the operational "considerations and constraints" (CCs) during each of the four seasons. The chart is intended to show only the time periods during which the CCs are considered when making operational decisions. It does not necessarily show when releases or other changes are actually made.

2.5.1 Fall Operations (August, September, October) — In August, river operators begin the transition to "Fall Operations" which establishes the demands, constraints, and operational criteria for the next operating period. The Fall Operations period overlaps summer/fall operations, to close the irrigation season. During August, September and October when the reservoirs are being drawn down to meet irrigation needs, releases are coordinated to maintain system storage flexibility so that flows can be ensured and provided for spawning, incubation, and rearing of spring chinook salmon eggs and fry during the next operating time period. Fishery flow needs are coordinated with SOAC.

2.5.2 Winter Operations (November, December, January, February) — Streamflows into the reservoirs in excess of downstream targets are stored. Flows are bypassed or releases are made to provide instream flows for the incubation of spring chinook salmon eggs and fry and other current fisheries demands. Release schedules also consider flood control requirements. Flood control operations that may occur are guided by flood control space guidelines for the storage reservoirs and forecasts of future runoff. Flood Control Operations (CC5) must consider real time streamflows downstream from the dams prior to releasing water from the reservoirs. For example, streamflows are evaluated prior to reservoir releases. Along the Yakima River, the gaging points are Easton (RM 202.0), Cle Elum (RM 183.1), Ellensburg (RM 155.9), Parker (RM 103.7), and Kiona (RM 29.9). Along the Naches River, the gaging points are at Cliffdell (RM 36.0) and near Naches (RM 17.1). The main objective during Flood Control Operations is to provide maximum protection against floods in the Yakima River basin, without jeopardizing the irrigation water supply for the following year. Other issues or constraints at this time include migration flows and possible power subordination in the lower river system.

2.5.3 Spring/Summer Operations (March, April, May, June) — Streamflows into the reservoirs in excess of downstream targets are stored. Irrigation diversion demands are largely met from natural flows accruing downstream from the reservoirs from unregulated tributaries. Some releases are made for instream flow maintenance for incubation and rearing (I&R) where unregulated inflow downstream from the dams is inadequate. Occasionally releases are made for enhanced passage flows, spikes, or other flow enhancements needed to encourage outmigration. Other issues or constraints at this time include migration flows, and possible power subordination in the lower river system. Releases to maintain appropriate flood control space are implemented as necessary. Spring/Summer Flood Control Operations (CC6) at the five Project reservoirs occur each water year, even including most dry years. The volume of runoff potential is estimated by the runoff forecast in balance with the TWSA process. The runoff forecast and the flood space guide curves are taken into account in the refill process and in the timing of attaining a full storage system. Reservoirs are generally brought to their highest level during the late-May through June time period. Some of the reservoir inflow is stored and some is passed through the reservoir to supplement unregulated flows and return flows to meet downstream diversion demands. Unregulated flows and return flows are generally adequate to meet irrigation diversions through June. However, storage releases have begun as early as May in dry years and as late as August in wet years. The average date of storage control (period of record, 1926-1999) in the Yakima River basin is June 24.

2.5.4 Summer/Fall Operations (July, August, September, October) — During July, reservoirs are generally operated to maximize storage and still meet downstream demands. From July through the end of the irrigation season (normally October 20) releases from stored water are required to meet both irrigation needs and Title XII instream flow targets. The system is on “storage control” when reservoir storage must be released to meet downstream demands, including the Title XII target flows. This results in a decline in total storage. Other issues or constraints at this time include passage flows, and power subordination. During Summer/Fall operations, the system is operated to bring the current irrigation season to conclusion. Starting in August, however, operations also switched to establishing the demands, constraints, and operation criteria for the next season.

TABLE 2-2. YAKIMA RIVER BASIN 15-MONTH OPERATION YEAR (note: ///// indicates time period of importance); see section 5.2 of the *IOP* (USBR 2002b) for explanation of CCs.

		FALL OPERATIONS			WINTER OPERATIONS				SPRING/SUMMER OPERATIONS				SUMMER/FALL OPERATIONS			
	Considerations & Constraints (CCs)	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**
1	Average Irrigation Season	///// ///// ///// /////	///// ///// ///// /////	///// ///// //////					///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// //////
2	Irrigation Supply – Flood Waters								///// /////	///// ///// ///// /////	///// ///// /////					
3	TWSA – Irrigation Supply Period	///// ///// ///// /////	///// ///// ///// /////							///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	
4	OWSA – Irrigation Supply Period			///// ///// /////												///// ///// /////
5	Flood Control – Winter				///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// //////								
6	Flood Control – Spring/Summer								///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////					
7	Runoff Forecast – Monthly						/////	/////	/////	/////	/////	/////	/////			
8	TWSA Compiled – Monthly								//// ////	//// ///	/// ////	/// ///	/// ////			
9	OWSA Compiled – October		/	////											/	////
10	TWSA – Short, Prorationing	///// ///// ///// /////	///// ///// ///// /////							///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	
11	TWSA – Short, NRP								///// /////	///// ///// ///// /////	///// ///// ///// /////					
12	TWSA – Short, Water Bucket	///// ///// ///// /////	///// ///// ///// /////							///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	
13	Storage Control – Historical & Average	///// ///// ///								///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /*//	///// ///// ///// /////	///// ///// ///		
14	YRBWEP Title XII Flow Period	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////						///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
15	Flip-Flop Operation		///// ///												///// ///------------	------------//
16	Mini Flip-Flop Operation	//////												//////	------------------	------------//
17	Spawning Flows		///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////				///// ///// ///// /////	///// ///// ///// /////
18	Incubation Flows			/ /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////							/ /////
19	Rearing Flows	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
20	Ramping Rates	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
21	Passage Flows	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
22	Flushing/Pulse Flows – Out-migration									///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////				
23	Power Subordination	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
24	Hydroelectric Power Operations	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
25	Winter Operations & Ice Watch					///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////							
26	O&M – Hydrology	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
27	O&M – Dams & Diversion	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
28	O&M – Fish Facilities	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////
29	Minimum Sep. 30 Storage – 76 kaf			//											//	
30	Maximize Storage Content											///// ///// ///// /////	///// ///// ///// /////			
31	Develop Storage Content				///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////	///// ///// ///// /////					
	Considerations & Constraints (CCs)	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**
		FALL OPERATIONS			WINTER OPERATIONS				SPRING/SUMMER OPERATIONS				SUMMER/FALL OPERATIONS			

3. STORAGE FACILITIES, OPERATIONS, AND DESCRIPTIONS

3.1 OVERVIEW

Six storage dams have been constructed in the Yakima River basin. Four of these (Bumping Lake, Kachess, Keechelus, and Cle Elum) are located at the outlets of natural lakes. Clear Lake Dam and Tieton Dam created new reservoirs by inundating portions of the upper Tieton River basin. Numerous fisheries-related impacts are associated with the construction and operation of these storage dams and reservoirs. The five major storage facilities (Clear Lake is a minor facility) store runoff during the Winter and Spring/Summer seasons. This water is released later during low-flow periods in the Summer and Fall seasons for irrigation. The total storage of the five major reservoirs is a little over 1 million acre-feet (MAF), but the total yearly runoff passing through the storage reservoir system averages 1.71 MAF.

The five major reservoirs are operated in a coordinated manner to provide for the needs of the system as a whole. The releases from each reservoir are balanced to meet system-wide irrigation and water demands in conjunction with natural runoff and return flow available in the basin. No single reservoir is designated to supply the needs of one particular area, irrigation district, or Project division. The following table provides some basic information about each of the five major storage reservoirs. The following sections discuss the important operational aspects of each reservoir, the part each plays in supplying Yakima River basin water, and the fishery impacts associated with construction and operation of the facility.

Table 3-1. System Storage Capacity and Average Annual Runoff on September 30

Reservoir	Drainage area (mi.^{2})	Capacity (acre-feet)	Avg. Annual Runoff (acre-feet)	Ratio of Avg. Runoff to Capacity	September 30 Historical Storage (acre-feet)		
					Minimum	Average	Maximum
Keechelus	54.7	157,800	244,764	1.5:1	4,800	40,500	126,900
Kachess	63.6	239,000	213,398	0.9:1	20,100	107,200	227,200
Cle Elum	203.0	436,900	672,200	1.5:1	12,900	118,000	359,500
Bumping	70.7	33,700	209,492	6.2:1	2,400	7,900	24,600
Rimrock	187.0	198,000	367,966	1.8:1	200	74,500	145,100
System	**579.0**	**1,065,400**	**1,707,820**	**1.6:1**	**51,700**	**357,500**	**660,200**
Period of Record = 1920-1999							

3.2 SNOWPACK, THE "SIXTH RESERVOIR"

The majority of spring/summer runoff is from snowmelt, therefore snowpack is often considered the "sixth reservoir." Because only 30 percent of the average annual total natural runoff can be stored in the storage system, the Project is very dependent upon the timing of spring/summer runoff (snowmelt and rainfall). The early Spring/Summer natural flow is used to supply most river basin demands through June in an average year. In most years, the five major reservoirs are operated so that storage peaks in June (average mid-June, period of record 1940-1999), about the same time the major natural runoff ends.

3.3 RESERVOIR STORAGE CARRYOVER

During the summer/fall period of operations, it is desirable to maximize reservoir storage carryover by the end of irrigation season (October 21). The Yakima River basin storage system is designed to store only the current year's spring/summer runoff and deliver it to meet irrigation demands from July through October. If there is only minimal storage (52,000 acre-feet or 52 kaf) remaining on October 21, then the winter and spring/summer periods of operations require a tighter control over the reservoir releases, lower base river flows, and greater flow variability during these time periods. A maximized storage carryover helps to ease those operations and meet demands during a dry year.

The adverse impacts of the drought year of 1977 were reduced because of favorable carryover storage from 1976. The 1994 drought had significant adverse effects on the fishery and water users because there was virtually no carryover after the drought years of 1992 and 1993. A good carryover allows for better overall flow for resident and anadromous fish downstream.

3.4 KEECHELUS DAM AND KEECHELUS LAKE

3.4.1 General — Keechelus Dam is located at Yakima river mile (RM) 214.5, about 10 miles northwest of Easton. Keechelus Dam is an earthfill structure situated at the lower end of a natural lake and was completed in 1917. It forms a reservoir with a capacity of 157,800 acre-feet, with 152,170 acre-feet available for use. The spillway consists of an uncontrolled crest concrete weir; the outlet works consist of a control tower with a single hydraulically operated slide gate. Keechelus Lake is operated to meet irrigation demands, flood control, and instream flows for fish.

3.4.2 Operations — The water in Keechelus Lake is used in conjunction with the rest of the system to provide a portion of the water supply to meet demands from Keechelus Dam to Sunnyside Diversion Dam (RM 103.8). However, a larger portion of the annual runoff to Keechelus Lake is used, along with that of Kachess Lake, to satisfy Upper Yakima Basin demands. Keechelus Lake also provides some carryover storage in normal water years. The prime flood control season extends from mid-November through mid-June. Irrigation demands are met by releases from Keechelus Lake either through bypassed reservoir inflows (beginning in mid-March) or stored water releases. When the Project is on storage control, diversions above Easton, including those for Kittitas

Reclamation District, are served primarily from Keechelus through late August. During September and October those diversions are satisfied primarily out of Kachess Lake.

Outflows from Keechelus Lake follow an annual pattern of relatively low flows during winter and relatively high flows during the April through late-August irrigation season. At a minimum, beginning in late August, during Mini Flip-Flop, releases from Keechelus Lake are reduced to meet a 60 cubic foot per second (cfs) target streamflow in the Yakima River at Crystal Springs (RM 213); this is based on past commitment and operations by Reclamation and water users.

In October, after spring chinook salmon spawning is complete, streamflows are reduced still further. In practicality, the flow is at least 30 cfs and often somewhat higher, depending on SOAC-presented considerations regarding incubation flows (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.) The 30 cfs represents a Keechelus Lake release of about 15 cfs with the balance from inflows in the reach between Keechelus Dam and Crystal Springs. If there were no inflows in this reach, the full 30 cfs would be released from Keechelus Lake.

This operation keeps downstream flows confined to the defined low flow channel so that spring chinook salmon will spawn in areas that can be kept watered throughout the winter incubation season. Releases are tangible attempts to keep all the spring chinook salmon redds under water in the reach from Keechelus Dam to Easton Dam (RM 202.5) without jeopardizing irrigation storage supplies. This operation is continued until reservoir releases are increased either due to flood control or to meet irrigation demand.

Currently, during the spawning and incubation period, these instream flows are variable depending upon the forecasted available runoff, and may be increased by the Yakima FOM after consultation with SOAC and the irrigation community. Currently, during Water Year (WY) 2003, the incubation flows are targeted at 80 cfs for Keechelus Lake release and 100 cfs at Yakima River at Crystal Springs (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.).

3.4.3 Facilities — Keechelus Dam is equipped with an uncontrolled, concrete overflow crest spillway capable of passing 8,000 cfs at elevation 2520.90 feet. The main outlet works has a single hydraulically operated slide gate (8.5 feet by 8.5 feet). The 7-foot maximum gate opening is capable of releasing 3,000 cfs, but the normal maximum release would be 1,500 to 1,700 cfs. This gate (sill elevation 2426.90 feet) has a minimum gate opening of 4 inches in the high head mode (over 33 feet) and 1.5 inches opening under low head mode (under 33 feet). Located in the same outlet works is a 22-inch outlet conduit to bypass minimum flows for fishery and stream enhancement when the main outlet gate is closed. The ramping rate for operations at Keechelus Dam is 2 inches per hour (river stage) as measured at the dam’s outflow gage.

The outlet works and stilling basin were rehabilitated in 1976. In mid-1998, it was determined that dam safety deficiencies existed at Keechelus Dam due to the potential for dam failure from piping or internal erosion of embankment materials or both. A reservoir operating restriction to elevation 2510 feet was imposed, together with increased monitoring and surveillance, pending implementation of corrective actions. This operating restriction limits storage to 140,920 acre-feet. The reservoir can be operated above elevation 2510 feet only for the control of large flood events. Corrective actions on the embankment began in April 2002 and are scheduled to be completed by November 2003.

3.5 KACHESS DAM AND KACHESS LAKE

3.5.1 General — Kachess Dam was constructed at the lower end of a natural lake and completed in 1912; it is located on the Kachess River, 2 miles northwest of the town of Easton. The earthfill dam has a structural height of 115 feet and a crest length of 1,400 feet. The spillway consists of a single 8-foot-tall, 50-foot-wide radial gate and a concrete -lined open channel in the right abutment. The outlet works consists of a conduit at the base of the dam controlled by slide gates. The dam impounds a reservoir with a capacity of 239,000 acre-feet, with up to 222,000 acre-feet available for use. Kachess Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The flood control season extends from mid-November through mid-June. Flood space control releases are normally minimal due to the poor refill ratio of 0.9 to 1. (A refill ratio of less than 1 to 1 means a reservoir will not fill in an "average" year if it starts the year empty.)

3.5.2 Operation — Kachess Lake storage is used in conjunction with the rest of the system to provide a portion of the water supply to meet irrigation and water demands from Easton Diversion Dam (RM 202.5) to Sunnyside Diversion Dam (RM 103.8). However, a larger portion of the annual runoff to Kachess Lake is used along with that of Keechelus Lake and Cabin Creek (RM 205) to satisfy Upper Yakima Basin demands. Kachess Lake provides some carryover storage in good water years.

Beginning in mid-March, Upper Yakima Basin irrigation demands are met by releases from Kachess Lake either through bypassed reservoir inflows or stored water releases. When the Project is on "Storage Control" (CC13), diversions above Easton Diversion Dam (including those for Kittitas Reclamation District) are served primarily from Keechelus Lake through late August, which is the start of Mini Flip-Flop. From the start of Mini Flip-Flop and Flip-Flop, the diversions above Easton Diversion Dam and up to 400 cfs of downstream diversion, during September and October, are provided primarily out of Kachess Lake.

Besides supplying a large portion of the system-wide irrigation demands, storage at Kachess Lake is needed to meet fishery resource's winter (incubation and rearing) minimum target flows along the Yakima River reach from Easton Diversion Dam (RM 202.5) to the Teanaway River (RM 176). In addition, when the reservoir is operated to meet multiple instream flow requirements, the high demand on storage water significantly reduces the ability of the reservoir to refill the following season; this is especially true of Kachess Lake, because the average annual runoff is less than reservoir capacity. Therefore, the reservoir does not fill every year even under normal runoff conditions. Kachess Dam minimum outflow during the winter is 5 to 8 cfs (equivalent to gate leakage) unless greater releases are needed for support of the Yakima River target flows.

3.5.3 Facilities — Kachess Dam is equipped with a gated spillway (sill elevation 2254.00 feet), consisting of one radial gate (50 feet by 8 feet high) with capacity of 4,000 cfs at full lake elevation of 2262 feet. The regulating outlet works has three slide gates (4.5 feet wide by 8 feet high) with an 8-foot maximum gate opening capable of releasing 3,690 cfs at full lake elevation. These gates (sill elevation 2192.75 feet) have a minimum gate opening of 0.17 foot and are the main release points for flows that support spawning and incubation in the Yakima River. There is an 18-inch butterfly valve located in the same outlet works at invert elevation of 2195.92 feet. At 25 feet of head and 100 percent gate opening, it bypasses approximately 35 cfs into the outlet conduit through the valve installed in the outlet works downstream from the main gates. When the main outlet gate is closed, and the auxiliary low flow bypass valve is being used, it is only capable of providing minimum flows for fishery and stream enhancement needs in the Kachess River. Kachess Dam has no fish passage facilities. The ramping rate for operations at Kachess Dam is 2 inches per hour (river stage) as measured at the first gage downstream from the dam.

3.6 CLE ELUM DAM AND CLE ELUM LAKE

3.6.1 General — Cle Elum Dam is located at at the lower end of a natural lake at RM 8.2 on the Cle Elum River, 8 miles northwest of the city of Cle Elum. Construction of Cle Elum Dam was completed in1935. The earthfill dam forms a reservoir with a capacity of 436,900 acre-feet, with 427,930 acre-feet available for use. The dam has a structural height of 165 feet and a crest length of 1,800 feet. The spillway consists of five 17-foot-tall by 37-foot-wide radial gates and a concrete-lined open channel in the right abutment. The outlet works consist of a control tower and concrete-lined tunnel through the right abutment.

3.6.2 Operations — Cle Elum Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The prime flood control season extends from mid-November through mid-June. Cle Elum Lake regulates about 20 percent of the entire runoff above Parker gage (RM 103.7) and is the largest storage facility in the Yakima River basin. Therefore, it is the main resource for meeting the large irrigation demands in the Lower Yakima Basin. The heaviest storage releases for irrigation are during the months of July and August, and it is normal for the main gates to reach hydraulic capacity in mid-August. Cle Elum Lake also provides the majority of carryover storage in normal water years.

In recent years, about 12 percent of the spring chinook salmon redds in the Upper Yakima Basin were found in the Cle Elum River while about 50 percent of the redds were found in the Yakima River reach upstream from the mouth of the Cle Elum River to Easton Diversion Dam. The presence of redds downstream from Cle Elum Dam and in the Yakima River downstream from the mouth of the Cle Elum River results in conflicting needs for the operational releases from the reservoir. Cle Elum releases meet most of the Lower Yakima Basin diversion demands during July and August. The majority of the summer release (3,200 cfs ±) is cut back during Flip-Flop to a minimum flow level (200 cfs) that is adequate to support both spawning and irrigation demands on the Upper Yakima Basin system. The larger portion of the Lower Yakima Basin diversion demands during the spring chinook salmon spawning period (September and October) are met from Rimrock releases. This allows Reclamation to minimize Cle Elum releases to meet a target flow (normally 150 cfs) in the Cle Elum River during the winter for spring chinook salmon incubation and early rearing.

3.6.3 Facilities — Cle Elum Dam is equipped with a gated spillway (sill elevation 2223.00 feet); this consists of five radial gates (37 feet wide by 17 feet high) with capacity of 40,000 cfs at reservoir elevation 2240 feet. The main outlet works has two slide gates (5 feet wide by 6.5 feet high). The 6.2-foot maximum gate opening is capable of releasing 4,600 cfs, but the August normal maximum would be around 3,400 cfs. The two slide gates (sill elevation 2112.25 feet) have a minimum opening of 0.10 foot, and they are the main support for the spawning and incubation flows. There are two 14-inch gate valves (invert elevation of 2127.09 feet) located in the same outlet works; at maximum head, each valve can only bypass 45 cfs into the main outlet conduit when the main outlet gates are closed. This bypass flow is not sufficient to support the normal spawning or incubation flows in the Cle Elum River reach. Maintenance work to the outlet works tunnel or guard gates requires stop-logging at intake to the tunnel. Currently this would allow no flow into the downstream river. Therefore, this type of required maintenance is attempted only when the lake is above spillway crest (elevation 2223.00 feet). Otherwise, pumping to maintain instream flows would be necessary. Cle Elum Dam has no fish passage facilities. The ramping rate for operations at Cle Elum Dam is 2 inches per hour as measured at the first gage downstream from the dam.

3.7 BUMPING LAKE DAM AND BUMPING LAKE

3.7.1 General — Bumping Lake Dam is located at the lower end of a natural lake at RM 17 on the Bumping River, about 29 miles northwest of the town of Naches. The earthfill dam was completed in 1910 and has a structural height of 61 feet and a crest length of 2,925 feet. The spillway consists of an uncontrolled concrete ogee crest and concrete-lined channel that extends to a wood flume. The outlet works consist of a gate tower and concrete conduit at the base of the dam. The reservoir has a total capacity of 33,700 acre-feet, with 31,220 acre-feet available for use.

3.7.2 Operations — The average annual runoff at Bumping Lake is much more than the reservoir’s capacity, which allows it to fill every year. Bumping Lake is normally operated in the “Flood Control” (CC6) mode during the Spring/Summer period, except for extreme water-short years (or multiple short years in a row). Depending on the timing of the runoff, the reservoir can be brought up to full pool a number of times each year. The facility is used to supplement water supply for demands in the upper Naches River during summer months. Until recently, it was also used during the winter months to provide bypass inflow to support the diversion right for the Wapatox Power Plant. Heavy drawdown of storage for summer irrigation demand normally starts in August and continues into early September. Bumping Lake is not used as a carryover facility, but is operated to provide 6 to 9 kaf of end-of-season storage needed to maintain winter incubation flows in the Bumping River.

During the early-September/late-October spawning period, the reservoir's outflows are kept under 200 cfs in order to minimize the required releases from storage for the winter incubation and rearing (I&R) period. During the winter I&R period, natural inflow to Bumping Lake often drops below 35 cfs; to provide winter minimum target flows, supplementation from the carryover storage (currently targeted to 12,000 to 16,000 acre-feet) is required. During the winter I&R period — and depending on earlier spawning flows — instream flows downstream from Bumping Lake Dam are kept at a minimum target of 50 cfs or more. Currently during this period, these instream flows are set by the Yakima FOM after consultation with SOAC (and others) and are variable depending on the results of redd surveys. During WY 2003 the incubation flows were targeted at 180 cfs but due to weather conditions drifted down to 115 cfs, but then increased up due to flood control operations (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.).

3.7.3 Facilities — Bumping Lake Dam has an overflow crest spillway (elevation 3426.20 feet) capable of passing 3,400 cfs at a reservoir elevation of 3429 feet. The main outlet works has two slide gates (4.5 feet wide by 5 feet high), each with a 5.0 foot maximum gate opening and each capable of releasing 1,240 cfs; August releases usually range from 500 to 700 cfs. The slide gates (sill elevation 3389.00 feet) have a minimum opening of 0.10 foot. They are the only support for the spawning and incubation flow releases; this is because there is no auxiliary low-flow bypass in Bumping Lake Dam. In order to perform maintenance on the outlet works or its guard gates, stop logs are needed at the intake of the outlet works; to perform work in the outlet tunnel, the main gates must be closed. Either action would allow no flow into the river downstream. To maintain instream flows, such required maintenance is attempted only when the lake is above spillway crest (elevation 3426.20 feet); otherwise pumping would be necessary to maintain instream flows. Bumping Lake Dam has no fish passage facilities. The ramping rate for operations is 2 inches per hour, as measured at the first gage downstream from the dam, 0.4 miles away.

3.8 TIETON DAM AND RIMROCK LAKE

3.8.1 General — Tieton Dam is located at RM 21.3 on the Tieton River, about 40 miles northwest of Yakima and was completed in 1925. The dam is an earthfill structure with a concrete core wall. It has a structural height of 319 feet and a crest length of 920 feet. The spillway consists of a concrete-lined open channel in the left abutment with a concrete side channel weir controlled by six 8-foot-tall by 65-foot-long drum gates. The outlet works consist of a tunnel through the left abutment controlled by jet-flow gates. The dam forms a reservoir with a capacity of 198,000 acre-feet at normal full lake, of which 197,800 acre-feet is available for use. Rimrock Lake is operated to meet irrigation demands, flood control, and instream flow for fish. The prime flood control season extends from mid-November through mid-June.

3.8.2 Operations — Releases of 2,700 cfs for flood control or greater during the winter could impact residents along the Tieton River. "Winter Operations & Ice Watch" (CC25) are conducted during the freezing periods of winter (January, February, and March). In order to prevent damage to the spillway structure and gates, the lake surface is held below elevation 2900 feet until the freezing danger is past. To meet irrigation and other flow demands downstream from the dam to the confluence of the Naches and Yakima Rivers, releases ranging from 500 to 700 cfs are made during the summer. In support of the Flip-Flop operation during September and October, releases up to 2,700 cfs are also made to meet Lower Yakima Basin irrigation needs; this allows the releases from the Upper Yakima Basin reservoirs to be reduced and provides a lower stage for spawning flows in the upper mainstem Yakima River. Rimrock Lake provides good carryover storage in normal or better water years. Outflow reductions may be necessary to allow maintenance work requiring river ford access to the canal or fish screens at Yakima-Tieton Diversion Dam.

Currently (2001), fishery interests support a minimum storage pool greater than 30,000 acre-feet, while the TWSA computation supports a 10,000 to 30,000 acre-feet carryover storage. With this in mind, Reclamation tries to maximize carryover storage in Rimrock Lake. At a minimum, to maintain the viability of the fisheries resource and supply the TWSA, 30,000 acre-feet is targeted for

September 30th. From 1996 to 2000, the minimum winter instream flows downstream from Tieton Dam have been between 15 and 50 cfs.

3.8.3 Facilities — Tieton Dam is equipped with a spillway weir controlled by six 65-foot-long by 8-foot-high floating drum gates (down position, invert elevation 2918.00 feet). These have a total capacity of 45,700 cfs at reservoir elevation 2928 feet. The main operating outlet works has two 60-inch-diameter jet-flow gates (invert elevation 2721.50 feet). At maximum opening (95 percent), these gates are capable of releasing 2,760 cfs at normal full lake elevation 2926 feet. When flow demands require operation of both gates at the same time, a minimum gate opening of 2 feet (40 percent) is maintained to allow rock passage. When only one gate is operating, the minimum opening is 4 inches (5 percent), resulting in a 15 to 20 cfs discharge. These gates are the only support for minimum instream winter flow as there is no auxiliary low-flow bypass located in Tieton Dam. Any maintenance work to the outlet works (sill elevation 2766 feet) or guard gates requires stop-logging at the head end of the outlet works to close the outlet tunnel. This allows no flow into the river downstream. This type of required maintenance is attempted only when the lake is above spillway crest (elevation 2918 feet), otherwise pumping to maintain instream flows would be necessary. Tieton Dam has no fish passage facilities. The ramping rate for operations at Rimrock Lake is 2 inches per hour (river stage) as measured at the first gage downstream from the dam, 0.4 miles away.

3.9 CLEAR CREEK DAM AND CLEAR LAKE

Clear Creek Lake provides negligible irrigation flow since it has a small storage capacity (5,300 acre-feet) and is located upstream from Rimrock Reservoir. However, in short water years and to offset irrigation and fishery minimum storage requirements in Rimrock Lake, Clear Creek might provide some benefit to the downstream storage demands. In normal runoff years, Clear Creek Lake is operated to maintain an elevation greater than 3011.40 feet for Project uses, including fish passage and recreation. Inflow and outflow are essentially equal and most all flow passes over a spillway weir crest at elevation 3011.00 feet. For the past 20 years, one 36-inch slide gate has been kept open 6 inches to prevent the outlet gate area from silting up. From mid-August to October 5th, Reclamation attempts to hold the lake at elevation 3011.40 feet; this provides the most effective passage through the fish ladder and maintains stable downstream spawning flow. In years of late-season, high-volume runoff, this elevation is nearly impossible to hold unless large releases are made through the dam’s slide gates; this is undesirable because the fish are attracted by the high gate releases and away from the spillway flows which supply the fish ladder passage.

The majority of operations functions occurring at Clear Creek Lake involve a short water year when it is possible to provide some benefit to the low storage pool in Rimrock Lake. The use of Clear Creek Lake storage occurs when Rimrock Lake’s September 30th storage drops below 34,000 acre-feet. Advance notice of intent to drawdown the lake must be given by August 10th to the Wenatchee National Forest so that timely notification may be given to recreation interests to protect facilities around the lake. After October 5th and concluding by October 20th, it is possible to transfer 2,200 acre-feet of Clear Creek Lake storage to Rimrock Lake for operational use by irrigation or fishery minimum pool demands. Increased outflows from the reservoir do not start until after October 5th because of the risk of kokanee spawning in the higher outflows. After October 20th, Clear Creek Lake can be refilled by closing the outlet gates, but incubation flows are maintained downstream from the dam based on September spawning flows.

4. FISHERIES AND FISH PASSAGE CONSIDERATIONS

4.1 OVERVIEW

The Yakima River basin supports spring chinook salmon, fall chinook salmon, coho salmon, and summer steelhead. Sockeye salmon were present historically, but have been extirpated; however, kokanee exist in all the lakes. The watershed also supports several other resident salmonids including bull trout, rainbow trout, cutthroat trout, and mountain whitefish. Additionally, several non-native salmonids have been introduced to the basin, including the brook trout *(Salvelinus fontinalis)* and the brown trout *(Salmo trutta).*

Prior to 1855, an estimated 300,000 to 800,000 anadromous salmonids returned to the Yakima River basin each year (WDFW 1993; Neilsen et al. 1991); Davidson (1953) estimated 500,000 chinook salmon (all races); Mullan (1983) estimated about 100,000 coho salmon. The historical total run size of Yakima River sockeye salmon has been estimated from 100,000 (Davidson 1953) to 200,000 (CBFWA 1990).

It is estimated that by 1900, prior to construction of the Project storage dams, the number of returning anadromous salmonid adults to the Yakima River basin had been reduced by about 90 percent, compared to historic runs (Davidson 1965, as cited in Tuck 1993). Salmon and steelhead runs continued to decline and by 1920 only an estimated 11,000 adults returned to the Yakima River basin (USBR 1979, as cited in Tuck 1993), a reduction of more that 98 percent of the historic run (NPPC 1990).

Irrigation projects were developed before Reclamation projects were authorized and constructed. Numerous irrigation diversion dams on the Yakima River mainstem and tributaries precluded anadromous salmonids from accessing portions of the watershed; unscreened diversions entrained salmon and steelhead smolts on their outmigration to the ocean, redirecting them instead to their death in agricultural fields. Dam construction on the mainstem Columbia River (which resulted in additional loss of downstream-migrating smolts) coupled with substantial commercial, tribal and recreational harvest of returning adults further decimated the numbers of anadromous salmonids returning to the Yakima River basin.

Crib dams, initially constructed to enlarge four existing natural glacial lakes, blocked fish passage to tributaries upstream from the dams and contributed to the eventual demise of the sockeye salmon runs by the early 20th century. Later construction by Reclamation of larger storage dams over the four crib dams and a fifth new dam (on the Tieton River) eliminated access to previously productive spawning and rearing habitat for spring chinook salmon, coho salmon, and steelhead, and resident fish populations — especially bull trout — that are now isolated but were formerly interconnected,.

The reservoirs created by the dams inundated a considerable amount of pristine, high-quality fish habitat. The historic natural lakes were notably smaller than the current reservoirs; construction of the dams inundated miles of streams. The lentic and lotic habitat in these historic lake basins were used by sockeye salmon and bull trout. Sockeye salmon generally spawn in flowing water but their young rear in lakes. Bull trout are currently present in all of the reservoirs and spawn in tributary streams. It can reasonably be assumed that other anadromous salmonids, particularly steelhead, used the upper reaches of these tributaries as well. In the case of Tieton Dam, an extensive meadow complex was inundated. The area was almost certainly valuable habitat for bull trout and other native anadromous salmonids, with the probable exception of sockeye salmon.

Even if this habitat were potentially productive, neither it nor any existing habitat upstream has been accessible to anadromous salmonids since construction of the storage dams, and in some cases since the construction of the crib dams several decades earlier. Construction of crib dams without fish passage facilities at Lakes Keechelus and Kachess in 1904 and at Lake Cle Elum in 1905 eliminated sockeye salmon populations in these lakes (Bryant and Parkhurst 1950; Davidson 1953; Fulton 1970; Mullan 1986). Construction of an impassable storage dam at Bumping Lake in 1910 likewise eliminated a sockeye salmon population in that lake, with an estimated annual run of 1,000 fish (Davidson 1953; Fulton 1970).

None of the existing dams are equipped with fish passage facilities. Sockeye salmon were extirpated in the Yakima River basin by 1933, following the completion of the last storage dam on the Cle Elum River. The lack of passage has also isolated local populations of bull trout, reducing or eliminating interconnectedness and the exchange of genetic material among populations, and preventing the recolonization of populations diminished by catastrophic natural events. It should be noted that there are no provisions at the storage dams for safe downstream passage of fish. The diversion dams on the Yakima River are screened to direct fish traveling downstream to a safe, fish bypass route. In contrast, the outlet works for all of the storage dams are unscreened and entrainment through these outlet works can injure and kill fish. The potential for entrainment increases as reservoirs are drawn down late in the irrigation season.

4.2 FISH SPECIES AFFECTED BY YAKIMA STORAGE RESERVOIRS

The four natural lakes supported Native American fisheries for sockeye salmon and other anadromous and resident fish. Detailed information is not available for pre-Yakima Project fish populations in these lakes. However, available information suggests that all of the native species currently found in each lake — as well as those found in the river reach downstream from each dam — were historically present in the watersheds above the dams. In addition, sockeye salmon and coho salmon were present but are now extinct. Rimrock Reservoir was not a natural lake so the watershed upstream would not have supported sockeye salmon and burbot that require a lake environment; however, it is likely the river and its tributaries would have been used by the other anadromous species.

The Yakima/Klickitat Fisheries Project (YKFP) is an all-stock initiative that is responding to the need for scientific knowledge for rebuilding and maintaining naturally spawning anadromous fish stocks in both basins (Sampson 2002). It is testing the principles of supplementation as a means to rebuild fish populations through the use of locally adapted broodstock in an artificial production program. This concept is being used on spring chinook salmon and coho salmon within the Yakima River basin. The coho salmon program's principal objective is to determine if naturally spawning coho salmon populations can be reintroduced throughout their biological range in the basin. The objective of the fall chinook salmon program is to determine if supplementation is a viable strategy to increase fall chinook salmon populations in the Yakima River basin.

One purpose of YKFP is to test the hypothesis that new supplementation techniques can be used in the Yakima River basin to increase natural production and to improve harvest opportunities while maintaining the long-term genetic fitness of the wild and native salmonid populations and keeping adverse ecological interactions within acceptable limits (Sampson and Fast 2001). The Yakama Nation — along with Washington Department of Fish and Wildlife — cooperates with the Bonneville Power Administration in YKFP.

Table 4-1 lists the fish species formerly and currently found in the Upper Yakima Basin that could inhabit the watersheds upstream of the storage dams if fish passage were provided.

Table 4-1. Fish Species Found in the Five Major Storage Reservoirs in the Yakima River basin (WDFW 2002c)

Western brook lamprey	***Lampetra richardsoni***	Longnose dace	*Rhinichthys cataractae*
Pacific lamprey	***Lampetra tridentata***	Leopard dace	*Rhinichthys falcatus*
		Speckled dace	*Rhinichthys osculus*
Mountain whitefish	*Prosopium williamsoni*	Chiselmouth	*Acrocheilus alutaceus*
Pygmy whitefish	*Prosopium coulteri*	Redside shiner	*Richardsonius balteatus*
Brown trout*	*Salmo trutta*	Peamouth	*Mylocheilus caurinus*
Bull trout	*Salvelinus confluentus*	Northern pikeminnow	*Ptychocheilus oregonensis*
Brook trout*	*Salvelinus fontinalis*	Largescale sucker	*Catostomus macrocheilus*
Lake trout*	*Salvelinus namaycush*	Mountain sucker	*Catostomus platyrhynchus*
Cutthroat trout	*Oncorhynchus clarki*	Bridgelip sucker	*Catostomus columbianus*
Rainbow trout (resident)	*Onchorynchus mykiss*		
Steelhead trout	***Onchorynchus mykiss***	Burbot	*Lota lota*
Coho salmon	***Oncorhynchus kisutch***		
Spring chinook salmon	***Oncorhynchus tshawytscha***	Three-spine stickleback	*Gasterosteus aculeatus*
Sockeye salmon	***Oncorhynchus nerka***		
Kokanee salmon	*Oncorhynchus nerka*	Paiute sculpin	*Cottus beldingi*
		Torrent sculpin	*Cottus rhotheus*
		Mottled sculpin	*Cottus bairdi*

Species in Bold are no longer present.
***** = indicates species not native to the Yakima River basin

4.3 PASSAGE TIMING REQUIREMENTS FOR UPPER BASIN FISH SPECIES

In order to develop and evaluate fish passage concepts and options for both upstream and downstream migration of anadromous and resident fish, it was necessary to delineate the timing of both adult and juvenile migration for the fish species considered most likely to benefit from providing passage at dams — spring chinook, coho, and sockeye salmon; steelhead; and bull trout. Tables 4-2 and 4-3 show estimated passage timing for all species individually; Tables 4-4 and 4-5 shows all species for upstream and downstream passage. These tables were developed using the experience and professional judgment of the interagency subteam of biologists participating in the assessment, and has also been informed by available data such as the timing of salmon runs in the Lower Yakima Basin.

Juvenile salmon tend to migrate downstream during the spring (March-June) and fall (late September through November) and are least active during the winter months (December-February). Generally, spring outmigrants are juvenile fish that are seeking habitat in larger streams or rivers or are fish actively migrating to the ocean. A significant exception to this pattern is sockeye salmon, which may migrate upstream to a lake as emergent fry in search of lacustrine habitat (Burgner 1991). In fall, some juvenile fish may also migrate downstream in search of overwintering habitat.

Adult salmon and trout typically migrate upstream seeking spawning habitat. Chinook salmon and steelhead travel thousands of miles throughout their lives and may migrate to a location near their spawning habitat months before they are ready to spawn. Resident fish species such as bull trout or rainbow trout may migrate upstream or downstream throughout a river system and may undertake a protracted spawning migration. Some species, such as rainbow trout and steelhead, spawn in the spring, while other species such as salmon and bull trout spawn in the fall; thus, the time period for upstream migration for all adult salmonids combined could extend from approximately March through November. Bull trout and steelhead are iteroparous (can spawn more than once) and so adult fish could also migrate downstream after the fish have spawned. Time periods for downstream migration of iteroparous species vary, but would probably be early summer or fall, after spawning.

Although the timing of peak adult upstream migration would differ between the Naches River and the upper mainstem Yakima River, peak timing of downstream juvenile migration should be similar in both arms (table 4-5). Because of the number of salmonid species that would be involved eventually in restoration and the different expressions of their life histories, it is reasonable to assume that nearly year-round fish passage would be required, considering all five storage projects.

Table 4-2. Upstream Migration or Passage Timing for Adults (WDFW 2002c)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Spring chinook salmon								■	▒	▒	▒	■
Coho salmon	▒	▒	■									▒
Sockeye salmon										▒	▒	▒
Bull trout	▒	■	■	■	■	■	■	■	■	▒	▒	▒
Steelhead (Naches)	■	▒	▒	■	▒	▒	▒	■	■	■	■	■
Steelhead (Yakima)	■	▒	▒	■	■	■	▒	▒	▒	■	■	■

■ = General Migration Period ▒ = Peak Migration Period

Table 4-3-a. Downstream Migration or Passage Timing for Juveniles (WDFW 2002c)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Spring chinook salmon	▒	▒	▒	■	■	■	▒	▒	■	■	▒	▒
Coho salmon	▒	▒	▒	■	■	■	■	■	■	■	▒	▒
Sockeye salmon						▒	▒	▒	▒			
Bull trout	▒	▒	■	■	■	■	▒	▒	▒	■	■	▒
Steelhead (Yakima)	■	■	■	■	■	■	▒	▒	▒	■	■	■
Steelhead (Naches)	■	■	■	■	■	▒	▒	▒	■	■	■	■

Table 4-3-b. Downstream Migration or Passage Timing for Kelts and Adults (WDFW 2002c)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Steelhead kelts (Yakima)								▒	▒	▒		
Steelhead kelts (Naches)							▒	▒	▒			
Bull trout adults	▒	▒	▒	■	■	■	■	■	■	■	■	▒

■ = General Migration Period ▒ = Peak Migration Period

Table 4-4. Composite Upstream Migration or Passage Timing (WDFW 2002c)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Yakima River	▒	▒	▒	■	■	■	▒	▒	▒	▒	▒	▒
Naches River	▒	▒	▒	■	▒	▒	▒	■	▒	▒	▒	▒

■ = General Migration Period ▒ = Peak Migration Period

Note: Table represents adult passage only for spring chinook, coho, sockeye salmon; steelhead; and bull trout. Juvenile (and/or subadult) upstream passage timing for sockeye salmon and bull trout is still being researched.

Table 4-5. Composite Downstream Migration or Passage Timing (WDFW 2002c)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Basin-Wide juveniles	▒	▒	▒	■	■	▒	▒	▒	▒	■	▒	▒
Yakima River adults	▒	▒	▒	■	■	■	■	▒	▒	▒	■	■
Naches River adults	▒	▒	▒	■	■	■	▒	▒	▒	■	■	■

■ = General Migration Period ▒ = Peak Migration Period

* Juveniles for species identified above. Adults are steelhead kelts and bull trout.

4.4 BENEFITS OF PROVIDING FISH PASSAGE

Providing fish passage at Yakima River basin storage projects could increase or enhance populations of Upper Yakima Basin steelhead, coho salmon, and spring chinook salmon by restoring access to historically occupied habitat, restoring life history and genetic diversity of salmonids, allowing reintroduction of sockeye salmon back into the watersheds where they occurred historically, and reconnecting isolated populations of bull trout and other resident fish species. Over time, anadromous salmonids would be expected to recolonize the watersheds upstream from the storage dams if fish passage were provided. Bull trout abundance would be expected to expand due to enhanced connectivity and interaction among the presently isolated populations, and expanded foraging and overwintering habitat.

Sockeye salmon apparently played a substantial ecological role in the upper mainstem Yakima River; the available information suggests that the bulk of the sockeye salmon run returned to Cle Elum Lake, Kachess Lake, and Keechelus Lake. Bumping Lake on the Naches arm was a relatively small contributor to the overall population in the system. The infusion of marine-derived nutrients into the system from these returning sockeye salmon as well as other salmon species would have contributed to the overall productivity of the upper mainstem Yakima River for all species. Restoration of these sockeye salmon and other anadromous salmonid runs would help restore some of this historical nutrient input and associated increased productivity.

Kokanee occur in all lakes and apparently spawn successfully in tributaries. Some shoreline spawning is believed to occur within at least some of the lakes. Successful kokanee reproduction may indicate that restoration of sockeye salmon might be successful there.

Restoring connectivity among presently isolated populations of bull trout would allow for dispersal of fish among local populations, providing a mechanism for supporting weaker populations or refounding those that might become extirpated. It would also allow for gene flow among populations, which prevents the loss of genetic variation that insures survival in variable environments and thus decreases the probability of local extirpations.

5. TRIBUTARY HABITAT CONDITIONS

5.1 OVERVIEW

The core team assessed tributary habitat conditions upstream of the storage reservoirs. The team also considered the potential for improving connectivity among populations of native fish. The team obtained tributary stream length in miles up to natural or man-made barriers from various published reports and USFS stream surveys. The team estimated, where possible, the additional length of tributary stream that might be available if man-made barriers to fish passage, such as improperly placed culverts or other obstructions, were replaced and/or improved to allow fish passage.

The team attempted a qualitative evaluation of the spawning and rearing habitat in the tributary streams based on information on numerous environmental variables such as stream gradient, reported assessments of the quality of spawning conditions, available information on water temperature, habitat conditions including large woody debris, and pool frequency and quality. The data were collected from various agency reports and peer reviewed papers; the team also considered on-the-ground observations and experiences of the team participants. The data are discussed in greater detail in Appendix B to this Phase I assessment report. Information relating to spawning and rearing habitat for anadromous salmonids was not uniform for all tributary streams, so quantitative comparison among tributary streams was not possible.

The team did not attempt to calculate potential increases or changes in anadromous salmonid production as a result of habitat expansion upstream from reservoirs. This would have required more time and information than was available. Therefore, miles of available and potentially accessible reservoir tributary habitat was used as a surrogate for production in this Phase I assessment. It must be emphasized that environmental conditions in the Columbia River migration corridor, the estuary and the ocean will also affect the population response of anadromous salmonids in the Yakima River basin, and any population response would not likely be apparent for at least several generations, so long-term observations and monitoring would be required.

For this preliminary assessment, the team assumed that on a scale of from excellent to poor, the newly accessible habitat would be "good" overall for successful spawning and rearing in all subbasins. The team assumed the "good" habitat rating since the reported quality of the habitat in some reaches was "excellent" (with parameters that met Forest Plan standards) while other reaches of the same tributary had poorer quality habitat (and did not meet Forest Plan standards). The team felt that habitat conditions overall were about average and assigned the "good" rating. This outcome was based on information from the environmental factors matrices compiled by the fisheries subteam and on Habitat Condition Rating information extracted from Table 39 of *Habitat Limiting Factors*

(WSCC 2001). The team did not have sufficient data to distinguish on a fine scale the habitat quality differences among the different reservoir tributaries.

The fisheries subteam used existing data and information to assess tributary habitat. In this process the subteam noted that different reports sometimes reported different values for the same parameter. This was particularly problematic regarding stream length and habitat condition. Inconsistent inventory data for the same stream reach surveyed in different years is straightforward to understand and explain, since environmental conditions prevailing at the time or season the survey was conducted could influence the value of a parameter, as could intervening natural or man-caused activities such as mass wasting events or fire, or a timber harvest operation. This dilemma required using professional judgment in some cases to resolve the problem of conflicting information. An example of this situation is stream length reported for the Cle Elum River and some of its tributaries.

Estimated overall reservoir tributary stream length in miles of suitable spawning and rearing habitat that would be potentially accessible to anadromous salmonids if passage were provided at the several dams is shown in Table 5-1, and in the case of Keechelus Dam, tributary stream length available if man-made fish passage barriers such as culverts were replaced, improved, or both.

Table 5-1. Combined tributary stream length potentially accessible to anadromous salmonids upstream from five Yakima River basin storage dams if fish passage were provided

Dam	Stream length to natural or man-made barrier (miles)	Stream length available if man-made barriers removed (miles)
Keechelus Dam	13.8	16.8
Kachess Dam	2.4	TBD
Cle Elum Dam	29.4	TBD
Bumping Lake Dam	6.0	TBD
Tieton Dam	36.8	TBD

- TBD = to be determined

In the following section, we provide additional detail on individual tributaries to the five reservoirs, and discuss quantity and quality of potentially accessible tributary habitat that would likely be available to anadromous salmonids if upstream and downstream passage were provided at the dams.

5.2 TRIBUTARY HABITAT CONDITIONS BY RESERVOIR

5.2.1 Keechelus Lake — Tributaries considered include Coal, Gold, Cold, Meadow, Mill, Townsend, and Roaring creeks.

Although bull trout and anadromous salmonids may have used numerous tributary streams prior to the construction of Keechelus Dam, the only tributary to Keechelus Lake documented to have historically supported anadromous salmonids (spring chinook salmon, coho salmon, and summer steelhead) and bull trout is Gold Creek (Haring 2001), which now supports a recognized subpopulation of bull trout. There is historical evidence of presence of bull trout in Rocky Run Creek (WDFW 1983) and it is likely that populations existed historically in Meadow Creek and Coal Creek. At least three tributaries to Keechelus Lake (Meadow, Cold, and Coal creeks) have potential to be restored to support anadromous salmonids and/or bull trout; surveys circa 1994 by Central Washington University students found only cutthroat trout in these streams (Brent Renfrow, WDFW, pers. comm.).

Anadromous salmonids may have historically used the smaller tributaries (Mill, Resort, Roaring Creeks, etc.), but data are lacking. Roaring, Resort and Rocky Run Creeks are thought to be too small or steep for anadromous salmonids. The best habitat in the smaller creeks would have been in the downstream area now inundated by the reservoir (reservoir drawdown photos indicate presence of likely suitable lower gradient habitat for anadromous salmonid juveniles, and even adults when adequate flow is present).

Table 5-2 lists miles of tributary streams to Keechelus Lake potentially accessible if passage was provided at the dam, along with miles of stream potentially available upstream to natural barriers (falls, steep gradient, etc.) if man-made barriers (such as culverts) were removed.

Table 5-2. Tributary streams to Keechelus Lake with habitat considered suitable for migratory salmonids

Tributary Stream	**Potentially accessible** [miles (km)]	**Potentially accessible if man-made barriers removed** [miles (km)]	**Comments**
Meadow Creek	3.9 (6.5)	3.9 (6.5)	Waterfall limits upstream migration (USFS 1995)
Gold Creek	7.0 (11.5)	7.0 (11.5)	Primary spawning stream for Keechelus; waterfall limits upstream migration (Craig 1997)
Cold Creek	0.0	1.9 (3.2)	Railroad culvert blocks access (USFS 1992)
Mill Creek	0.2 (0.32)	1.0 (1.6)	Railroad culvert blocks access, habitat surveys may be needed
Coal Creek	2.5 (4.2)	2.5 (4.2)	I-90 culverts and stream channelization limit access
Townsend Creek	0.2 (0.32)	0.5 (0.8)	I-90 culverts limit access
Total	***13.8 (22.2)***	***16.8 (27.0)***	

- Other tributaries to Keechelus Lake were considered too small or steep to support migratory fish.

If passage were provided at Keechelus Dam, Gold Creek and Meadow Creek would be the most likely tributary habitats potentially accessible and suitable for anadromous salmonids, providing about 10.9 miles of accessible habitat. Habitat quality in the several tributaries varies, due to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet “Forest Plan” standards (USFS 1994), or passage barriers relatively close to the mouth.

In addition, passage may be impeded at times in these creeks due to low streamflow conditions. Such is the case in Gold Creek which frequently contains a dewatered reach one-to-two kilometers in length during the late summer and early fall. The length of time this condition persists is variable with sporadic reconnection occurring as a result of rainfall events and full time reconnection usually occurring by early October.

5.2.2 Kachess Lake — Nearly all the Kachess River watershed is presently inaccessible to anadromous salmonids, due to presence of Kachess Dam at RM 1. Historically, the natural lake had anadromous runs of sockeye, coho and spring chinook salmon, and steelhead. Resident fishes, including bull trout, would have had year-round access into the lake.

Table 5-3 lists the stream habitat that would be accessible to anadromous salmonids if passage were provided at Kachess Lake.

Table 5-3. Tributary streams to Kachess Lake, with habitat considered suitable for anadromous salmonids

Tributary Stream	**Potentially accessible** [miles (km)]	**Potentially accessible if man-made barriers removed** [miles (km)]	**Comments**
Kachess River	0.5 (0.8)	0	Primary spawning stream
Box Canyon Creek	1.6 (2.57)	0	Primary spawning stream; natural barrier falls
Mineral Creek	0.25 (0.40)	0	Series of cascades blocks fish passage
Gale Creek*	1.5 (2.4)	0	Barrier falls in third reach (about 1.5 miles upstream); in late summer, stream commonly goes subsurface in the lake bed and upstream
Thetis Creek*	1.0 (1.6) based on map		In late summer, stream commonly goes subsurface in the lake bed and upstream
Total	**2.35 (3.76)**		

* Since Gale Creek and Thetis Creek commonly go subsurface, they are not considered as being accessible to anadromous salmonids, and the overall tributary stream length is 2.35 miles.
• Other tributaries to Kachess Lake were considered too small or steep to support migratory fish.

If passage were provided for anadromous salmonids at Kachess Dam, about 2.35 miles of tributary habitat would be accessible upstream from the lake. Habitat quality in the several tributaries varies, due to difference in substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards. Depending on precipitation, the Kachess River is usually but not always dry near its confluence with Kachess Reservoir in late summer through late October, which may impact bull trout movement into the river. Other species (coho salmon and spring chinook salmon) would likely also be impacted by this occasional and temporary dewatering.

5.2.3 Cle Elum Lake — Cle Elum Lake is the largest of the four reservoirs in the Yakima River basin that once supported runs of anadromous salmonids. Historically, sockeye salmon used the lake for rearing and, along with coho and spring chinook salmon, the streams above the lake for spawning (Robison 1957, Mongillo and Faulconer 1982, both as cited in Flagg and Ruehle 2000). Resident fishes including bull trout would have had year-round access into the lake.

The lake has a large and diverse watershed with numerous tributaries, three of which (the Cle Elum, Cooper, and Waptus Rivers) contain a large amount of potential spawning habitat for anadromous salmonids and bull trout (Spotts 1981, cited in Slatick and Park 2000; Thomas, FWS, 2003, pers. comm.). A series of steep cascades on the Cle Elum River (about RM 9) is a potential upstream barrier to fish passage, but it may be passable under certain flow conditions. The Cooper River has a barrier approximately 0.6 mile (1 km) upstream from Salmon La Sac, while Waptus Falls at about RM 7.2 in the Alpine Lakes Wilderness Area is a barrier on the Waptus River.

Table 5-4 lists the stream habitat that would be potentially accessible to anadromous salmonids if passage were provided at Cle Elum Lake.

Table 5-4. Tributary streams to Cle Elum Lake with habitat considered suitable for migratory salmonids

Tributary Stream	**Potentially accessible** [miles (km)]	**Potentially accessible if man-made barriers removed** [miles (km)]	**Comments**
Cle Elum River	21.6 (34.6)		Steep cascades at RM 9 may impede upstream fish migration
Thorp Creek	0		Barrier cascades and high gradient in lower reach
Cooper River	0.6 (1)		Barrier falls
Waptus River	7.2 (11.5)		Impassable falls
Total	**29.4 (47.0)**		

• Other tributaries to Cle Elum Lake were considered too small or steep to support migratory fish.

The combined length of tributary streams potentially available upstream from Cle Elum Dam if fish passage were provided was complicated by the fact that the several reports available provided different estimates of the habitat potentially available in the Cle Elum River. For example, Flagg et al. (2000) reported that “Cle Elum Falls” (considered by local fisheries biologists as a series of cascades), about 9 miles upstream from the full pool end of the reservoir, would block adult fish migration under most water flow conditions. However, Haring (2001) stated that migratory fish would have access to 18.4 miles of Cle Elum River habitat up to Hyas Lake, and Croci (FWS, Yakima, WA, pers. comm., 2002) reported Cle Elum River length as 21.6 miles. Since adult anadromous salmonids are generally strong swimmers, it is reasonable to expect that some fish would be able to negotiate the cascades at RM 9 and access the river upstream, based on the description of this area as a series of small falls with a maximum height of about 3 m (≈10 feet).

If passage were provided for anadromous salmonids at Cle Elum Dam, about 29.4 miles of tributary habitat would be accessible upstream from Cle Elum Lake. Habitat quality in the several tributaries varies, due in some cases to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards.

5.2.4 Bumping Lake — Table 5-5 lists the stream habitat that would be accessible to anadromous salmonids if passage were provided at Bumping Lake.

Table 5-5. Tributary streams to Bumping Lake with habitat considered suitable for migratory salmonids

Tributary Stream	Potentially accessible [miles (km)]	Potentially accessible if man-made barriers removed [miles (km)]	Comments
Bumping River	1.0 (1.6)		Waterfall limits upstream migration (USFS 1995)
Deep Creek	5-5.6 (8-9)		Upper 0.5 miles goes subsurface in low water years
Total	**6-6.6 (9-10.6)**		

• Other tributaries to Bumping Lake were considered too small or steep to support migratory fish..

If passage were provided for anadromous salmonids at Bumping Lake Dam, about 6 miles of tributary habitat would be accessible upstream from Bumping Lake. Habitat quality in the several tributaries varies, due to differences in substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards.

5.2.5 Rimrock Lake — Table 5-6 lists the stream habitat that would be accessible to anadromous salmonids if passage were provided at Rimrock Lake.

Table 5-6. Tributary streams to Rimrock Lake with habitat considered suitable for migratory salmonids

Tributary Stream	Potentially accessible [miles (km)]	Potentially accessible if man-made barriers removed [miles (km)]	Comments
South Fork Tieton River	13.5 (21.6)		Falls at 13.5 mi. limits upstream migration
Short and Dirty Creek	0.1 (0.16)	0	Natural barrier limits upstream migration
Corral Creek	2.2 (3.5)		Falls at 2.2 mi. limits upstream migration
Bear Creek (SF Tieton)	0.5 (0.8)		Natural barrier limits upstream migration
Bear Creek (Rimrock)	3.7 (5.9)	0	High sedimentation
NF Tieton River	9.9 (15.9)		Falls at 9.9 mi. limit upstream migration
Clear Creek	2.0 (3.2)		Barrier falls limit upstream migration
Indian Creek	4.9 (7.8)	0	Falls at 4.9 miles limit upstream migration
Total	**36.8 (59)**		

• Other tributaries to Rimrock Lake were considered too small or steep to support migratory fish.

6. PASSAGE CONCEPTS

6.1 INTRODUCTION

This section is a reconnaissance-level assessment of the engineering requirements for concepts that could provide passage for anadromous salmonids and bull trout at the five Project storage dams. The dams reviewed are Keechelus, Kachess, Cle Elum, Bumping Lake, and Tieton. The report is prepared to collect and analyze the hydrologic data and information on the existing features of each of the dams and then to determine potential upstream and downstream fish passage options.

As a starting point for this assessment the team members reviewed the Reclamation report *Appraisal Design Study, Keechelus Dam Fish Passage* (2001a). Based on the review and comments received, several of the upstream and downstream passage concepts were included in this report. Several other concepts involving downstream passage were reviewed and considered but not pursued further. These will be discussed in Section 6.5.5 – Other Downstream Fish Passage Concepts.

In general, fish passage at each of these dams is complicated by the large fluctuation of reservoir water surface elevations. Typically, the reservoirs begin to fill at the start of the water year (October), reach maximum water surface elevation in the spring (at the start of the irrigation season), and are drawn down through the remainder of the year. Depending on the reservoir, the annual difference in elevation can be as much as 120 feet. Under these conditions, a traditional fish ladder would not function because of large water surface differential on the headwater to the ladder.

The passage concepts in this report describe means of providing fish passage that is exacerbated by the problem of high water surface elevation fluctuations. Some concepts would provide fish passage over the entire range of elevations. Others are designed to operate over a specific and more limited range of elevations that would result in shorter time periods when passage could be provided.

6.2 FISH PASSAGE DESIGN CONSIDERATIONS

A number of physical, hydrological, and biological considerations are involved in the analysis of a fish passage concept. The biological considerations are related to the species targeted for passage, the periods when passage is required, and other issues that are presented elsewhere in this assessment report.

Considerations for upstream passage of adult fish involve providing passage facilities that would minimize delays and would aid in their upstream migration. This would be accomplished by providing adequate attraction flow to the fish passage system, maintaining proper hydraulic conditions in the system, and locating and designing the passage exit to aid fish egress.

Considerations for downstream passage of juvenile fish involve attracting and capturing them within the reservoir and then transporting them to the river. The method of transportation to the river should minimize delay and injury to fish. For design purposes, the attraction flow for upstream passage was assumed to be 10 percent of the release flow from the reservoir. During the irrigation season, this amount of water would not constitute an additional impact on storage.

The attraction flow necessary to attract downstream migrants is a function of site-specific variables such as reservoir orientation, surface currents, depth of existing outlet works, reservoir water surface elevation, and spill from the existing spillway. The features described in this report for downstream passage are designed with the assumption of an attraction flow that is 20 percent of the reservoir release flow. However, an attraction flow that is a higher percentage of the release flow could be used in the design but would likely increase the capital cost of construction.

The percentage of the reservoir releases used as attraction flow for either upstream or downstream passage design methods is assumed to be a percentage of the normal operational releases from the reservoir. The fish passage systems do not require additional releases from storage.

In developing new fish passage operations and structures at Project storage reservoirs, the winter hydrology and/or conditions under which these facilities would need to operate must be carefully considered. All of the storage reservoirs have frozen-over solid some times in the past. In many years, this layer of ice will support light vehicle traffic and in most years the snowpack. Generally, the snowpack in the Keechelus reservoir area ranges from 15 inches (early December) to 105 inches (early April); in the Cle Elum reservoir area, it ranges from 8 inches (early December) to 42 inches (early March); and in the Bumping reservoir area, it ranges from 17 inches (early December) to 90 inches (early April). The cold, snowy conditions would not necessarily preclude the development of fish passage at the dams; however, when designing and installing fish passage features, the winter conditions and associated impacts on operations and maintenance (O&M) activities must be taken into account.

6.3 GENERAL INFORMATION

The five dams studied in this assessment were constructed in the early 1900s to provide irrigation water to the areas adjacent to the Yakima River. None of the dams have power generation facilities. Specific information relative to each dam was presented in Chapter 3.

6.3.1 Hydrologic Data — The assessment team obtained data for reservoir water surface elevations and reservoir releases from Reclamation's Hydromet Archive data base. We selected the period 1994-2001 for this Phase I assessment. Flip-Flop and Mini Flip-Flop operations of the Project began in 1994, and the period also contains representative high, low, and normal water years. These data are presented in Appendix D, Figures 1 through 5, with a pair of hydrographs for each dam.

The upper graph shows "actual reservoir water surface elevation versus time" for WY 1994-2001. This demonstrates how the reservoirs fluctuate seasonally and typical high and low water elevations. The horizontal lines at specific elevations show levels at which fish passage would be provided for various concepts (these concepts are discussed below). The "Time Period for Juvenile Passage" is also shown; this is the "window" when juvenile passage is required; these were previously established and are summarized in Table 4-5. The lower graph shows the actual outflows, or reservoir releases, for the same time period.

6.3.2 Attraction Flows — An adequate attraction flow is a critical design consideration for fish passage. As discussed in Section 6.2, the attraction flow for adult upstream passage is assumed to be 10 percent of the release flow from the reservoir and 20 percent of the release flow for juvenile downstream passage. The release flow or reservoir outflow can be expressed as a percent exceedance flow, or percentage of the time the flow is equaled or exceeded. Exceedance flow data are shown on Figure 6 (in Appendix D) for various reservoir water surface elevations at each dam. Some of the passage concepts provide passage at specific reservoir water surface elevation ranges. The data in Figure 6 are used to determine the reservoir outflows for the concepts at each dam.

6.4 UPSTREAM FISH PASSAGE CONCEPTS

The methods for providing upstream passage for anadromous salmonids examined in this report include trap-and-haul, fish ladder with pumped flow, and a traditional fish ladder. A general discussion of each concept is provided below. Site-specific information for applications at each dam is presented later in this report.

6.4.1 Trap-and-Haul — The trap-and-haul is a conventional but labor intensive method that has been used at other sites in the past. Fish swimming upstream are attracted into a collection facility where they can be captured and then transported over the dam, usually by trucks equipped with tanks and water-quality equipment.

As previously discussed, an attraction flow for upstream passage of a minimum of 10 percent of the flow would be provided. This concept also assumes the use of a barrier dam to provide the attraction flow and to prevent upstream migrants from swimming past the collection facility. The barrier dam would span the width of the river downstream from the storage dam and would be designed to produce approximately a 10-foot water-surface differential to function as a physical barrier to upstream migrating fish.

The entrance to the collection facility consists of a short section of fish ladder. Flow to the ladder is provided by the head differential created by the barrier dam. Fish swim up the ladder and into a fish collection facility; this might include holding ponds, sorting and tagging areas, crowder, hopper, and truck-loading area. After the fish are collected in a hopper, they would be loaded on a truck, transported, and released upstream from the dam. The fish could be released into the reservoir or tributary streams.

The cost of this concept includes the construction of a barrier dam, collection-and-trap facility, and haul roads, and the purchase of transportation trucks. The total estimated construction cost of this concept is about $7 million. (Site-specific conditions that might cause some cost variations among sites were beyond the scope of this Phase 1 assessment.)

The primary annual operation and maintenance (O&M) cost for the trap-and-haul concept is for personnel to operate the facility. This assumes two people working 8-hour days and 7-day weeks for 10 months, the time period when passage is required. Additional O&M costs include the operation of a haul truck, electric power at the trap facility, routine maintenance of facility and haul roads, and replacement costs for pumps (and other facility equipment), all assumed to have a 20-year operational life. The total estimated annual O&M cost is $250,000.

A trap-and-haul system offers several advantages. Upstream migrants can be released at a variety of locations in the reservoir or tributary streams, depending on fish management considerations. The facilities can also be used for monitoring, gathering biological data, and evaluating fisheries restoration objectives. A disadvantage of this type of system is that it requires personnel and their associated costs to operate the system and requires handling the fish.

6.4.2 Fish Ladder with Pumped Flow — This concept uses a traditional fish ladder to the top of the dam and a flume (slide) that slopes down to the reservoir. Ladder flow would be pumped from the river to the top of the dam.

The concept has the same requirements of attracting fish to the entrance of the ladder as described above for the trap-and-haul concept. A barrier dam would also be used for this concept to attract fish to the ladder entrance. The ladder could be a pool-and-weir, vertical slot, or orifice type.

A typical ladder for this concept would begin at the barrier dam in the river and extend to the crest of the dam at either abutment. A “false weir” would be at the top of the ladder on the crest of the dam. Pumped flow would enter the ladder at the weir with the majority of the water flowing down the ladder. A portion of the water would flow over the reservoir side of the weir. When fish jump over the weir, they enter a chute that extends into the reservoir. The lower end of the chute is at the reservoir minimum pool elevation. Fish exit the chute at the current reservoir water surface elevation.

For purposes of this assessment, the pumping structure would be located in the river downstream from the dam. The intake to the pump would be screened to meet juvenile fish screen criteria. The large fluctuation in the reservoir water surface elevation would make the placement of pumps on the upstream side of the dam difficult (but not impossible). The pipe from the pump structure to the false weir would be located next to the ladder.

The cost to construct this concept would include the cost to construct the fish ladder, pump with pump structure, fish screen on the pump intake, pipeline, and chute. The total estimated cost of this concept is approximately $8.5 million with some possible variations from site to site that are beyond the scope of this Phase 1 assessment.

Most of the O&M cost for the fish ladder with pumped flow is the cost of electricity to pump water for the ladder flow from the river to the top of the dam. It was assumed that the pumps would run continuously for a 10-month operating season and costs would vary depending on the height of the dam. Additional costs for this concept include inspection and minor work, assuming 1 staff-hour every other day for the 10-month operating season; routine maintenance of the system; and replacement costs for the pumps and motors with a 20-year operational life. Depending on the site, the total estimated annual O&M costs range from $210,000 to $380,000.

The advantage of this concept is that it does not require on-site, full-time personnel to operate the system for passage to function. Fish are provided volitional upstream passage opportunities. The system would also have minimal debris problems since all ladder flow would be pumped. Disadvantages include high O&M costs due to the need to provide pump flow to the top of the ladder continuously. If the pumps were to fail or if there were a power failure, fish ascending the ladder could become stranded. The length of the ladders and number of pools might be a concern for passage of some species of fish.

6.4.3 Fish Ladder — A traditional gravity flow fish ladder using a series of stepped pools with orifices may be feasible at Bumping Lake Dam. The reservoir's annual water surface fluctuation is approximately 34 feet. At the other dams, water surface differentials range between 60 and 120 feet. A description of the ladder is presented in Option 7.4.2. "Bumping Lake Dam Upstream Fish Passage – Fish Ladder."

The cost involved with this concept would primarily be the cost of the construction of the fish ladder which is estimated to be $11 million.

The O&M cost for the traditional fish ladder would be much less than the fish ladder with pumped flow because there are no pumping costs or pumps to maintain and replace. The associated costs include inspection every other day for one person for one hour for the 10-month operating season, routine maintenance, debris removal, minor repairs, and replacement costs for gates and valves assuming a 20-year life. The total estimated annual O&M cost for this concept is $15,000.

The advantage of this concept is that it would not require staff to operate the system. It would only require periodic cleaning of trashracks, minor maintenance, and adjustments to gates and valves to account for changes in the reservoir elevation. The gate and valve adjustment could be automated.

6.5 DOWNSTREAM FISH PASSAGE CONCEPTS

The methods for providing downstream fish passage examined in this Phase 1 assessment include surface spill with modification to the existing spillway, construction of new spillways, use of a fish collection barge, and construction of new outlet works. A general discussion of each concept is presented below. Site-specific information and the application of concepts at each dam are presented later in this report.

6.5.1 Spillway Modifications — Several concepts at each dam would involve downstream passage through the use of "overshot gates," which operate by spill over the top. At Cle Elum Dam, fish were not attracted to the spill from submerged radial gates (NMFS 2000). This concept would provide surface releases that would attract fish and then encourage them to pass out of the reservoir. No additional water would be required since the surface spill would be taken from normal operational releases. Operational releases from the reservoir would be maximized at the surface spill system and any additional flow beyond the design capacity of the overshot gate would be released from the existing outlet works. Releases from the outlet works are in deep water and would not likely cause a false attraction for juvenile fish away from the overshot gate. If there is a temperature problem in the river downstream from the dam caused by flow from the surface spill only, releases from the outlet works would be used for part of the total release. It is assumed that during periods of the year with ice on the reservoir, the Spillway Modifications concept would not operate and reservoir releases would be made only from the outlet works.

An existing spillway would be modified by the installation of gates or by the addition of gates for those dams with uncontrolled spillways. At least four manufacturers market adjustable-crest overshot-type gates that could be used for these installations. These gates include Langemann (adjustable horizontal bi-fold gates that spill over the top), Obermeyer (weir gates, a steel panel adjusted by an air-inflated, reinforced rubber bladder), Rodney Hunt (crest gates, a steel panel operated by hydraulic cylinders from above), and Waterman (downward operating slide gates or roller gates).

Surface spill concepts would involve the construction of gates at a lower elevation on the spillways than the existing gates; this would allow a surface release of water to lower elevations. Many of these concepts require the excavation of entrance channels upstream from the spillways. Further geologic investigations as to the implications of these excavations on the embankments would be required. The Spillway Modifications concept and the other downstream passage concepts are assumed to require the installation of trashracks to remove debris.

The estimated construction costs for this concept vary by dam and by the type of system used. These are summarized in Table 7-1 and listed in the subsection in Chapter 7 describing each option. The estimated costs range from $1.7 million (Bumping Lake Dam) to $5.0 million (Kachess Dam).

The O&M costs for this concept are relatively minor. The costs are assumed to include inspection and debris removal every other day by one person for the 10-month operating season, routine maintenance and repairs, and replacement costs of the gates assuming a 20-year life. The total estimated annual O&M cost for this concept is $20,000.

These downstream passage concepts have three main advantages — they would be relatively simple to construct, less expensive than other concepts, and easier to operate and maintain. Their biggest disadvantage is that they do not permit passage over the entire range of reservoir water surface elevations, and therefore limit the overall time during which passage would be provided. This will be discussed in more detail for each specific concept at each dam.

6.5.2 New Fish Spillway — The New Fish Spillway operates under the same principle as the Spillway Modifications. The idea of this concept is to provide surface-spill releases at lower reservoir elevations than could be obtained by modifications to the existing spillways. NMFS (2000) noted:

> "…safe exit routes from the reservoir through reconfiguration of the radial gates at Cle Elum Dam and through installation of floating surface weirs were unsuccessful … an adequate smolt bypass system will probably need to be configured at elevations of at least 10+ m below the current spilldeck elevation."

For this concept, a new fish spillway would be located adjacent to existing spillways. The existing spillways would remain in place and operational, and no additional water would be required for the new fish spillway. It is assumed that normal operational reservoir releases would be made by maximizing flow through the fish spillway. Any additional required water would be released through the outlet works. Depending on the proportion of flow between the new fish spillway and the outlet works, the deep-level release through the outlet works would likely not be a false attraction flow for juvenile fish away from the fish spillway.

The New Fish Spillway concepts typically contain a series of gates at various elevations. The gate at the current water surface reservoir elevation would be opened to provide a surface spill into the spillway. The New Fish Spillway concept allows a release of water at lower elevations than the modified spillway concepts. This requires excavations into the abutments and deeper channel excavations upstream into the reservoirs. Further geologic investigations as to the implications of these excavations on the embankments are required.

The estimated construction costs for this concept vary by dam. They are summarized in Table 7-1 and listed in the subsection in Chapter 7 describing each option. The estimated costs range from $4.6 million (Bumping Lake Dam) to $42 million (Tieton Dam).

The O&M costs for this concept are expected to be about the same as stated previously for the Spillway Modifications concept. The same assumptions and cost items apply. The total estimated annual O&M cost is approximately $20,000.

The advantages of the New Fish Spillway Passage concept would be similar to the Spillway Modification concept — relatively simple to construct, less expensive than some other concepts, and easier to operate and maintain.

The disadvantages are also similarly — it would not permit passage over the entire range of reservoir water surface elevations and it is limited in the overall time during which passage would be provided. However, this concept would offer a greater range of passage than the Spillway Modification concepts. Specific elevation ranges will be discussed in more detail for each specific concept at each dam.

6.5.3 Fish Collection Barge — This system consists of a barrier net (to guide fish), a collection (or “gulper”) barge with pumps, an underwater bypass pipe, and a holding barge. The concept was modeled after existing facilities at Upper Baker Dam (on the Baker River in western Washington and owned by Puget Sound Energy). Drawing 11 shows a detail of the system as envisioned at Keechelus Dam.

A small-mesh guide-net would extend across the reservoir and direct fish toward a collection barge positioned to use outlet works flow for additional attraction. A log boom on the upstream side of the net would help protect it from floating debris. The net at the Upper Baker Dam has been used without major debris problems; however, it was reported that the orientation of the reservoir is such that debris does not drift toward the dam. This is not the case at all Project dams. Guide nets would be difficult if not impossible to manage at some sites due to debris and ice (Ken Bates, WDFW, pers. comm.). Significant debris drifts onto the dam at Keechelus Reservoir.

The collection barge would be similar in function to a fish screen. The barge’s main pumps would be located at its downstream end and would draw an attraction flow into the upstream end (front) of the barge and through a sloping screen. The main pumps would be sized to draw 20 percent of the 10-percent exceedance flow release from the reservoir (figure 6 in appendix D). The sloping screen would meet current screen criteria for juvenile fry-sized fish. The portion of the attraction flow containing the fish would be diverted over the screen into a flume. Smaller pumps would then draw the flow through a second screen, further reducing the flow containing the fish. The fish would then be diverted into a collection hopper. A bypass pipe at the base of the hopper would convey the fish to a holding barge, equipped with a crowder and hopper.

The holding barge would be located in the low-reservoir channel in front of the outlet works. A bridge to the barge would be required from the crest of the dam to a point near the outlet works. A jib crane at the end of this bridge would be used to lift the fish hopper to a truck on the bridge. The truck would then transport fish for release in the river downstream from the dam. This would be a water-to-water transfer.

The primary cost for this concept is the cost of the fish collection barge and holding barge. Additional costs include the bridge on the dam embankment and trap and haul system. The total estimated cost for this concept is $11 million (for each of the five storage dams).

In calculating the O&M costs for the Fish Collection Barge concept, it was assumed that the barge would be operated 8 hours per day for a 10-month operating season. Two people would be required to operate the facility. Other O&M costs include annual maintenance on the barge, electric power to operate the attraction flow pumps, and replacement cost of the barge assuming a 20-year life. The total annual estimated O&M cost for this concept is $340,000.

The advantage of the Fish Collection Barge concept is that it can provide downstream passage for the full range of water surface elevations in the reservoir. This would allow passage over the entire downstream passage window, except for extreme winter conditions.

There are several disadvantages. One is that during the time of the year when the reservoir may be iced over, the barge would have to be removed or winterized. Another disadvantage is that it requires personnel to operate the barge and trap-and-haul system during the entire time that passage is required. Also, reservoir debris conditions simply may preclude this concept at some sites.

6.5.4 New Outlet Works — This concept is a stationary collection structure that provides an attraction flow to draw downstream migrants to the structure. Fish are separated from the attraction flow by a screen and are then transferred with a bypass flow that moves them into a collection chamber. From there, they are moved below the dam by one of two methods; either through a pipe or a trap-and-haul system.

Drawing 12 shows a detail of this concept as envisioned at Keechelus Dam. The concept was modeled after a fish passage facility being designed by the Army Corps of Engineers for Howard Hanson Dam on the Green River in western Washington. The system shown on Drawing 12 uses an adjustable "collection horn" that can be raised or lowered by a hoist to adjust to the level of the reservoir. (The Howard Hanson design has recently been revised to replace the adjustable collection horn with a series of smaller vertically aligned stationary screens.)

The existing outlet works would remain in place and operational. No additional water release would be required. Normal operational releases would provide the attraction flow used in the new outlet works.

The system is also designed to minimize detrimental impacts to fish. For example, the water surface elevation in the fish collection chamber can be controlled to minimize the free-fall distance the fish travel after being screened out to drop into the chamber. For the alternative of using a pipe to transport fish below the dam, an acceptable velocity of the flow in the pipe can be maintained by controlling the water level in the fish collection chamber when the fish are released.

The costs involved for this concept include the cost of the outlet works structure, the costs of collection and modular inclined screen, hoist system, numerous piping systems, valves, and controls.

The estimated costs for this concept vary by dam. These costs are summarized in Table 7-1 and listed in the subsection in Chapter 7 describing each option. The estimated constructions costs of this concept range from $20 million (Bumping Lake Dam) to $25 million Keechelus, Kachess, and Cle Elum dams).

As previously discussed, this concept provides for two methods to transport fish downstream from the dam. One is to move the fish in a bypass flow with a pipe that extends through the existing outlet works. This method would not require personnel to operate the system. The second method would be to collect the fish in a trap within the new outlet works and use a trap-and-haul method to move the fish downstream from the dam. This method assumes two people working 8 hours per day for a 10-month operating season. Other O&M costs that are common to both methods are routine maintenance of facility components; electric power for lights, controls, and other systems; and replacement cost of the major components, such as collection horn, rubber dam, and modular inclined screen. These items are assumed to have a life of 20 years. The estimated annual O&M costs for the bypass pipe option is $110,000; annual O&M for the trap-and-haul option is estimated to be $320,000.

Like the fish collection barge concept, the main advantage of this concept is that it could provide downstream passage over the full range of water surface elevations in the reservoir. This would allow downstream passage over the entire passage window. This concept would also be less susceptible to problems with winter icing conditions and with debris than the barge concept. The biggest disadvantage would be the construction cost of a large structure in the reservoir; that would likely require a low reservoir pool elevation combined with extensive cofferdams.

6.5.5 Other Downstream Passage Concepts — Several additional methods were considered in the *Appraisal Design Study, Keechelus Dam Fish Passage* (USBR 2001a) but were not pursued further in the Phase I assessment for various reasons. These include:

- ***Fish collection barge with a fish conveyance pipe* —** This concept would use the fish collection barge (as described above) with a conveyance pipe through the dam to transport the fish downstream to the river. The main objection to this method is the inability to maintain hydraulic conditions inside the pipe that are within juvenile bypass pipe criteria. Because of the fluctuating reservoir water surface elevation, the flow depths and velocities would vary widely.
- ***Multiple level intake gates with multiple bypass pipes* —** This concept would use a collection structure with juvenile fish intakes at multiple levels in the reservoir. The intakes connect to several bypass pipes at multiple levels that extend through the dam. The concept was dropped because the pipes through the dam are a dam-safety concern due to potential leakage or failure of the pipe, which could result in erosion of the embankment and catastrophic failure of the dam.
- ***Multiple-level intakes with bottom flow energy dissipation wells* —** This concept would use the same type of multiple-level collection structure as described above with a series of interconnected vertical shafts (or well-type structures) and a single pipe through the dam. The wells are connected at the base and would dissipate the hydraulic head from a high reservoir water surface elevation and then move fish in the pipe through the dam at a reasonable velocity. This concept was rejected because of the dam-safety issue with the pipe through the dam, debris problems in the wells, and turbulence in the system.
- ***Multiple level intakes with top flow energy dissipation wells* —** This is the same as the previously described concept, except that the wells are connected at the top. The same concerns apply.

7. UPSTREAM AND DOWNSTREAM FISH PASSAGE OPTIONS BY DAM

The following section contains descriptions of each of the upstream and downstream passage options examined at each of the dams. Each option uses one of the previously described concepts or a variation of the concept. Figures and Drawings are located in Appendix D. Table 7-1 summarizes the estimated construction and annual O&M costs of the various concepts.

Table 7-1. Estimated costs of upstream and downstream passage options

	Concept Construction Cost (in $1 millions) **Estimated Annual O&M** (in $1,000s ["k"]) *(Concept No.)*				
Upstream Passage					
	Keechelus	**Kachess**	**Cle Elum**	**Bumping Lake**	**Tieton**
Trap-and-Haul	Const = $7.0 O&M = $250k *(7.1.1)*	Const = $7.0 O&M = $250k *(7.2.1)*	Const = $7.0 O&M = $250k *(7.3.1)*	Const = $7.0 O&M = $250k *(7.4.1)*	Const = $7.0 O&M = $250k *(7.5.1)*
Fish Ladder with Pumped Flow	Const =$8.5 O&M = $260 *(7.1.2)*	Const =$8.5 O&M = $210k *(7.2.2)*	Const =$8.5 O&M = $380k *(7.3.2)*		
Fish Ladder				Const =$11.0 O&M = $15k *(7.4.2)*	
Downstream Passage					
Spillway Modifications	Const =$3.5-4.5 O&M = $20k *(7.1.3; 7.1.4)*	Const = $5.0 O&M = $20k *(7.2.3)*	Const = $2.2 O&M = $20k *(7.3.3)*	Const = $1.7 O&M = $20k *(7.4.3)*	Const = $2.5 O&M = $20k *(7.5.2)*
New Fish Spillway	Const =$8.0 O&M = $20k *(7.1.5)*	Const =$10.0 O&M = $20k *(7.2.4)*	Const =$10.0 O&M = $20k *(7.3.4)*	Const =$4.6 O&M = $20k *(7.4.4)*	Const =$42.0 O&M = $20k *(7.5.3)*
Fish Collection Barge	Const =$11.0 O&M = $340k *(7.1.6)*	Const =$11.0 O&M = $340k *(7.2.5)*	Const =$11.0 O&M = $340k *(7.3.5)*	Const =$11.0 O&M = $340k *(7.4.5)*	Const =$11.0 O&M = $340k *(7.5.4)*
New Outlet Works	Const =$25.0 *O&M = $320k *(7.1.7)*	Const =$25.0 O&M = $320k *(7.2.6)*	Const =$25.0 O&M = $320k *(7.3.6)*	Const =$20.0 O&M = $320k *(7.4.6)*	
* O&M cost for the downstream trap-and-haul method from the New Outlet Works					

7.1. KEECHELUS DAM – UPSTREAM AND DOWNSTREAM FISH PASSAGE OPTIONS

Keechelus Dam was the first facility examined in this overall assessment. The full range of upstream and downstream passage concepts were analyzed. Many of the concepts described are applied at the other dams; however, detailed descriptions and drawings are not repeated.

Option 7.1.1 Keechelus Dam Upstream Passage – Trap-and-Haul — This option is shown on Drawing 1. The barrier dam and fish collection facility are located in the river downstream from the point where the spillway channel enters the river. This is to prevent upstream migrants from swimming up the spillway channel and missing the fish trap facility. However, this would eliminate a reach between the barrier and the dam about 1 mile long. As an alternative, the barrier could be placed closer to the dam and a second barrier placed in the spillway channel.

A haul route would be built along the left bank of the river, extending to the left abutment of the dam. A ramp would be constructed from the crest of the dam down to the reservoir from which the fish transportation truck would back down to release fish into the reservoir. The alignment of the haul route (as shown on Drawing 1 in Appendix D) may pass through an area currently used as a materials borrow source for the Safety of Dams project work. This area is planned to be restored as a wetlands mitigation area. The final alignment of the haul route would be adjusted to minimize impacts to the wetlands.

The estimated construction cost for this option is $7 million.

Option 7.1.2 Keechelus Dam Upstream Passage – Fish Ladder with Pumped Flow — This option is shown on Drawing 2. A barrier dam would be constructed in the river at the ladder entrance to provide attraction flow into the ladder and prevent fish from swimming past the ladder entrance. The ladder would extend to the crest of the dam on the left abutment. However, a segment of the ladder might align through the wetlands mitigation area; if so, impacts would be minimized as much as possible. Fish would swim up the ladder to the false weir at the crest of the dam and then jump over the false weir into a chute that flows to the reservoir. Excavation of a channel at the end of the chute would be required for periods of low-reservoir-elevation.

The pump structure for the pumped ladder flow is located in the river just downstream from the end of the outlet works conduit. The ladder discharge pipe from the pump station to the false weir would be aligned next to the ladder.

The estimated construction cost for this option is $8.5 million.

Option 7.1.3 Keechelus Dam Downstream Passage – Modify Spillway with Single Level Gates — This option is shown on Drawings 3, 4, and 5. Drawing 3 shows the location of the spillway modifications and the extent of the channel excavations required for this option. Drawings 4 and 5 show the details of the modifications to the existing spillway. This option consists of four downward-operating slide gates that would allow a surface spill from the reservoir from above elevation 2507 feet. Figure 1 illustrates the timing and duration of downstream passage that would have occurred if this passage option was in place during WY 1994-2001.

After flow passes over the gates, it would enter a pool that is excavated in the spillway channel. A low-flow channel would be excavated downstream from the pool. The velocity for this flow would be approximately 6 feet per second.

The estimated construction cost for this option is $ 3.5 million.

Option 7.1.4 Keechelus Dam Downstream Passage – Modify Spillway with Multiple Level Gates — This option is shown on Drawings 6, 7, and 8. It would be essentially the same as Option 7.1.3 above, except that gates would be placed at multiple levels to permit a surface spill release from the reservoir at a lower elevation.

This option would allow a release from the reservoir to elevation 2497 feet and above. Figure 1 shows the time periods for downstream fish passage for this option. Drawing 6 shows the extent of the approach channel excavation required for the lower level discharge. The spillway modifications required would be similar to the Option 7.1.3.

The estimated construction cost for this option is $4.5 million.

Option 7.1.5 Keechelus Dam Downstream Passage – New Spillway — This option would be a new spillway adjacent to the existing spillway (as shown on Drawing 9). The spillway would include multiple-level gates to provide a surface spill discharge out of the reservoir from elevation 2480 feet and above. Figure 1 shows the time period when downstream passage would occur for this option.

Emigrating fish would enter the spillway through one of the downward operating slide gates and spill into a pool. The gate and pool in use depends on the water surface elevation in the reservoir. Water would flow out of the pool and into a chute. The chutes would merge into one chute at the downstream end that would then convey fish to the existing spillway channel and back into the Yakima River.

The estimated construction cost for this option is $8 million.

Option 7.1.6 Keechelus Dam Downstream Passage – Fish Collection Barge — This option would be the application of the fish collection barge described in Section 6.5.3 above. Drawing 10 shows the placement of the barges in front of the outlet works at Keechelus Dam. Drawing 11 shows sections and details of the system. This system could be used for downstream passage of fish through the entire range of reservoir water surface elevations.

This option would require the construction of an access bridge on the dam embankment. A jib crane on the bridge would be used to lift the hopper containing fish from the fish collection barge. The fish would then hauled by truck from the bridge to a release point downstream from the dam.

The estimated construction cost for this option is $11 million.

Option 7.1.7 Keechelus Dam Downstream Passage – New Outlet Works — Drawing 12 shows the new outlet works option at Keechelus Dam. The outlet works would function as previously described. This system could be used for downstream fish passage over the entire range of reservoir water surface elevations.

Two options for moving the fish downstream were previously described — a pipe extending through the outlet works conduit or a trap and fish-transfer hopper that could be lifted out and hauled downstream from the dam by truck (section 6.5.4). The outlet works conduit at Keechelus Dam consists of an open-channel flow conduit with room at the top of the conduit for a fish bypass pipe, so that method is presented for this dam.

The estimated construction cost for this option is $25 million.

7.2 KACHESS DAM – UPSTREAM AND DOWNSTREAM PASSAGE OPTIONS

The full range of upstream and downstream passage concepts used previously at Keechelus Dam are applied at Kachess Dam. They are as follows.

Option 7.2.1 Kachess Dam Upstream Passage – Trap-and-Haul — This is assumed to be the same as Keechelus Dam Option 7.1.1. No drawing is provided. The estimated construction cost for this option is assumed to be about the same as for Keechelus Dam, $7 million.

Option 7.2.2 Kachess Dam Upstream Passage – Fish Ladder with Pumped Flow — This is assumed to be the same as Keechelus Dam Option 7.1.2. No drawing is provided. The estimated construction cost for this option is assumed to be about the same as for Keechelus Dam, $8.5 million.

Option 7.2.3 Kachess Dam Downstream Passage – Modify Spillway Gate — This option is shown on Drawing 13. It would be a fairly simple modification to the existing spillway at Kachess Dam that would allow a surface spill release from the reservoir from elevation 2254 feet and above. Figure 2 shows the time period when downstream passage could occur with this option.

The spillway at the dam contains a single 8-foot-high by 50-foot-wide radial gate. This option assumes replacing the radial gate with a “Rodney Hunt” crest gate that would discharge water over its top. Water would then flow down the existing spillway. A modification to the spillway invert by constructing a V-shaped channel would provide increased flow depth at minimum flow.

The estimated construction cost of this option is about $5 million.

Option 7.2.4 Kachess Dam Downstream Passage – New Spillway — This option would include construction of a new spillway in an abandoned spillway channel as shown on Drawing 14. It would allow a surface spill from elevation 2240 feet and above. Figure 2 shows the time period when downstream passage could occur.

The abandoned spillway is approximately 3,000 feet to the left of the dam. The spillway crest is 250 feet long. This option would require excavation of a channel upstream from the spillway down to elevation 2240 feet. The dike in the abandoned spillway would be excavated to allow the placement of an Obermeyer weir gate (or any overshot gate). Flow would pass over the weir and into a plunge pool. It would then flow down the abandoned spillway channel that is assumed to be lined with a geomembrane fabric and riprap. Information on the abandoned channel is not currently available; such data would be required to investigate this option further.

The estimated construction cost of this option is about $10 million.

Option 7.2.5 Kachess Dam Downstream Passage – Fish Collection Barge — This is assumed to be the same as Keechelus Dam Option 7.1.6. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $11 million.

Option 7.2.6 Kachess Dam Downstream Passage – New Outlet Works — This is also assumed to be similar to Keechelus Dam Option 7.1.7. No drawing is provided. The estimated construction cost of this option is assumed to be about the as for Keechelus Dam, $25 million.

7.3 CLE ELUM DAM – UPSTREAM AND DOWNSTREAM PASSAGE OPTIONS

The same upstream and downstream passage concepts examined for Keechelus Dam have been applied to Cle Elum Dam, and they are listed below. However, any proposed excavations through the natural foundation materials at Cle Elum Dam must consider a unique geologic feature. Cle Elum Lake has a natural layer of densely compacted, overconsolidated silt and clay lining the upstream edge of the terminal moraine that forms a very tight seal for the reservoir. This natural silt-and-clay lining was recognized early in the exploration of the site in the 1920s and the dam was constructed to take advantage of its presence. The natural lining likely contributes to the fact no seepage has ever been documented downstream from Cle Elum Dam or any of the three saddle dikes on the left abutment. Any excavations considered for fish passage structures need to keep the integrity of the natural liner in mind (Link 2002).

Option 7.3.1 Cle Elum Dam Upstream Passage – Trap-and-Haul — This is assumed to be the same as described in Keechelus Dam Option 7.1.1. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $7 million.

Option 7.3.2 Cle Elum Dam Upstream Passage – Fish Ladder with Pumped Flow — This option is shown on Drawing 15. It is assumed to be very similar to that described for Keechelus Dam Option 7.1.2. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $8.5 million.

Option 7.3.3 Cle Elum Dam Downstream Passage – Modify Spillway with New Gate — This option is shown on Drawing 16. It would be a fairly simple modification to the existing spillway at Cle Elum Dam that would allow a surface-spill release from reservoir elevation 2223 feet and higher. Figure 3 shows the time period when downstream passage can occur for this option.

The spillway at Cle Elum Dam contains five radial gates. This option assumes installation of an Obermeyer gate (or some other type of overshot gate) that discharges water downstream from one of the existing radial gates. The radial gate would be fully raised and remain in place as a backup to the weir gate. Water would then flow into a pool and down a chute formed by constructing a wall parallel to the existing spillway wall. The velocities in the chute would range from about 18 feet per second in the upper part of the spillway to about 40 feet per second in the steep section that enters the stilling basin. If the higher velocity is unacceptable, an alternative may be to extend the lower, steeper portion of the chute at a flatter slope.

The estimated construction cost for this option is $2.2 million.

Option 7.3.4 Cle Elum Downstream Passage – New Spillway — This option is shown on Drawing 17. It would consist of an excavated channel upstream from the spillway, a new spillway structure, and two concrete pipes to discharge fish to the downstream side of the dam. It would allow a surface spill discharge from the reservoir at elevation 2190 feet and above. Figure 3 shows the time period when downstream passage would have occurred for this option during WY 1994-2001.

Fish would enter the new structure through one of the multiple level gates and pass over a downward-operating slide gate. From this point, this option differs from the fish spillway option described for Keechelus Dam. Fish spill into one of a series of pools depending on the water surface elevation of the reservoir. The flow would drop over a weir to the next lower pool below. The maximum height drop would be 10 feet and to protect the fish, the pools would be of depths appropriate to the drop. At the bottom pool, flow would enter the concrete pipes that discharge into the existing spillway for a total discharge of 400 cfs; velocity in the concrete pipes would be about 11 feet per second.

After discharge into the existing spillway, the flow would continue down the spillway. A concrete wall could be constructed in the spillway to concentrate the flow into a minimum depth, similar to the previously described option. The velocity in the steep section of the spillway would be similar, approximately 40 feet per second. As was discussed for the previous option, the lower portion of the chute could extend farther downstream at a flatter slope. A second alternative would be to extend the concrete pipes further downstream at a flatter slope to reduce the velocity.

The estimated construction cost for this option is about $10 million.

Option 7.3.5 Cle Elum Downstream Passage – Fish Collection Barge — This is assumed to be the same as Keechelus Dam Option 7.1.6. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $11 million.

Option 7.3.6 Cle Elum Dam Downstream Passage – New Outlet Works — This is also assumed to be similar to Keechelus Dam Option 7.1.7. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $25 million.

7.4 BUMPING LAKE DAM – UPSTREAM AND DOWNSTREAM PASSAGE OPTIONS

The upstream passage concepts examined at Bumping Lake Dam include trap-and-haul and a traditional type of fish ladder with gravity flow. The downstream passage concepts are similar to those previously examined for Keechelus Dam; they are "New Gate on Spillway," "New Spillway," "Fish Collection Barge," and "New Outlet Works."

Option 7.4.1 Bumping Lake Dam Upstream Passage – Trap-and-Haul — This is assumed to be the same as Keechelus Dam Option 7.1.1. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $7 million.

Option 7.4.2 Bumping Lake Dam Upstream Passage – Fish Ladder — This option is shown on Drawing 18. The drawing shows a combined upstream and downstream passage system.

The upstream passage method is a fish ladder and the downstream passage method is a new spillway with downstream passage pipes. By placing the two systems together, flow from the downstream passage pipes would exit at the fish ladder entrance and provide attraction water flow. There may also be a cost savings from placing the systems in a parallel arrangement. (The option "Bumping Lake Dam Downstream Passage – New Spillway" is described in section 7.4.4 below.)

The fish ladder is an orifice type ladder similar to Reclamation's fish ladder at Easton Diversion Dam on the Yakima River. The ladder could function with a total differential of 34 feet, from the top of the pool (elevation 3427 feet) downward. This would be accomplished with the use of two ladder exits, each of which functions over a 17-foot range.

The ladder entrance would be located on the right side of the river close to the outlet works. This is the furthest point upstream that migrating fish could swim. The ladder would extend from the river to the right abutment of the dam. A channel would be excavated from the right abutment extending upstream. The depth of the channel required is to elevation 3390 feet. Further explorations and analysis are required to determine any dam safety implications of this channel.

The ladder is assumed to be designed to meet the current criteria for upstream passage for adult anadromous salmonids. However, it can be designed for other species that may have different passage criteria. The primary criterion is a 1-foot water surface differential between pools in the ladder. The ladder would achieve a 1-foot head differential between pools by sizing the orifice in the pool wall for one foot of head loss at the design ladder flow and the maximum reservoir pool at elevation 3427 feet. There is about a 36-foot water surface elevation differential between the maximum pool (elevation 3427 feet) and the water surface in the river (elevation 3391 feet). The 36-foot difference would be divided by 35 orifices and a 1-foot head loss at the ladder entrance gate. The top profile shown on Drawing 19 illustrates this flow condition.

As the reservoir water surface elevation drops, the head differential on each orifice would decrease and the flow through the ladder would decrease. To make up for the reduced flow, additional water would be added to the ladder by an auxiliary flow pipe. For example, when the water surface elevation in the reservoir is at elevation 3411 feet, additional water would be added by an auxiliary flow pipe that would enter the ladder downstream from Weir 19 to maintain the design flow in the lower-ladder section. The flow and head differential through the upper ladder would be reduced. When the water surface in the reservoir is below elevation 3411 feet, the lower fish exit gate would be opened and fish would swim up the lower ladder and through the channel to the lower ladder exit. As the reservoir water surface elevation drops below elevation 3410 feet, the flow and head differential decrease and additional water is added through the auxiliary flow pipe that enters below Weir 1. The bottom profile on Drawing 19 illustrates the low reservoir conditions.

This system of gates and valves on the auxiliary flow pipes requires adjustment for every change in the water surface elevation in the reservoir. This could be accomplished by daily monitoring and adjustment or by automation.

As previously noted, the concept was modeled after the Easton Diversion Dam fish ladder. However, the Easton ladder is designed for a maximum water surface fluctuation of 14 feet, rather than 17 feet as proposed by this design. Use of this type of ladder may require further biologic and hydraulic study and modeling to confirm its application at this site for all required species.

The estimated construction cost for the ladder-only portion of this option is about $11 million. (The New Spillway component is described in section 7.4.4 below.)

Option 7.4.3 Bumping Lake Dam Downstream Passage – New Gate on Spillway — This option is shown on Drawing 20. It consists of adding an Obermeyer weir gate to the crest of the uncontrolled concrete weir spillway that would allow a surface spill from the reservoir from above elevation 3420 feet. Figure 4 shows the time period for WY 1994-2001 that would have downstream passage for this option.

After flow passes over the weir gate, it would enter a pool that would be excavated in the spillway channel. Water would then flow into a chute that would be formed on the spillway by constructing a small wall parallel to the existing spillway wall. The velocities in the chute would vary from about 7 feet per second in the upper spillway to 35 feet per second in the lower spillway section. As an alternative to the higher velocities, the lower section of the fish chute could be extended at a flatter slope.

The estimated construction cost for this option is about $1.7 million.

Option 7.4.4 Bumping Lake Dam Downstream Passage – New Spillway — This downstream passage option is shown combined with the upstream passage fish ladder on Drawing 18. Flow would enter the system through multiple-level, downward-operating slide gates. The gates allow downstream passage over the full range of reservoir water surface elevations. Fish would spill into one of a series of pools depending on the water surface elevation of the reservoir. The flow would drop over a weir to the next lower pool below. The weir would also create a pool that flow and fish would enter. The maximum height drop would be 10 feet. The depth of pool would be sufficient to prevent injury to fish. At the bottom pool, flow would enter the concrete pipes that discharge downstream into the river. The velocity in the concrete pipe would be approximately 5 feet per second.

The estimated construction cost for this option is $4.6 million. (The fish ladder component is described in section 7.4.2 above.)

Option 7.4.5 Bumping Lake Dam Downstream Passage – Fish Collection Barge — This is assumed to be the same as Keechelus Dam Option 7.1.6. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $11 million.

Option 7.4.6 Bumping Lake Dam Downstream Passage – New Outlet Works — This is assumed to be similar to Keechelus Dam Option 7.1.7. However, Bumping Lake Dam is not as high has Keechelus Dam, so it would not require an outlet works structure as tall. No drawing is provided. The estimated construction cost is assumed to be somewhat less than for Keechelus Dam, $20 million.

7.5 TIETON DAM – UPSTREAM AND DOWNSTREAM PASSAGE OPTIONS

The upstream passage options considered for Tieton Dam are limited to trap-and-haul only. A fish ladder with pumped flow concept did not appear viable because of the dam's structural height (more than 300 feet), and it's location (in a narrow canyon). The downstream passage concepts are modifications to the existing spillway gates, a new spillway, and the barge collector. The New Outlet Works concept also was considered not viable because of the height of the dam and the inability to extend an attraction flow pipe into the existing outlet works, as was proposed at Keechelus Dam.

Option 7.5.1 Tieton Dam Upstream Passage – Trap-and-Haul — This is assumed to be the same as Keechelus Dam Option 7.1.1. No drawing is provided. The estimated construction cost of this option is assumed to be the same as for Keechelus Dam, $7 million.

Option 7.5.2 Tieton Dam Downstream Passage – Modify Spillway Gate — This option would be a modification to the existing drum gates on the spillway at Tieton Dam by adding hydraulic cylinder operators to provide control of the gate crest. Drawing 21 shows this modification. It consists of adding hydraulic operators to one of the drum gates and modifications to the invert of the spillway. This would allow a surface spill from the reservoir to above elevation 2918 feet. Figure 5 shows the time period that downstream passage from the reservoir could occur for this option.

The modification would provide better control over the operation and crest elevation of the drum gate than is currently available. The minimum discharge at the gate would be 75 cfs. Once water passed over the gate, it would flow about 35 feet down a 0.5:1 slope to the concrete invert. The invert adjacent to the spillway would be modified with a circular cross section which would then transition to a V-shaped invert.

The spillway is 20 feet wide and 1,250 feet long. The longitudinal slope of the spillway varies; starting at 0.0938 ft/ft at the upstream end, changing to 0.0607 ft/ft, then changing to 0.233 ft/ft, then becoming flat at the lower end. Velocities down the spillway would vary with slope and flow. At a minimum flow of 75 cfs, the maximum velocity would be about 17 feet per second and depth of flow about 0.2 feet; at a flow of 200 cfs, the maximum velocity would be about 25 feet per second and depth of flow about 0.4 feet. A hydraulic jump would occur in the stilling basin at the base of the spillway; this may cause injury or mortality to juvenile fish.

The estimated construction cost of is about $2.5 million.

Option 7.5.3 Tieton Dam Downstream Passage – New Spillway — This option consists of a new spillway structure to bypass fish around the existing spillway. It would be located adjacent to the existing spillway. A plan of the system is shown on Drawing 22 and additional details are shown on Drawing 23. The facility would be designed to allow a surface spill from the reservoir at elevation 2900 feet and above. Figure 5 shows the time period that downstream passage would occur for the option.

Flow would enter the structure over two 10-foot-wide weir gates. The weir gates would be adjusted with hoists to allow a surface spill into the new spillway structure. After flowing over the weirs, fish would be separated by a 50-foot-long, angled, wedge-wire bar screen to guide them to a vertical well. The screened water would flow through a 4-foot-wide by 8-foot-high conduit extending through the existing spillway channel. In the vertical well, 14-inch gated orifices would be placed over the range of pool elevations (as shown on Section B-B on Drawing 23). The orifices would discharge flow into the pool-drop structure that lowers fish through a series of 8-foot drops over weirs to the entrance of the fish bypass conduit.

The 2-foot-diameter fish-bypass conduit would transport fish on a slope of 0.03 ft/ft for approximately 6,500 feet to the river. The bypass conduit would be placed in the spillway with a concrete encasement or possibly buried in the spillway channel until it diverges away from the spillway. It would then follow the existing ground slope until it reached a suitable outfall. The maximum velocity in the bypass conduit would be 17 feet per second.

The estimated construction cost of this option is about $42 million.

Option 7.5.4 Tieton Dam Downstream Passage – Fish Collection Barge — This is assumed to be the same as Keechelus Dam Option 7.1.6. Dam. No drawing is provided. The estimated construction cost of this option is assumed to be about the same as for Keechelus Dam, $11 million.

8. DISCUSSION — INTEGRATING BIOLOGICAL, ENGINEERING, AND OPERATIONAL CONSIDERATIONS

8.1 FINDINGS

During the Phase I assessment process, we determined that there are a range of options and opportunities for providing fish passage and potentially reestablishing populations of anadromous salmonids in some tributaries of the five Yakima River basin reservoirs. Some combinations of passage options and associated biological benefits are more feasible than others. Costs vary widely among options, especially for downstream passage of juvenile fish. All five reservoirs have some tributary habitat that would be available if passage were provided at the dams. However, the amount and quality of the habitat varies considerably from reservoir to reservoir. The effective passage window also varies considerably from one option to another and would significantly affect the feasibility of a given proposal.

From our initial assessment, it appears that some form of upstream and downstream passage is technically feasible at all the storage projects. Passage at some would be much more expensive in relation to available habitat than at other locations.

Another factor to consider is that optimizing fish passage at one storage project might require changing operations at another in order to ensure continuity of water delivery obligations and other Yakima Project purposes. However, for purposes of this Phase I assessment, each project was considered separately, based on existing operational considerations and constraints.

The assessment team developed a procedure for comparing the passage projects, which considered engineering aspects, habitat, and system operational constraints. This provided a framework to understand the various upstream and downstream passage options combined with a preliminary assessment of the tributary habitat that would be potentially available to anadromous salmonids. Initially, the team used "stream miles potentially accessible upstream" from each reservoir; these were derived from the environmental factors matrices compiled by the fisheries subteam (shown as appendix C). We noted discrepancies in stream length reported from various published sources and used the experience and professional judgment of the fisheries biologists to determine potentially accessible stream miles up to impassable barriers.

The estimated costs of the several upstream and downstream passage options were divided by the number of stream miles to determine the cost per mile for each upstream and downstream passage option at each storage project. Upstream comparisons are shown in Table 8-1 and downstream comparisons in Table 8-2. These values were summed where both upstream and downstream options were available and then compared in Table 8-3. For ease of comparison, the estimates were rounded up or down to the nearest $100,000 per mile.

Table 8-1. Estimated cost of three upstream fish passage options at Yakima River basin storage dams; costs per mile, based on estimated construction costs; and miles of accessible tributary habitat

Project	**Newly accessible habitat**		**Estimated cost for upstream passage** ($1 millions)			**Cost per mile for upstream passage** ($1 millions)		
	Miles	Assumed quality	Opt. 1 Trap-and-haul	Opt. 2 Fish ladder w/ pumped flow	Opt. 3 Fish ladder w/ gravity flow	Opt. 1	Opt. 2	Opt. 3
Keechelus	13.80	Good	7.0	8.5	—	0.5	0.6	—
Kachess	2.35	Good	7.0	8.5	—	3.0	3.6	—
Cle Elum	29.40	Good	7.0	8.5	—	0.2	0.3	—
Bumping	6.00	Good	7.0	—	11.0	1.2	—	1.8
Rimrock	36.80	Good	7.0	—	—	0.2	—	—

Table 8-2. Estimated costs of four downstream fish passage options at Yakima River basin storage dams and costs per mile based on estimated construction costs and miles of accessible tributary habitat

Project	**Newly accessible habitat**		**Estimated cost for downstream passage** (in $1 millions)				**Cost per mile for downstream passage** ($1 millions)			
	Miles	Assumed quality	Opt. 1 Spillway modifi-cations	Opt. 2 New spillway	Opt. 3 Fish collection barge	Opt. 4 New outlet works	Opt. 1	Opt. 2	Opt. 3	Opt. 4
Keechelus	13.80	Good	4.5	8.0	11.0	25.0	0.3	0.6	0.8	1.8
Kachess	2.35	Good	5.0	10.0	11.0	25.0	2.1	4.3	4.7	10.6
Cle Elum	29.40	Good	2.2	10.0	11.0	25.0	0.1	0.3	0.4	0.9
Bumping	6.00	Good	1.7	4.6	11.0	20.0	0.3	0.8	1.8	3.3
Rimrock	36.80	Good	2.5	42.0	11.0		0.1	1.1	0.3	—

Table 8-3. Estimated construction costs per mile of combined upstream and downstream passage for three upstream passage options and four downstream passage options

(Numbers reflect summed cost per mile in $1 millions, calculated from tables 8-1 and 8-2).

Upstream options	**Downstream options**	**Keechelus**	**Kachess**	**Cle Elum**	**Bumping**	**Rimrock**
1. Trap-and-haul	1	0.8	5.1	0.3	1.5	0.3
	2	1.1	7.3	0.6	1.9	1.3
	3	1.3	7.7	0.6	3.0	0.5
	4	2.3	13.6	1.1	4.5	—
2. Fish ladder w/ pumped flow	1	1.0	5.7	0.4	—	—
	2	1.2	7.9	0.6	—	—
	3	1.4	8.3	0.7	—	—
	4	2.4	14.2	1.1	—	—
3. Fish ladder w/ gravity flow	1	—	—	—	2.1	—
	2	—	—	—	2.6	—
	3	—	—	—	3.7	—
	4	—	—	—	5.2	—

- No upstream passage Opt. 2 at Bumping Lake Dam and Tieton Dam
- No upstream passage Opt. 3 at Keechelus, Kachess, Cle Elum and Tieton dams.

In Table 8-3, a lower number indicates a lower passage construction cost per mile of stream habitat if O&M costs and duration of passage window are not considered. At some storage projects, various upstream and downstream passage options were not available or not considered to be feasible, so only those cells in the table that include both upstream and downstream passage options were compared in this Phase I assessment. For example, Tieton Dam is not included in some comparisons because early in the assessment process we recognized that installing a fish ladder there would be prohibitively expensive.

Other factors not considered in detail here but that should be evaluated in Phase II are the long-term O&M costs associated with a trap-and-haul passage option for adult salmonids versus the costs of maintaining pumped or gravity flow in a ladder.

A third consideration not reflected in Table 8-3 is the downstream migrant passage window that each of the options would encompass. The hydrographs for the five reservoirs (figures 1 through 5 in appendix D) show that each option provides a different window of passage. For example, at Cle Elum Dam, a new spillway would provide a much broader window of passage than spillway modification, but at a higher cost. In drier years such as 2001, a new spillway still would not provide for season-long, volitional, juvenile fish passage.

Another consideration not reflect in Table 8-3 is that juvenile outmigrants passing over the Tieton Dam spillway might encounter severe conditions that could cause substantial injury and result in some level of mortality. Further study would be needed to evaluate the degree of injury and mortality on juvenile outmigrants.

In Table 8-3, we see that for all storage projects, the lowest initial cost per mile (that is, without considering passage window or O&M costs) for anadromous salmonids to access suitable habitat is trap-and-haul for adult upstream passage and spillway modification for juvenile downstream passage. Cle Elum Dam and Tieton Dam have the lowest overall estimated construction costs per mile of stream habitat. These were followed by Keechelus, Bumping, and Kachess dams. In considering fish ladders for adult upstream passage (upstream options 2 and 3), Cle Elum Dam with spillway modifications for juvenile outmigrants is substantially less than the other passage projects in cost per mile (table 8-3).

Cle Elum Lake is the largest reservoir in the Yakima River basin, and it has a substantial amount of tributary and mainstem habitat upstream from the reservoir that would be accessible for anadromous salmonids and bull trout if passage were provided there. Generally, this habitat is in good condition and some is pristine since much of the watershed lies within the Alpine Lakes Wilderness Area. Considerable research has been conducted on the Cle Elum watershed, especially in relation to the restoration of sockeye salmon (Flagg et al. 2000).

8.2 ADDITIONAL ISSUES AND CONCERNS

The team encountered numerous issues and concerns that were beyond the scope of this Phase I assessment. These issues and concerns as well as identified data gaps will need to be addressed in later phases of this effort. As a followup to this final Phase I report, Reclamation will draft a Phase II proposal to provide the context for discussion by the entire assessment team in early spring 2003. Some of the items and issues that Reclamation identifies as pertinent and appropriate for Phase II are discussed below. These and other issues will be developed in greater detail in the draft Phase II proposal.

Numerous data gaps were noted, especially related to tributary habitat quality. Data gaps relate directly to the feasibility of providing passage for anadromous salmonids and bull trout and the expected increase in fish production that would be achieved in the newly accessible habitat.

Several issues and concerns were raised regarding the engineering feasibility of some of the concepts proposed in this Phase I report. One concern is the potential for increased seepage that could pose a dam safety concern for the passage concepts that require excavating channels upstream from the dams. This issue was discussed previously in regard to Cle Elum Dam, but the issue would be valid at all the dams. It would require further study and possibly geotechnical investigations and analysis.

Another concern is in regard to the orifice type of ladder proposed for Bumping Lake Dam, which was modeled after the fish ladder at Easton Dam. The Bumping Lake Dam ladder, under some reservoir conditions, would require fish to sound and pass through somewhat deeper orifices than at Easton Dam ladder. Further biological and hydraulic evaluations should be made to determine if the conditions in the ladder would meet criteria for passage of the targeted fish species.

For the passage concepts at the taller dams that use fish ladders with pumped flow, the length of the ladders and the number of pools may be a concern for some species because there is a risk of fish not swimming the height of these fishways. This may require further investigation and review of existing tall facilities with ladders.

The severe winter conditions at the dams and the potential for ice formation on the reservoirs is a concern for the operation of passage concepts. It is not completely known at what conditions the facilities may cease to function. This is likely the most critical for the fish collection barge and for concepts that require personnel to operate. Ice formation and the inability to operate would limit the passage window. An additional concern, particularly for downstream passage concepts, is problems with debris. The net used for the fish collection barge may be the most susceptible component to problems with debris. A site-specific assessment of potential debris loads is recommended.

One pertinent issue is the potential for injury to and/or mortality of outmigrating juveniles for each of the several downstream passage options, especially spillway options. Long spillways with shallow depth and high water velocity such as exist at Tieton Dam may injure or kill juvenile or adult fish.

An adequate monitoring and evaluation program must be an integral part of any fish passage and restoration program. Appropriate sampling must be conducted to evaluate adult use and passage, and numbers of outmigrating juvenile must be assessed. The measure of success of the fish passage program must be developed, including a discussion of whether there are trade-offs between upstream passage, downstream passage, and habitat restoration, including off-site habitat improvements in lieu of passage. A decision must be made on whether interim and long-term population targets for each subbasin are appropriate or necessary as part of measuring success. A longer-term consideration is to determine if passage has contributed to the basin-wide salmonid recovery efforts.

Several other issues include whether there would be additional competition for limited resources among the restored populations of anadromous salmonids and resident fish; how best to expedite restoration efforts for coho and sockeye salmon where they occurred historically; the extent of predation in the tributaries or lakes and/or poaching on adult or juvenile anadromous salmonids.

As reintroduction and restoration efforts proceed, the potential ecological interactions within the systems will need to be considered and evaluated, especially since the lakes are oligotrophic with limited production of prey items. Fertilization may be required to boost primary and secondary production and enhance the food web in the lakes to sustain the added demands for food from rearing sockeye salmon juveniles.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The assessment team submits the following conclusions regarding the preliminary assessment of tributary habitat available upstream from five Yakima River basin dams and opportunities for providing passage for anadromous salmonids at the associated dams. The team considered issues such as how to expedite passage and restoration of anadromous salmonid populations, data gaps that need to be addressed, and engineering concerns.

- **There are definite benefits to restoring fish passage at Yakima Project storage dams.**

Providing passage at Yakima River basin dams would allow anadromous salmonids the opportunity to expand their range into historically occupied areas. Passage would also restore connectivity of historic bull trout habitat that could improve gene flow among currently isolated populations. Passage facilities would allow opportunities for greater expression of the full range of salmonid life history strategies. We believe that passage facilities could also improve overall watershed productivity through the infusion of marine-derived nutrients to stimulate aquatic production. As a result, bull trout may experience a more stable and abundant forage base, which would affect them positively. In addition, fish passage facilities are expected to provide secondary or indirect benefits to the existing fish species assemblages of the reservoirs and tributaries.

Nothing in the Phase I assessment suggested that providing passage for anadromous salmonids and the eventual restoration of fish populations at any of the reservoirs is undesirable. Although some adult and juvenile passage options have substantial implementation costs, in this Phase I effort we neither considered nor evaluated alternative activities such as habitat improvement projects elsewhere in the basin that might provide equivalent or greater biological benefits.

- **It is technically feasible to construct fish passage facilities at all five Yakima Project storage dams.**

It appears to be technically feasible, although costly, to provide passage for anadromous salmonids and bull trout at each of the five Yakima Project storage reservoirs. Several upstream and downstream passage options were considered for each reservoir, varying in design concept, passage window for adults and juveniles, and cost. Limited passage can be provided at each dam with relatively minor modifications to infrastructure. However, this would only provide a narrow passage window for downstream migrants, if spilling over the existing spillway is an acceptable strategy. Longer passage windows can be provided with increasing cost and construction sophistication.

Passive (volitional) adult and juvenile fish passage with a long time window (i.e., over a wide range of reservoir operational elevations) is difficult to achieve and may be cost-prohibitive at most of the reservoirs. One exception is Bumping Lake Dam, where because of its relatively low dam height and hydrologic regime, it may be possible to construct a gravity fish ladder that would provide almost year-round volitional adult and juvenile passage under current reservoir operations. But the biological benefit expected for Bumping Lake Dam, as measured by miles of tributary habitat potentially accessible, is much smaller compared to other fish passage projects, thereby significantly inflating the cost in relation to benefits to anadromous salmonid populations.

- **Longer passage windows would provide the greatest biological benefits for migratory species.**

Because of the number of anadromous salmonid species and life history strategies, it is probable that some life history stage would use passage facilities most months of the year, if passage were available. There are identifiable peak use times when passage facilities would be used by greater numbers of fish that are also within the readily achievable operational regimes of the reservoirs. While any level of adult and juvenile fish passage will be beneficial, the greater the window when fish can pass, the more species, life history stages and strategies that can be supported. The length of the fish passage window is also directly related to the cost of construction.

Operational changes under some circumstances might improve juvenile fish passage windows at one reservoir, but this could be at the expense of the passage windows at other reservoirs. Accordingly, there is a cost and operational flexibility trade-off that must be made to provide passage at all Project reservoirs. The benefits to the species and tradeoffs should be examined from a systems perspective jointly by Reclamation and the fish managers to determine the most advantageous configuration for upstream and downstream passage.

There were limited discussions regarding how operational changes might be used either separately or in conjunction with engineering approaches to improve or extend the time windows during which passage could be provided for anadromous salmonids or bull trout. In-depth studies of potential operational changes were not done in Phase I and will be considered in Phase II and later studies.

- **Suitable habitat is available for anadromous and resident salmonids in the tributaries above the dams.**

There is generally good quality habitat upstream from the reservoirs, ranging from about 2.35 miles upstream from Kachess Lake to about 36.8 miles upstream from Rimrock Lake. Quality of the accessible habitat is not uniform across all watersheds, but considering numerous environmental factors, the overall quality can be considered good, and would support anadromous salmonids. Many of the Yakima River basin bull trout populations currently reside above the reservoirs, although most of these stocks are depressed or at critical population levels. General isolation likely contributes significantly to this decline. Habitat quality is generally good, although several spawning streams have problems with seasonal dewatering. Assessment of habitat will be refined in Phase II and later studies to help establish priorities for implementation of passage facilities at the different sites.

- **It is likely that self-sustaining populations of anadromous salmonids and bull trout connectivity could be restored if passage is provided.**

Over the “long term” (10 generations or so), anadromous salmonid populations in the tributaries upstream from the reservoirs could be expected to become self-sustaining. This is expected to occur concurrently with expansion and restoration of populations in the Yakima River basin downstream from the dams. However, it must be recognized and acknowledged initially that anadromous salmonid populations in the entire Columbia River basin are for the most part at reduced population size and extensive restoration efforts are in progress to restore or improve populations throughout the basin. We should not expect quick results or substantial increases in the populations to occur in the short-term.

9.2 RECOMMENDATIONS

- **Recommendation 9.2.1 — Contingent upon available funding, evaluate two reservoirs in greater detail in Phase II.**

We recommend that fish passage and its potential biological benefits be studied during Phase II in greater detail at Cle Elum Dam, and either Tieton Dam or Bumping Lake Dam, contingent upon available funding. These reservoirs present substantially different opportunities for developing fish passage concepts, expediting restoration of anadromous salmonids populations, and studying bull trout movement patterns.

A detailed study of these reservoirs would provide both Reclamation and fisheries managers an opportunity to develop a systematic, phased approach to evaluating fish passage concepts as well as developing a plan to evaluate the consequences of introducing long extirpated fish species back into the watersheds upstream from selected dams.

The upper Cle Elum River watershed has a substantial amount of habitat and there appears to be some opportunity for flexibility with respect to reservoir operations. In addition, Reclamation has authority under YRBWEP to provide juvenile fish passage at Cle Elum Dam.

Bumping Lake has a relatively modest amount of tributary habitat and potential for restoring anadromous salmonid populations. However, its relatively low dam height, substantial water supply and operational flexibility would allow construction of technologically simple, year-round volitional passage facilities (at significant cost) or allow a broad window of relatively inexpensive salmonid passage using surface spill for juvenile passage and trap-and-haul for adult passage.

Tieton Dam presents some challenges in providing downstream passage for outmigrating juvenile fish. If Tieton Dam is considered, we should also consider installing a fish trap at Tieton Diversion Dam ladder and starting trap-and-haul and spill operations for whichever passage window is feasible.

- **Recommendation 9.2.2 — Contingent upon funding, continue in Phase II to evaluate tributary habitat initiated in Phase I.**

Conduct a more thorough evaluation of the tributary habitat that was identified in Phase I. Through a combination of remote sensing and field work, assess the quality and quantity of accessible stream miles as well as any additional habitat that would be available if man-made barriers to fish passage were removed or improved.

We recommend that the tributary habitat upstream from each of the selected dams in Phase II be evaluated in more detail initially from aerial photography as well as in the field in order to:

- Better characterize the extent and quality of accessible tributary habitat,

- Clearly locate, identify, and characterize barriers to fish movement from the lake upstream to the first substantial natural barrier insurmountable to anadromous salmonids at all flows,
- Identify any measures necessary to facilitate restoration of anadromous salmonid populations and enhance connectivity of bull trout habitat.

- **Recommendation 9.2.3 — Plan for operational adjustments**

Fish passage facilities should be designed to operate to take advantage of potential future changes in Yakima Project operations.

- **Recommendation 9.2.4 — Evaluate potential operational changes, including new basin storage, to determine possible benefits to fish passage.**

- **Recommendation 9.2.5 — Monitor results of passage and restoration activities and institute an adaptive management approach as part of Phase III.**

Restoring anadromous salmonid populations upstream from Yakima Project storage dams presents significant challenges. The design of the dams and large natural reservoir fluctuations makes these facilities much different than the other dams on the Yakima and Columbia rivers where fish passage has been addressed. Experience has shown us that there is a significant amount of "trial and error" learning associated with correcting or removing barriers to anadromous salmonid passage. It is therefore essential to monitor rigorously any activities implemented to provide fish passage or expedite anadromous salmonid restoration efforts. Since results of any course of action taken will require years to obtain and evaluate, an adaptive management approach must be incorporated into the overall program since unanticipated events and results will need to be considered or addressed. An adaptive management approach will allow managers and engineers to respond to unforeseen events or unexpected results by refining structural and operational measures.

- **Recommendation 9.2.6 — As part of Phase II efforts, develop a detailed scope of work for Phase III and later stages of the feasibility study in collaboration with other entities and organizations involved with fish passage and recovery issues in the Yakima River basin.**

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12. GLOSSARY, ACRONYMS, ABBREVIATIONS

1945 Decree, Decree	The January 1945 consent decree of [Federal] District Court of Eastern Washington ("Civil Action No. 21) set forth obligations of United States to operate the Yakima Project to meet the needs of the irrigation district that predated the Project (see ***IOP*** p. 4-3).
303(d)	A section of the **Clean Water Act** requiring state listings of impaired waterbodies, including rivers and their tributaries
ACOE	U.S. Army Corps of Engineers, a major producer of hydropower in the Columbia River Basin; a member of the **FCRPS**
BIA	U.S. Bureau of Indian Affairs of **DOI**
BPA	Bonneville Power Association of the U.S. Department of Energy, responsible for marketing hydropower produced int the Columbia River Basin by ACOE and Reclamation; a member of the **FCRPS**
CC, CCs	Operational **C**onsiderations and **C**onstraints of the Yakima River basin; see ***IOP*** Section 5.1
CFR	U.S. Code of Federal Regulations
cfs	cubic feet per second, measuring the volume of water flow past a point
CWA Clean Water Act	U.S. Clean Water Act of 1972 (Public Law 92–500, as amended) with the objective "to restore and maintain the chemical, physical, and biological integrity of the Nation's water"; administered by **EPA**
EA	Environmental Assessment — a systematic analysis of site-specific activities used to determine whether such activities have a significant effect on the quality of the human environment and whether an **EIS** is required
EIS	Environmental Impact Statement — planning document required by **NEPA** before major Federal actions significantly affecting the quality of the human environment; also shown as Draft EIS and Final EIS
elevation	vertical measurements (in feet) in relation to mean sea level
EPA	U.S. Environmental Protection Agency; established by **NEPA**
ESA	U.S. Endangered Species Act of 1973 (Public Law 93–205, as amended), provides legal means to conserve and protect species listed as Threatened and Endangered, and a program for the conservation of such species; administered by **FWS** and **NMFS**; also to actually list species as Threatened or Endangered.
FCRPS	Federal Columbia River Power System — **BPA, ACOE**, and **Reclamation**
Flip-Flop	An operational mode with the purpose to encourage spring chinook salmon to spawn at lower river stages and thus keep redds under water and protect incubating eggs (November-March); see "Flip-Flop Operations (CC15)" at ***IOP*** page 5-37
FWS	U.S. Fish & Wildlife Service of **DOI;** primary mission to conserve, protect, and enhance fish and wildlife, and their habitats.
HPA	"Hydraulic Project Approval" permit from WDFW; issued April 17, 2002 to **Reclamation**
interrogation	the process of scanning a fish for the presence of a PIT tag (passive integrative transponder)

IOP	*Interim Comprehensive Basin Operating Plan* of November 2002, produced by the **YRBWEP** Program Office of Reclamation's Upper Columbia Area Office
ISRP	Independent Scientific Review Panel, providing advice to ***NPPC***
kaf	kilo [thousands of] acre-feet,
lentic	of or pertaining to still waters such as lakes, reservoirs, etc.
lotic	of or pertaining to swiftly moving waters
Lower Yakima Basin	the drainage area from Parker gage (RM 103.7) downstream to confluence with the Columbia River (RM 0)
LWD	large woody debris
MAF	million-acre feet
Mini Flip-Flop	An operational mode relating to release of water from Keechelus and Kachess reservoirs, performed in years of sufficient water supply; see "Mini Flip-Flop (CC16)" at ***IOP*** page 5-39
MOU	memorandum of understanding — written agreement between parties, not obligating Federal money
natural flows	"Natural flows, usually produced from precipitation during the early winter and snowmelt during the late winter and spring/summer operation periods, are captured for storage. Downstream of major storage facilities, winter outflows can be greatly reduced, with major variations to natural hydrologic conditions. Peaking natural flows from rain, or rain-on-snow events, causing "flood events," are captured in available storage and bypassed later during a lower flow period in the downstream basin. *(IOP 6.1.2)*
NEPA	National Environmental Policy Act of 1969 (Public Law 91–190)
NMFS	National Marine Fisheries Service of the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce; also self-termed as "NOAA Fisheries."
NPPC	Northwest Power Planning Council — established by the "Pacific Northwest Electrical Power Planning and Coordination Act of 1980" (P.L. 96–501; 16 U.S.C. 839 et seq.)
PNRO	Reclamation's Pacific Northwest Regional Office (Boise, ID)
PP&L	Pacific Power and Light (now owned by Scottish Power), owner-operator of the Wapatox Power Plant and the related water rights from the Naches River
Reclamation	U.S. Bureau of Reclamation of **DOI** (also **USBR** when used in a reference); a member of **FCRPS**
RM, river mile	distance of a point as measured upstream from its mouth; parameters are taken from *River Mile Index, Yakima River, Columbia River Basin, Washington* (October 1964), produced by the Hydrology Subcommittee of the Columbia Basin Inter-Agency Committee
ROD	Record of Decision — a decision document signed by an agency head based on a Final **EIS**
Roza I.D.	Roza Irrigation District
Secretary	U.S. Secretary of the Department of the Interior
SOAC	System Operations Advisory Committee; advises Reclamation on Yakima River basin matters; consists of fishery biologists representing **FWS**, **YN**, **WDFW**, and **YBJB** (see ***IOP***, page 4-7)
SOD	Safety of Dams

SOD Acts	Reclamation Safety of Dams Act of 1978 (Public Law 95–578) and the Reclamations Safety of Dams Act Amendments of 1984 (Public Law 98–404), 2000 (P.L. 106–377), and 2001 (P.L. 107–117
SVID	Sunnyside Valley Irrigation District
TAG	Enhancement Technical Advisory Group
Title XII	**YRBWEP** authorization; Title XII of the Act of October 31, 1994 (Public Law 103-434, Section 1210)
TMDL	total maximum daily load
TWSA	Total Water Supply Available, from natural flows of the Yakima River, its tributaries (see ***IOP***, section 5.2.3
UCAO	Upper Columbia Area Office (Yakima, WA) of Reclamation's **PNRO**
Upper Yakima Basin	The area upstream from Parker gage to the headwaters of the mainstem and all tributaries.
USBR	U.S. Bureau of Reclamation; format used within references; for example (USBR 2001a)
USFS	U.S. Forest Service of the Department of Agriculture
USGS	U.S. Geological Survey of **DOI**
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology, state agency responsible for water rights and **303(d)** lists
WIP	Wapato Irrigation Project, administered by **BIA** and serving the **Yakama Nation**
WY, Water Year	The 12-month period from October 1 through September 30.
Yakama Nation	Tribally preferred name for the Confederated Tribes and Bands of the Yakama Nation, Washington
Yakima River basin	the entire Yakima River watershed, from the Columbia River to the headwaters of the mainstem and all its tributaries
YBJB	Yakima Basin Joint Board, a collective of irrigation entities
YN	**Yakama Nation**
YRBWEP	Yakima River Basin Water Enhancement Project; Title XII of Public Law 103–343 (October 31, 1994); see ***IOP*** p. 4-8
YTID	Yakima-Tieton Irrigation District

YAKIMA DAMS FISH PASSAGE

PHASE I ASSESSMENT REPORT

YAKIMA PROJECT, WASHINGTON

APPENDICES

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Appendix A-2.	Washington Department of Fish and Wildlife, "Conditions number 57 through 59, Hydraulic Project Approval"; log number 00-E1998-01 (pursuant to RCW 77.55.100), Region 3 Office, Yakima, WA (17 April 2002)
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APPENDIX A.

AGREEMENTS

Appendix A-1. "Mitigation Agreement Between the USDI Bureau of Reclamation and Washington Department of Fish and Wildlife Regarding Keechelus Dam Construction Issues Including Fish Passage," Washington Department of Fish and Wildlife Region 3 Office, Yakima, WA (4 April 2002).

Appendix A-2. "Fish Passage at Keechelus Dam or Alternative, Conditions number 56 through 58, Hydraulic Project Approval"; Log Number 00-E1998-01, Washington Department of Fish and Wildlife Region 3 Office, Yakima, WA (17 April 2002)

MITIGATION AGREEMENT BETWEEN THE USDI BUREAU OF RECLAMATION AND WASHINGTON DEPARTMENT OF FISH AND WILDLIFE REGARDING KEECHELUS DAM CONSTRUCTION ISSUES INCLUDING FISH PASSAGE.

This Mitigation Agreement ("Agreement") is made between the Washington State Department of Fish and Wildlife, hereinafter referred to as WDFW, and the USDOI Bureau of Reclamation, hereinafter referred to as Reclamation. For purposes of this Agreement, the above entities are referred to collectively as "the Parties." The terms of this Agreement shall be binding upon the respective successors or assigns of each Party.

WHEREAS the U.S. Department of Interior Bureau of Reclamation ("Reclamation") and the Washington Department of Fish and Wildlife ("WDFW") share a common objective to protect, maintain and enhance water, fish and wildlife resources, and they recognize their mutual desire to continue a long-standing working relationship;

WHEREAS Congress established that the purposes of the Federal Yakima Project include fish, wildlife and recreation and that the existing storage rights of the project include storage for the purposes of fish, wildlife and recreation (Public Law 103-434, Title XII Yakima River Basin Water Enhancement Project - Sec 1205(e) Operation of Yakima Project);

WHEREAS Congress established that said storage for the purposes of fish, wildlife and recreation shall not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts (Public Law 103-434, Title XII Yakima River Basin Water Enhancement Project - Sec 1205(e) Operation of Yakima Project);

WHEREAS The Washington State law requires that a dam or other obstruction shall be provided with a durable and efficient fishway approved by the director of WDFW and that the fishway shall be maintained in an effective condition and continuously supplied with sufficient water to freely pass fish (RCW 77.55.060);

WHEREAS Reclamation and WDFW agree that Reclamation's authorities in the Yakima Basin provide for a broad range of fish enhancement activities including such things as barrier removal, screening of diversions and restoration of instream flows on both the mainstem river and tributaries, within proscribed limits;

WHEREAS Reclamation and WDFW agree that restoring fish passage at man-made barriers is, in nearly all cases, biologically preferable for conserving, restoring and enhancing indigenous fish species; and

WHEREAS the parties agree that moving forward expeditiously with repairs to Keechelus Dam is in the public interest to protect public safety and provide necessary water for project purposes.

THEREFORE the parties agree to work collaboratively to carry out their respective responsibilities and agree as follows:

I. Commitments of WDFW:

WDFW Agrees:

1) To issue a Hydraulic Project Approval (HPA) for the proposed Safety of Dams reconstruction of Keechelus Dam as soon as possible. The HPA shall incorporate the provisions of this agreement.

2) To provide technical support to Reclamation so that the fisheries objectives of this agreement may be met.

II. Commitments by the United States of America

Reclamation Agrees:

1) To abide by the provisions of the HPA.

2) To immediately conduct an assessment of fish passage at all Yakima Project storage reservoirs in the Yakima River Basin as outlined in the HPA for the Keechelus Safety of Dams Modification Project. The assessment shall include consideration of the potential fish production and likelihood of sustainability above each dam using a mutually acceptable assessment tool. Where fish passage is determined to be desirable and practicable, based upon the results of this assessment, Reclamation shall examine engineering feasibility. Where fish passage is determined to be impracticable or infeasible, Reclamation shall negotiate with WDFW to provide an alternative to fish passage, consistent with state law.

3) To seek appropriate funding to ensure timely implementation of: a) fish passage facilities, where passage is determined to be desirable and practicable by the project-wide passage assessment (item 2 above), and b) alternative fish restoration measures for locations where fish passage is determined by the project-wide assessment to be biologically beneficial but impractical or infeasible.

4) Until construction of fish passage facilities at each of the Yakima Project storage reservoirs where fish passage has been determined as necessary as per item 2 above, and such fish passage facilities are in operation, to provide interim fish passage (e.g. trap and haul program) in collaboration with WDFW at each of those reservoirs.

5) To restore fish passage for salmonids from Lake Keechelus into Cold Creek, in collaboration with WDFW, as an interim measure to address fish passage concerns at Keechelus Dam and construction-related impacts of the Safety of Dams project. Reclamation shall do this in concert with the reconstruction of Keechelus Dam and ensure that conditions suitable for adult passage into Cold Creek from the reservoir are restored.

6) To develop a formal process involving regularly scheduled meetings to occur no less than biannually to ensure that there is ample opportunity for input by the fish management agencies (WDFW, National Marine Fisheries Service, US Fish and Wildlife Service and the Yakama Nation) into decisions concerning fish enhancement measures implemented by Reclamation under its various authorities in the Yakima River basin.

7) To ensure that construction materials for major Reclamation projects (including Safety of Dams projects) are sourced from sites not in the geomorphic flood plain of the Yakima River, or tributaries, whenever practicable.

8) To ensure that the proposed Safety of Dams reconstruction-related actions at Keechelus Dam will not result in significant additional costs for retrofitting fish passage facilities at Keechelus Dam nor require future significant modification of the portions of the dam being reconstructed as part of the SOD work.

9) To ensure that the functions of the large (approximately 300 acres) wetland complex below the toe of Keechelus Dam are not impaired. This wetland is the source of water for three different water courses, at least two of which are fish-bearing streams, which flow into a river side channel complex below Keechelus Dam. Reclamation shall mitigate for unavoidable impacts to this wetland as outlined in the Final Environmental Impact Statement (FEIS) for the Keechelus Dam Safety of Dams Modification (September 2001). If for some reason the land acquisition outlined in the FEIS cannot be accomplished, alternative mitigation strategies shall be developed in cooperation with the WDFW and others.

III. DISPUTE RESOLUTION

1) In the event that a dispute between the parties should arise, the parties shall make every effort to informally resolve the matter. Should a dispute arise, the aggrieved party shall send the other parties written notice of the issue in dispute, which shall state the aggrieved party's preferred resolution to the matter. Nothing shall prevent the parties from using any other remedy otherwise available to them if informal dispute resolution does not work; provided, however, that no party shall engage in self-help without first notifying the other parties of its intended act(s) and providing reasonable time for the other parties to respond.

2) Each Party shall have all remedies otherwise available in equity or at law to enforce the terms of this agreement, including specific performance and injunctive relief. No party shall be liable in damages to any other Party or other person for any breach of this agreement, any performance or failure to perform a mandatory or discretionary obligation imposed by this agreement, or any other cause of action arising from this agreement.

IV. MODIFICATION OF AGREEMENT

This agreement may only be modified upon written agreement of the parties.

V. SAVINGS CLAUSE

Nothing herein shall prevent, waive or diminish the right or authority of WDFW to use any statutory or other remedy available to enforce the provisions of this agreement. Nothing herein shall prevent, waive or diminish the right or authority of WDFW to protect populations of fish, or any other aquatic life in Lake Keechelus, theYakima River or tributaries to the fullest extent allowed by law, nor shall this preclude the WDFW from using any statutory or other remedy available concerning or relating to these fish. Nothing contained in this agreement is intended to unlawfully limit the authority or responsibility of the Department of Fish and Wildlife to invoke penalties or otherwise fulfill its responsibilities as a public agency.

VI. GENERAL PROVISIONS

1) Nothing herein shall or shall be construed to obligate Reclamation to expend or involve the United States of America in any contract or other obligation for the future payment of money in excess of appropriations authorized by law and administratively allocated for the purposes and projects contemplated hereunder.

2) No member of, or delegate to Congress or resident Commissioner, shall be admitted to any share or part of this Agreement or to any benefit that may arise out of it.

3) The parties agree to comply with all federal statues relating to nondiscrimination, including but not limited to: Title VII of the Civil Rights Act of 1964, as amended which prohibits discrimination on the basis of race, color, religion, sex or national origin; Title IX of the Education amendments of 1972, as amended, which prohibits discrimination on the basis of sex; the Rehabilitation Act of 1973, as amended, and the Americans with Disabilities Act of 1990, as amended, which prohibit discrimination on the basis of disability: the Age Discrimination in Employment Act of 1976, as amended, which prohibits discrimination based on age against those who are at least 40 years of age; and the Equal Pay Act of 1963.

4) The Agreement shall become effective on the date of last signature hereto and

extended until terminated. Either party may formally request modification of the agreement.

5) Nothing in this Agreement shall, or shall be construed to alter or affect the authorities, rights or obligations of the parties under existing law or regulations.

THE UNITED STATES OF AMERICA

By: Eric Glover
Dated: 4/8, 2002

Eric Glover
Area Manager
Bureau of Reclamation

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

By: Jeff Tayer
Dated: 11/14-08-, 2002

Jeff Tayer, Regional Director
Department of Fish and Wildlife

State of Washington
Department of Fish and Wildlife
Region 3 Office
1701 South 24th Avenue
Yakima, Washington 98902-5720

FISH PASSAGE AT KEECHELUS DAM OR ALTERNATIVE

56. Permittee shall immediately conduct a project-wide assessment of fish passage at all Yakima Project reservoirs. This assessment shall be done in collaboration with WDFW and the first phase of the assessment shall be completed and distributed by January 31, 2003. The first facility to be considered in this project-wide assessment shall be Keechelus Dam. The assessment shall include investigations as to the engineering, constructability and biological considerations of fish passage at each facility. The assessment shall include consideration of the potential fish production and likelihood of sustainability above each dam using a mutually acceptable assessment tool. Phase II of the assessment shall prioritize where fish passage is determined to be desirable and practicable, based upon the results of the phase I assessment. Phase II shall focus on engineering feasibility, cost, water management implications, and biological parameters for restoring specific stocks. Phase II of the assessment shall be completed by January, 2004. Where fish passage is determined to be both desirable and feasible, the permittee shall seek funding and complete design and construction of fish passage facilities in a timely manner. A separate HPA or HPA amendment is required for construction of these facilities. Where fish passage is determined to be undesirable or impractical, based upon the results of this assessment, Reclamation shall negotiate with WDFW an alternative to providing fish passage consistent with state law. The net benefit of this alternative shall provide equal or greater productivity and ecological function than that predicted for fish passage facilities if constructed at the dam(s).

57. The Permittee shall immediately begin the assessment of Keechelus Dam as per provision #56 above, and determine whether the proposed design and construction of the Safety of Dams Project will adversely affect the feasibility, cost or efficacy of fish passage facilities at this dam. Reclamation shall modify the Safety of Dams work as necessary to ensure that the proposed Safety of Dams reconstruction-related actions at Keechelus Dam will not result in significant additional costs for retrofitting fish passage facilities at Keechelus Dam nor require future modification of the portions of the dam being reconstructed as part of the SOD work.

58. The Permittee shall provide interim fish passage (e.g. trap and haul program) in collaboration with WDFW at facilities where fish passage is desirable based upon the results of the project-wide passage assessment. Interim passage shall be provided at locations agreed upon by the fish management entities as soon as possible but not later than one year from completion of Phase II of the passage study.

APPENDIX B

HABITAT ANALYSES AND DATA

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FIGURES

TABLES

YAKIMA PROJECT BASE MAPS *(in color, following page B-50)*

Keechelus Lake (HUC 17 030 001 0101)
Kachess Lake (HUC 17 030 001 0102)
Cle Elum Lake (HUCs 17 030 001 0103, 0104, 0105, 0106)
Bumping Lake (HUC 17 030 002 0105)
Rimrock Lake (HUCs 17 030 002 0301, 0302)

B-1. SUMMARY

Selected tributaries upstream from five U.S. Bureau of Reclamation storage reservoirs in the "Upper Yakima Basin"[1/] were assessed to determine the amount of spawning and rearing habitat that would be available and accessible for anadromous salmonids and the potential for improving connectivity among populations of native fish and native aquatic species if fish passage were provided at the five dams.

The length in miles of tributary stream habitat up to natural or manmade barriers that would be immediately available and accessible to anadromous salmonids was estimated. The fisheries subteam also estimated where possible the additional length of tributary stream habitat that might be available if manmade barriers to fish passage such as improperly placed culverts or other obstructions were replaced and/or improved to allow fish passage. A qualitative evaluation of the spawning and rearing habitat in the tributary streams was attempted based on numerous environmental variables such as stream gradient, reported assessments of the quality of spawning conditions, available information on water temperature, habitat conditions including large woody debris, and pool frequency and quality.

Information was collected from agency reports and peer-reviewed papers, as well as personal observations of the subteam participants. Quality and availability of information relative to spawning and rearing habitat for anadromous salmonids was not uniform for all tributary streams, so a quantitative comparison among tributary streams was not possible. Much of the information was entered into a tributary habitat matrix, include in this Phase I Assessment report as Appendix C.

Estimated overall reservoir tributary stream length in miles of suitable spawning and rearing habitat that would be accessible to anadromous salmonids if passage were provided at the several dams is shown in Table B-1-1, along with tributary stream length if manmade fish passage barriers such as culverts are replaced and/or improved.

TABLE B-1-1. EXISTING AND POTENTIAL HABITAT FOR ANADROMOUS FISH

Reservoir	**Stream Habitat** (in miles)	
	Currently accessible	**Potentially available above manmade barriers**
Keechelus Lake	13.8	16.8
Kachess Lake	2.35	TBD
Cle Elum Lake	16.8	TBD
Bumping Lake	6	TBD
Rimrock Lake	36.8	TBD
TBD = to be determined		

1 "Yakima Basin" designates the entire Yakima River watershed, from the Columbia River to the headwaters of the mainstem and all its tributaries;
"Lower Yakima Basin" is the area downstream from Parker gage (RM 107.1) to the Columbia River;
"Upper Yakima Basin" is the area from Parker gage to the headwaters of the mainstem and all tributaries;

Sections of some tributary streams such as Gold Creek above Keechelus Dam are dewatered seasonally for varying periods of time, usually in the later summer-early fall, which would impede potential migration of some anadromous salmonids and migration of local populations of bull trout to and from their spawning and overwintering habitats.

No attempt was made to calculate increases or changes in anadromous salmonid production as a result of habitat expansion upstream from reservoirs; quality and quantity of available and accessible reservoir tributary habitat was used as a surrogate for production in this first phase report.

In addition, the response of the population to newly accessible tributary habitat would not likely be apparent for at least several generations, so long-term observations and monitoring would be required to assess the biological benefits of fish passage. Environmental conditions in the Columbia River migration corridor, the estuary, and the ocean will also affect the population response of anadromous salmonids in the Yakima Basin.

B-2. INTRODUCTION AND BACKGROUND

2.1 PURPOSE AND SCOPE

This report assesses the quality and quantity of selected tributary habitat upstream from five U.S. Bureau of Reclamation (Reclamation) Yakima Project storage reservoirs relative to providing passage for anadromous salmonids and native resident fish at the dams. There are five major storage reservoirs including Keechelus, Kachess, and Cle Elum lakes in the upper Yakima Basin, and Bumping and Rimrock lakes in the Naches River basin. Clear Lake is a small reservoir upstream from Rimrock Lake that presently has no active storage. Its fish ladder functions poorly and is ineffective in providing fish passage. For the purpose of this study, we assumed that this ladder would be repaired in the foreseeable future.

This assessment includes investigations as to engineering, constructability, biological, and operational considerations of upstream and downstream fish passage at each facility, the potential benefits for restoring anadromous salmonid runs to suitable habitat above each reservoir, and restoring connectivity for native fish, including isolated populations of bull trout. There is a disparity of information across all tributaries and reservoirs so an uniform set of criteria for comparison could not be developed.

2.2 IMPACTS TO FISH FROM BASIN DEVELOPMENT AND PROJECT OPERATIONS

The Yakima River watershed supports anadromous stocks of spring chinook salmon, fall chinook salmon, coho salmon, and summer steelhead. Sockeye salmon were present historically, but have been extirpated. The watershed also supports several other resident salmonids including: bull trout, rainbow trout, cutthroat trout, and mountain whitefish. Additionally, several non-native salmonids have been introduced to the Yakima Basin including brook trout and brown trout. Prior to 1855, an estimated 300,000 to 800,000 anadromous fish returned to the Yakima Basin each year (WDFW 1993, Neilsen et al. 1991). Davidson (1953) estimated 500,000 chinook salmon (all races); Mullan (1983) estimated about 100,000 coho salmon; Smoker (1956) estimated 100,000 steelhead; the historical total run size of Yakima River sockeye salmon has been estimated to be either 100,000 (Davidson 1953) or 200,000 (CBFWA 1990).

There were dams on the river prior to the construction of the five Yakima Project (the Project) storage dams. Crib dams without fish passage facilities were constructed at Keechelus Lake and Kachess Lake (in 1904) and at Cle Elum Lake (in 1905); these eliminated sockeye salmon populations in these lakes (Bryant and Parkhurst 1950, Davidson 1953, Fulton 1970, Mullan 1986). An impassable storage dam was constructed at Bumping Lake in 1910; this likewise eliminated a sockeye salmon population in that lake, with an estimated annual run of 1,000 fish (Davidson 1953, Fulton 1970). These four crib dams were obliterated or removed when the five Project storage dams were constructed; four to enlarge existing natural glacial lakes and one on-stream storage facility (Tieton Dam). These crib dams initially blocked fish passage to tributaries upstream from the dams, resulting in the eventual demise of the sockeye salmon runs by the early 20th century, the elimination of access to previously productive spawning and rearing habitat for spring chinook salmon and coho salmon and steelhead, and genetic isolation of formerly interconnected resident fish populations, especially bull trout.

Irrigation projects were developed prior to the time when the Reclamation storage projects were authorized and constructed. Numerous irrigation diversion dams on the mainstem Yakima River and its tributaries precluded anadromous fish from accessing portions of the watershed; unscreened diversions entrained salmon and steelhead smolts on their outmigration to the ocean, redirecting them instead to their death in agricultural fields. Dam construction on the mainstem Columbia River (which resulted in additional loss of downstream-migrating smolts) coupled with substantial commercial, tribal and recreational harvest of returning adults further decimated the numbers of anadromous salmonids returning to the Yakima Basin.

2.3 FISH SPECIES AFFECTED BY YAKIMA STORAGE RESERVOIRS

Four of the five Project storage reservoirs were originally natural lakes and supported Native American fisheries for sockeye salmon and other anadromous and resident fish. While detailed information is not available for pre-Project fish population abundance in these lakes, it is reasonable to assume that some of the native salmonid species currently found in the river reaches downstream from the dams would have been able to migrate upstream prior to the dams' construction, and would have been present there historically, where suitable habitat conditions existed in the watersheds above the dams. Sockeye salmon and coho salmon were present; however, endemic Yakima Basin stocks of sockeye salmon and coho salmon are extinct. Coho salmon currently returning to the Yakima River are descendants from a mix of hatchery stocks. The fifth reservoir (Rimrock Lake) was not originally a natural lake, and therefore the watershed upstream would not have supported sockeye salmon and burbot that require a lake environment for some portion of their life history, but the river and tributaries could have been used by salmon and steelhead.

Anadromous salmonids are expected eventually to recolonize the watersheds upstream from the storage dams if fish passage were provided. Local populations of native fish such as bull trout would have a pathway through which to interact with other local populations.

2.4 NEED FOR RESTORATION OF FISH PASSAGE

There are several biological reasons for providing fish passage at Yakima River storage projects, including increasing or enhancing populations of upper basin steelhead, and coho and spring chinook salmon by restoring access to historically occupied habitat; restoring life history and genetic diversity of salmonids and other native fish; reintroducing sockeye salmon to the watershed where they occurred historically, and reconnecting isolated populations of bull trout. Over time, if fish passage were provided, anadromous salmonids are expected to recolonize and expand into the watersheds upstream from the storage dams as populations in the rivers downstream from the storage dams increase in abundance. Some effort might be needed to expedite the restoration. Bull trout populations would experience restored historic connectivity and increased gene flow among the presently isolated populations.

There are several administrative requirements and justifications for restoring fish passage, such as the conditions of a Washington Department of Fish and Wildlife-Bureau of Reclamation mitigation agreement; Washington state law regarding fish passage (RCW 77.55.060); conditions of a Washington state "Hydraulic Project Approval" (HPA # 00-E1998-01); and Reclamation-State of Washington commitments associated with the Keechelus Dam Safety of Dams project. Furthermore, the Yakama Nation has a strong interest in restoring native salmon runs. In addition, NOAA Fisheries (National Marine Fisheries Service, NMFS) and Reclamation negotiated a Reclamation-driven study to examine fish passage at the five Project storage reservoirs, and the *Biological Opinion on the Federal Columbia River Power System* (NMFS 2000) includes a conservation recommendation that reiterates this commitment on the part of Reclamation.

2.5 POTENTIAL OUTCOMES OF ACTIONS

There are numerous potential outcomes of an assessment of fish passage options and reservoir tributary habitat. These include a plan or guidance for systematic construction of fish passage facilities at Yakima River storage dams; modification of reservoir and Project operations to facilitate upstream and downstream fish passage; implementation of fish passage or habitat improvement projects in tributary streams that complement fish passage efforts at dams; and modification of fisheries management practices (harvest, supplementation, etc.) to complement fish passage efforts and facilitate restoration of anadromous salmonid populations upstream from the dams.

The Phase I assessment of tributary habitat upstream from five storage reservoirs will not attempt to estimate potential fish production in habitat available after fish passage is provided or restored, but will describe the quality and quantity of tributary habitat where information is available (tributary stream miles accessible now, tributary stream miles accessible after the removal of manmade barriers such as culverts, quality of spawning and rearing habitat, etc.) as a surrogate for estimating fish production. Much of the information on which these assessments are based is found in the matrices in Appendix C. It is premature in this Phase 1 Assessment report to discuss long-term sustainability of anadromous salmonid populations as a result of providing passage at dams and access to previously occupied or new habitat in reservoir tributaries and their contribution to the overall status of populations due to the numerous unknown factors and environmental variables that affect population sustainability.

Bull trout and other native fish populations will be reconnected, thus providing for genetic exchange and expanded foraging and overwintering habitat.

B-3. SPECIES MIGRATION TIMING

In order to evaluate fish passage options for both upstream and downstream migration of anadromous and resident fish, it was necessary to estimate the timing of both adult and juvenile migration for the target fish species considered most likely to benefit from providing passage at reservoirs — spring chinook, coho, and sockeye salmon; steelhead; and bull trout. This information was consolidated into several tables showing estimated passage timing for adults and juveniles of all species individually, as well as a composite table combining all species for upstream and downstream passage (tables B-3-1 through B-3-4). Because fish passage at the dams is not currently provided and because certain runs such as sockeye salmon are no longer present in the Yakima Basin, these tables were developed using the professional judgment of the interagency team of biologists participating in the evaluation, as well as being informed by available data such as the timing of salmon runs as they return to the lower Yakima River.

In general, juvenile fish primarily outmigrate during the spring (March-June) and fall (late September through November). Juvenile fish would be least active during the winter months (December-February). Spring outmigrants are generally juvenile fish that are seeking habitat in larger streams or rivers or fish that are actively migrating to the ocean. A notable departure from this migration pattern is sockeye salmon, which may migrate upstream to a lake as emergent fry (Burgner 1991) in search of lacustrine habitat. In fall, juvenile fish may also migrate downstream, a behavior commonly described as a search for over-wintering habitat.

Adult salmon and trout typically migrate upstream seeking spawning habitat. Anadromous fish such as chinook salmon or steelhead travel thousands of miles throughout their lives and may migrate to a location near their spawning habitat months before they are ready to spawn. Resident fish species such as bull trout or rainbow trout may migrate upstream or downstream throughout a river system and may undertake a protracted spawning migration. Some species such as rainbow trout and steelhead spawn in the spring; other species such as salmon or bull trout spawn in the fall, thus the time period for upstream migration of all adult salmonids could extend from approximately March through November. Some species such as bull trout and steelhead are iteroparous (can spawn more than once) and thus adult fish could also migrate downstream after spawning. Time periods for downstream migration of iteroparous species will vary but would probably be early summer or fall after the fish have spawned.

Although the timing of peak adult upstream migration would differ between the two arms (the Naches River and the upper mainstem Yakima River), peak timing of downstream juvenile migration should be similar in both arms (table B-3-4). Because of the number of salmonid species that would be involved eventually in restoration and the different expressions of their life histories, it is reasonable to assume that nearly year-round fish passage would be required, considering all five Project storage projects.

TABLE B-3-1. UPSTREAM MIGRATION OR PASSAGE TIMING FOR ADULTS

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Spring chinook salmon								■	░	░	░	■
Coho salmon	░	░	■									░
Sockeye salmon										░	░	░
Bull trout	░	■	■	■	■	■	■	■	■	░	░	░
Steelhead (Naches)	■	░	░	■	░	░	░	■	■	■	■	■
Steelhead (Yakima)	■	░	░	■	■	■	░	░	░	■	■	■

■ = General Migration Period ░ = Peak Migration Period

TABLE B-3-3A. DOWNSTREAM MIGRATION OR PASSAGE TIMING FOR JUVENILES

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Spring chinook salmon	░	░	░	■	■	■	░	░	■	■	░	░
Coho salmon	░	░	░	■	■	■	■	■	■	■	░	░
Sockeye salmon						░	░	░	░			
Bull trout	░	░	■	■	■	■	░	░	░	■	■	░
Steelhead (Yakima)	■	■	■	■	■	■	░	░	░	■	■	■
Steelhead (Naches)	■	■	■	■	■	░	░	░	■	■	■	■

TABLE B-3-3B. DOWNSTREAM MIGRATION OR PASSAGE TIMING FOR KELTS AND ADULTS

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Steelhead kelts (Yakima)								░	░	░		
Steelhead kelts (Naches)							░	░	░			
Bull trout adults	░	░	░	■	■	■	■	■	■	■	■	░

■ = General Migration Period ░ = Peak Migration Period

TABLE B-3-3. COMPOSITE UPSTREAM MIGRATION OR PASSAGE TIMING

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Yakima River	░	░	░	■	■	■	░	░	░	░	░	░
Naches River	░	░	░	■	░	░	░	■	░	░	░	░

■ = General Migration Period ░ = Peak Migration Period

Note: Table represents adult passage only for spring chinook, coho, sockeye salmon; steelhead; and bull trout. Juvenile (and/or subadult) upstream passage timing for sockeye salmon and bull trout is still being researched.

Table B-3-4. Composite Downstream Migration or Passage Timing												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Basin-Wide juveniles	░	░	░	■	■	░	░	░	░	■	░	░
Yakima River adults	░	░	░	■	■	■	■	░	░	░	■	■
Naches River adults	░	░	░	■	■	■	░	░	░	■	■	■
	■	= General Migration Period					░	= Peak Migration Period				
* Juveniles for species identified above. Adults are steelhead kelts and bull trout												

B-4. TRIBUTARY HABITAT CONDITIONS

In this section, we discuss quality and quantity of potentially accessible tributary habitat that would likely be available to anadromous salmonids if upstream and downstream passage were provided at the dams. There are an estimated 1,380 miles of anadromous salmonid habitat (total of known, presumed, and historic use) in the Yakima River watershed. Utilization of this habitat has been affected to varying degrees, depending on the species. Much of the difference between current and historic use is due to restricted fish access, mostly associated with irrigation diversions and irrigation water storage throughout the watershed. The occurrence and severity of habitat limiting factors varies among streams and reaches within individual subwatersheds. The extent and quality of current salmonid utilization is impaired to varying degrees throughout the watershed by loss of floodplain function (including loss of side-channel habitat and reduced bank stability), increased presence of fines in the substrate that impairs spawning and rearing success and benthic invertebrate productivity, impaired riparian function, water quality impacts from agricultural runoff, and perhaps altered hydrology throughout much of the watershed due to land use and irrigation water delivery.

We also discuss the potential benefits to anadromous salmonid populations that would have access to historic spawning and rearing habitat. Migratory bull trout would be expected to gain increased population connectivity with fish passage at the dams. To assess quality and quantity of tributary habitat, we developed a matrix of habitat conditions and parameters for selected reservoir tributaries (presented in Appendix C) and from those matrices developed the narrative descriptions and semi-quantitative analyses provided below. As a general template for discussion, we follow to some extent the six abiotic and four biotic parameters described in the "Functional Analysis of Factors Limiting Natural Production" in the *Yakima Subbasin Summary* (NPPC 2001).

The six abiotic parameters include

(1) **water quality** — temperature, suspended sediment, turbidity, chemical pollution/pesticides, nutrient concentrations, dissolved oxygen, and biological oxygen demand;

(2) **habitat accessibility** — presence of physical barriers to anadromous salmonids;

(3) **habitat structure** — pool frequency and quality, fine sediment delivery and deposition, size distribution of substrate, the quantity and distribution of large woody debris, off-channel habitat, and refugia;

(4) **channel conditions and dynamics** — width-to-depth ratio, streambank stability, channel stability, channel confinement and simplification, and floodplain connectivity;

(5) **instream flow/hydrology** — similarity of peak and base flows to normative values, similarity of drainage network to the historical drainage network, and mortalities caused by irrigation or hydropower diversions;

(6) **watershed condition** — road density, condition and location, disturbance history, and the quantity and distribution of riparian reserves.

The four major biotic elements include:

(1) **predation**, both inter- and intraspecific;

(2) **competition**, both inter- and intraspecific;

(3) **pathogens/parasites**;

(4) **mutualism** — species that benefit each other.

We will address the elements listed above for the reservoir tributaries where the data and information exist. Information was compiled from several sources, including but not limited to U.S. Forest Service (USFS) stream surveys, the "Habitat Limiting Factors Analysis" (Haring 2001), and the *Draft Yakima Subbasin Summary* (NPPC 2001). The HLFA provides a wealth of information and analysis and was used extensively in developing this Phase I report. The following general descriptions of salmonid habitat are principally derived from the HLFA (Haring 2001).

4.1 KEECHELUS LAKE

Keechelus Dam is located in the Wenatchee National Forest on the Yakima River in Kittitas County, approximately 10 miles northwest from Easton, Washington. It was constructed at RM 214.5 between 1913 and 1917 at the lower end of a natural lake in order to provide storage water for irrigation, recreation, flood control, and fish and wildlife purposes. Historically, Keechelus Lake had anadromous runs of sockeye, coho, and chinook salmon and steelhead. Resident fishes including bull and cutthroat trout would have had year-round access into and out of the lake.

4.1.1 Salmonid species potentially benefitting from fish passage facilities at Keechelus Dam

- Spring chinook salmon
- Coho salmon
- Sockeye salmon
- Steelhead
- Bull trout
- Mountain whitefish
- Rainbow trout
- Cutthroat trout
- Brook trout*
- Kokanee salmon

** (asterisk) indicates species not native to the Yakima River basin*

4.1.2 Assessment of Keechelus Lake tributary habitat conditions — Tributaries considered include Coal, Gold, Cold, Meadow, Mill, Townsend, and Roaring Creeks. Bull trout and anadromous salmonids may have used several tributary streams prior to the construction of Keechelus Dam. Gold Creek is the only tributary to Keechelus Lake that is documented to have historically supported anadromous salmonids and bull trout; it currently supports a remnant run of bull trout and historically may have supported spring chinook salmon, coho salmon, and summer steelhead. However, there is historical evidence of presence of bull trout in Rocky Run Creek (WDFW 1983) and it is likely populations existed historically in Meadow Creek and Coal Creek. At least three other tributaries to Keechelus Lake (Meadow, Cold, and Coal creeks) have potential to be restored to support anadromous salmonids and/or bull trout (surveys circa 1994 by Central Washington University students found only cutthroat trout in these streams; Brent Renfrow, WDFW, pers. comm.). Anadromous salmonids may have used historically the smaller tributaries such as Mill, Resort, and Roaring creeks, but data are lacking. Roaring, Resort, and Rocky Run creeks are considered to be too small or steep for anadromous fish. The best habitat in the smaller creeks would have been in the downstream area now inundated by the reservoir (reservoir drawdown photos indicate presence of likely suitable lower gradient habitat for anadromous salmonid juveniles, and even adults when adequate flow is present). Adult steelhead would most likely utilize these habitats when adequate flow is available. Currently, reservoir operations/inundation and man-made barriers (such as dam and some culverts) limit anadromous fish use of most of the smaller tributary streams.

The main floodplain modification that has occurred is the increased inundation area associated with the reservoir, which inundates the lower reach of each of the tributaries. Generally these lower tributary reaches were meandering, low-gradient channels with more complex habitat than that remaining upstream from reservoir full-pool elevation. Inundation alters the characteristic of the sediment-deposition fan at the mouth of each of the tributaries, and the repeated cycle of inundation/drawdown prevents the establishment of riparian vegetation and recruitment of large woody debris (LWD). These alterations affect the channel characteristics and impair fish passage into the tributaries during low flows at low pool levels. In addition, some portions of tributaries upstream from the inundation zone or full pool elevation have high gradients.

Table B-4-1 lists potentially accessible miles of tributary streams to Keechelus Lake, along with miles of stream potentially available upstream to natural barriers (falls, steep gradient, etc.) if manmade barriers (such as culverts) are removed. Reclamation plans to repair or replace the impassable culvert on Cold Creek.

TABLE B-4-1. KEECHELUS LAKE TRIBUTARY STREAMS WITH HABITAT CONSIDERED SUITABLE FOR MIGRATORY SALMONIDS

Tributary Stream	Stream habitat [miles (km)]		Comments
	Potentially accessible	Potentially available above manmade barriers	
Meadow Creek	3.9 (6.5)	3.9 (6.5)	Waterfall limits upstream migration (USFS 1995)
Gold Creek	7.0 (11.5)	7.0 (11.5)	Primary spawning stream for Keechelus; waterfall limits upstream migration (Craig 1997)
Cold Creek	0.0	1.9 (3.2)	Railroad culvert blocks access (USFS 1992)
Mill Creek	0.2 (0.32)	1 (1.6)	Railroad culvert blocks access; habitat surveys may be needed
Coal Creek	2.5 (4.2)	2.5 (4.2)	I-90 culverts and stream channelization limit access
Townsend Creek	0.2 (0.32)	0.5 (0.8)	I-90 culverts limit access
Total	***13.8 (22.2)***	***>16.8 (27.4)***	
Note: Other tributaries to Keechelus Lake were considered too small or steep to support migratory fish.			

Table B-4-2 shows conditions of tributary habitat in miles upstream from Keechelus Lake (USFS 1997).

TABLE B-4-2. HABITAT CONDITIONS UPSTREAM FROM KEECHELUS DAM (in miles)

Forest Planning Unit Habitat Type	Good	Fair	Poor
Tributaries to Keechelus Lake (excluding Gold Creek)			
Spawning habitat	9	11	33
Summer rearing habitat	19	22	11
Winter rearing habitat	19	7	26
Gold Creek			
Spawning habitat	6	2	12
Summer rearing habitat	8	4	9
Winter rearing habitat	8	1	11
Source: USFS 1997			

4.1.3 Summary — If fish passage were provided at Keechelus Dam, Gold Creek and Meadow Creek would be the most likely tributaries accessible to anadromous salmonids, and would amount to about 11 miles of suitable habitat accessible. Cold Creek and Coal Creek are each less than 3 miles long, with passage barriers relatively close to the mouth. However, if the fish barrier on Cold Creek were removed and replaced with an on-grade culvert, an additional 2 or so miles of stream habitat could be available and accessible to anadromous salmonids. Bull trout are documented in Gold Creek but not in the other tributaries. Historic use of these tributaries by anadromous salmonids is unknown. Habitat quality in the several tributaries varies, due to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS "Forest Plan" standards,[2/] or passage barriers relatively close to the mouth.

Many of the current barriers in streams on the east side of the reservoir occur along the Interstate 90 corridor and are expected to be fixed during the I-90 expansion project by the Washington State Department of Transportation (WDOT). The "Aquatic Species Discipline Report" for the Interstate 90-Snoqualmie Pass East Project (WDOT 2001) provides detailed information on barriers, species present, temperatures and habitat conditions.

Based on a surface spill elevation of Keechelus Lake for Water Years 1994-2001, spill of Keechelus Lake down to elevation 2507 feet (the elevation of the existing spillway) would provide a limited period of volitional passage of juvenile fish. Increasing spill to elevation 2497 feet would provide additional volitional juvenile fish passage in most years, while going down to elevation 2480 feet would increase the opportunity for volitional juvenile passage in drier years like the last few years, but also cover periods when it is unlikely juvenile fish would be outmigrating. Figure 1 in Appendix D shows that during many years, even spill at elevation 2480 feet would not overlap entirely the fall juvenile migratory period.

4.2 KACHESS LAKE

Kachess Dam is located in the Wenatchee National Forest in Kittitas County, about 2 miles northwest from Easton, Washington. It was constructed between 1910 and 1912 at RM 1.0 on the Kachess River and was improved in 1936 (a reinforced concrete spillway was built on the right abutment). The intake tower was reconstructed in 1996-1997. The dam is a zoned, rolled, earth-fill structure with a height of 115 feet, a hydraulic height of 69.25 feet, a crest width of 20 feet, and a crest length of 1,400 feet. The lake has a surface area of 4,535 acres, a drainage area of about 63 square miles, an active storage capacity of 239,000 acre-feet, and dead-storage capacity of 671,272 acre-feet (USBR 1981). As such, it has the second-largest active storage capacity in the Yakima River watershed.

Nearly all the Kachess River watershed is inaccessible to anadromous salmonids, due to presence of Kachess Dam. Historically, the natural lake had anadromous runs of sockeye salmon, coho salmon, spring chinook salmon, steelhead. Sockeye salmon were extirpated upstream from Kachess Dam in 1904 by the construction of a crib dam. Currently the lake supports resident kokanee salmon, rainbow trout, cutthroat trout, bull trout, and burbot. Resident fishes, including bull trout, would have had year-round access into the lake. Lake level fluctuation and drawdown likely reduces production of phytoplankton, zooplankton and aquatic insects (USBR 2000a), which in turn reduces the prey base for bull trout and kokanee salmon residing in the reservoir. Bull trout overwinter in Kachess Lake (Haring 2001). The Kachess River upstream from the

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2 *Wenatchee Land and Resource Management Plan*. 1990. Wenatchee National Forest, Wenatchee, WA (as amended by *Northwest Forest Plan* of 1994, Region 6, Seattle, WA)

reservoir is dry near its confluence with Kachess Lake in late summer through late October, depending on fall precipitation, which may impact bull trout movement into the lake. Other species (coho salmon and spring chinook salmon) might also be impacted by this annual and temporary seasonal dewatering.

4.2.1 Salmonid species potentially benefitting from fish passage facilities at Kachess Lake

- Spring chinook salmon
- Coho salmon
- Sockeye salmon
- Steelhead
- Bull trout
- Mountain whitefish
- Rainbow trout
- Cutthroat trout
- Brook trout*
- kokanee salmon

** (asterisk) indicates species not native to the Yakima River basin*

4.2.2 Assessment of Kachess Lake tributary habitat conditions — Table B-4-3 summarizes the stream habitat that would be accessible to anadromous salmonids if passage were provided at Kachess Lake.

Table B-4-3. Kachess Lake tributary streams with habitat considered suitable for anadromous salmonids

Tributary	Stream Habitat [miles (km)]		Comments
	Potentially accessible	Potentially available above manmade barriers	
Kachess River	0.5 (0.8)	0	Primary spawning stream
Box Canyon Creek	1.6 (2.57)	0	Primary spawning stream; natural barrier falls
Mineral Creek	0.25 (0.40)	0	Series of cascades blocks fish passage
Gale Creek	1.5 (2.4)	0	Barrier falls in third reach (about 1.5 miles upstream); in late summer, stream commonly goes subsurface in the lake bed and upstream
Thetis Creek	1.0 (1.6) based on map		In late summer, stream commonly goes subsurface in the lake bed and upstream
Total	**2.35 (3.76)**		

Notes: Since Gale Creek and Thetis Creek commonly go subsurface, they are not considered as being accessible to anadromous salmonids, and the overall tributary stream length is 2.35 miles. Other tributaries to Kachess Lake were considered too small or steep to support migratory fish.

4.2.3 Summary — If passage were provided for anadromous salmonids at Kachess Dam, about 2.35 miles of tributary habitat upstream from the lake would be accessible. Habitat quality in the several tributaries varies, due in some cases to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards. Spill of Kachess Lake down to elevation 2254 feet would encompass some of the period of volitional juvenile outmigration, with additional opportunity for volitional outmigration provided with a spill elevation down to elevation 2240 feet. However, the spill to elevation 2240 feet would provide additional coverage but generally not completely encompass the fall juvenile migratory period.

4.3 CLE ELUM LAKE

Cle Elum Lake is the largest of the four reservoirs in the Yakima Basin that once supported runs of anadromous salmonids. It was a natural lake that was first enlarged with a log crib dam in 1906. The present dam was constructed at RM 8 in 1933. The lake has an active storage capacity of 436,900 acre-feet and a surface area of 4,800 acres (USBR 1981). Before construction of the dam, the lake contained a variety of sport fish, including mountain whitefish, rainbow trout, cutthroat trout, bull trout, and burbot. Historically, sockeye salmon used the lake for rearing and, along with coho and chinook salmon, the streams above the lake for spawning (Robison 1957, Mongillo and Faulconer 1982; both cited in Flagg and Ruehle 2000). Resident fishes, including bull trout, would have had year-round access into the lake. Currently the lake supports resident kokanee salmon, rainbow trout, cutthroat trout, bull trout, lake trout, pygmy whitefish, and burbot.

The lake has a large and diverse watershed with numerous tributaries, three of which (the Cle Elum, Cooper, and Waptus Rivers) are thought to contain substantial potential spawning habitat for anadromous salmonids (Spotts 1981, cited in Slatick and Park 2000). Cle Elum Falls on the Cle Elum River at about RM 9 is a potential upstream barrier to fish passage. It may be passable by strong-swimming fish during high flows. The Cooper River has a barrier approximately 0.6 miles (1 km) upstream from Salmon la Sac, while Waptus Falls in the Alpine Lakes Wilderness Area is a barrier on the Waptus River.

Cle Elum Lake undergoes annual drawdown that seriously impacts the lake's littoral zone resulting in an extremely limited littoral biological community that is nearly devoid of benthic macroinvertebrates (Flagg et al. 2000). Benthic invertebrates have nearly been eliminated from the littoral zone due to water level fluctuations. Primary production is probably reduced in the lake compared to historic conditions, based on analysis of phosphorus in lake sediments and algal bioassay studies (Dey 2000 in Flagg et al. 2000).

4.3.1 Salmonid species potentially benefitting from fish passage facilities at Cle Elum Dam

- Spring chinook salmon
- Coho salmon
- Sockeye salmon
- Steelhead
- Bull trout
- Mountain whitefish
- Rainbow trout
- Cutthroat trout
- Brook trout*
- Kokanee salmon
- Brown trout*
- Lake trout*

** (asterisk) indicates species not native to the Yakima River basin*

4.3.2 Assessment of tributary habitat conditions — Table B-4-4 summarizes the stream habitat that would be accessible to anadromous salmonids if passage were provided at Cle Elum Lake.

TABLE B-4-4. CLE ELUM LAKE TRIBUTARY STREAMS WITH HABITAT CONSIDERED SUITABLE FOR MIGRATORY SALMONIDS

Tributary Stream	**Stream habitat** [miles (km)]		Comments
	Potentially accessible	**Potentially available above manmade barriers**	
Cle Elum River	21.6 (34.8)		Steep cascades at RM 9 may limit upstream migration for some fish
Thorp Creek	0		Barrier cascades and high gradient in lower reach
Cooper River	0.6 (1)		Barrier falls
Waptus River	7.2 (11.5)		Impassable falls
Total	**29.4 (47.3)**		
Note: Other tributaries to Cle Elum Lake were considered too small or steep to support migratory fish.			

4.3.3 Summary — The determination of projected length of tributary streams potentially available upstream from Cle Elum Dam if fish passage were provided was complicated by the fact that the several reports available provided different estimates of the habitat potentially available in the Cle Elum River. For example, Flagg et al. (2000) reported that "Cle Elum falls" (considered by local fisheries biologists as a series of cascades), about 9 miles upstream from the full pool end of the reservoir, would block adult fish migration under many water flow conditions. However, Haring (2001) stated that migratory fish would have access to 18.4 miles of Cle Elum River habitat up to Hyas Lake, and Croci (FWS, Yakima, WA, pers. comm., 2002) reported available Cle Elum River stream length as 21.6 miles, if passage for anadromous fish were provided at Cle Elum Dam. If passage were provided for anadromous salmonids at Cle Elum Dam, about 29.4 miles of tributary habitat upstream from Cle Elum Lake would be accessible. Habitat quality in the several tributaries varies, due in some cases to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards. Spill of Cle Elum Lake down to elevation 2223 feet would encompass the period of most volitional juvenile outmigration, with some additional coverage provided with a spill elevation down to elevation 2190 feet. Spill to elevation 2190 feet would provide additional opportunities for volitional juvenile passage, but in some years would not entirely overlap the juvenile fall migratory period (see Figure 3 in Appendix D).

Flagg et al. (2000) reported that the Cle Elum, Cooper, and Waptus rivers contain substantial potential spawning habitat for anadromous salmonids. Habitat in these rivers could support tens of thousands of returning salmonids. The extreme fill/spill cycle of Cle Elum Lake poses substantial challenges for outmigrating juvenile salmonids, especially sockeye salmon during the early spring (late March-early May) outmigration season. Once past Cle Elum Dam, outmigrating juvenile salmonids would not encounter migration obstacles in the Yakima River, although they could be affected by irrigation diversions.

An "Ecosystem Diagnosis and Treatment" (EDT) simulation estimated that the headwaters area in the Cle Elum River would be capable of sustaining a spawning population of 328 spring chinook salmon, with a productivity of 2.7 adults progeny per spawner (Haring 2001).

4.4 BUMPING LAKE

Bumping Dam is located in the Snoqualmie National Forest in Yakima County about 29 miles northwest from Naches, Washington. The dam was constructed at the lower end of a natural lake between 1909 and 1910 at RM 15.7 on the Bumping River in order to provide water for irrigation, recreation, flood control, and fish and wildlife purposes. The dam is an earth-fill structure with a height of 61 feet, a hydraulic height of 36 feet, and a crest length of 2,925 feet. Some Safety of Dams modifications were made between 1994 and 1997. Bumping Reservoir has a drainage area of about 68 square miles, with an active conservation capacity of about 33,700 acre-feet (USBR 1981).

4.4.1 Salmonid species potentially benefitting from fish passage facilities at Bumping Lake Dam

- Spring chinook salmon
- Coho salmon
- Sockeye salmon
- Steelhead
- Bull trout
- Mountain whitefish
- Rainbow trout
- Cutthroat trout
- Brook trout*
- Kokanee salmon

** (asterisk) indicates species not native to the Yakima River basin*

4.4.2 Assessment of tributary habitat conditions — Table B-4-5 summarizes the stream habitat that would be accessible to anadromous salmonids if passage were provided at Bumping Lake.

TABLE B-4-5. BUMPING LAKE TRIBUTARY STREAMS WITH HABITAT CONSIDERED SUITABLE FOR MIGRATORY SALMONIDS

Tributary Stream	Stream habitat [miles (km)]		Comments
	Potentially accessible	Potentially available above manmade barriers	
Bumping River	1.0 (1.6)		Waterfall limits upstream migration (USFS 1995)
Deep Creek	5-5.6 (8-9.28)		Lower 0.5 miles goes subsurface in low water years
Total	**6-6.6 (9-10.88)**		
Note: Other tributaries to Bumping Lake were considered too small or steep to support migratory fish			

4.4.3 Summary — If passage were provided for anadromous salmonids at Bumping Dam, about 6 miles of accessible tributary habitat would be provided upstream from Bumping Lake. Habitat quality in the several tributaries varies, due in some cases to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet Forest Plan standards. Based on a surface spill elevation of

Bumping Lake for water years 1994-2001, spill of Bumping Lake down to elevation 3420 feet (the elevation of the existing spillway) would provide a limited period of volitional passage of juvenile fish. As noted above, spill to elevation 3420 feet would not entirely or in some cases even partially overlap the fall juvenile migratory period (see Figure 4 in Appendix D).

4.5 RIMROCK LAKE (Tieton Dam)

Tieton Dam is located in the Snoqualmie National Forest in Yakima County about 40 miles northwest from Yakima, Washington. It was constructed between 1917 and 1925 at RM 21.3 on the Tieton River to provide water for irrigation, recreation, flood control, and fish and wildlife purposes. It is an earth-fill structure with a concrete core wall, a height of 319 feet, a hydraulic height of 198 feet, and a crest length of 920 feet. The reservoir, Rimrock Lake, has a drainage area of about 186 square miles. Clear Lake Dam is located on the North Fork Tieton River about 8 miles upstream from Tieton Dam. The drainage area upstream from Clear Lake Dam is about 58 square miles. The drainage area between Clear Lake Dam and Tieton Dam is about 128 square miles. Rimrock Lake has an active storage capacity of 198,000 acre-feet, with a surcharge capacity of 5,600 acre-feet (USBR 1981).

The dam does not have fish passage facilities and is a barrier to fish migration. It precludes access to 1.5 miles of the Tieton River, about 22 miles of the North Fork Tieton River, about 4 miles of the North Fork tributaries of Clear Creek and Indian Creek, and about 13.5 miles of the South Fork Tieton River (Haring 2001). An EDT analysis estimated that this area is capable of sustaining a spawning population of 350 spring chinook salmon, with a productivity of 3.8 adult progeny per spawner.

The Yakima-Tieton Diversion Dam at RM 14.2 is also a barrier to upstream fish migration at low flows (WDFW 1998, cited in Haring 2001). There is some ongoing work to improve fish passage at this dam.

Clear Creek Dam upstream on the North Fork Tieton River has a fish ladder, but it is apparently ineffective in providing passage for bull trout.

4.5.1 Salmonid species potentially benefitting from fish passage facilities at Rimrock Lake

- Spring chinook salmon
- Coho salmon
- Sockeye salmon
- Steelhead
- Bull trout
- Mountain whitefish
- Rainbow trout
- Cutthroat trout
- Brook trout*
- Kokanee salmon

** (asterisk) indicates species not native to the Yakima River basin*

4.5.2 Assessment of tributary habitat conditions — Table B-4-6 summarizes the stream habitat that would be accessible to anadromous salmonids if passage were provided at Rimrock Lake.

TABLE B-4-6. RIMROCK LAKE TRIBUTARY STREAMS WITH HABITAT CONSIDERED SUITABLE FOR MIGRATORY SALMONIDS			
Tributary Stream	**Stream habitat** [miles (km)]		**Comments**
	Potentially accessible	**Potentially available above manmade barriers**	
South Fork Tieton River	13.5 (21.6)		Falls at 13.5 mi. limits upstream migration
Short and Dirty Creek	0.1 (0.16)	0	Natural barrier limits upstream migration
Corral Creek	2.2 (3.5)		Falls at 2.2 mi. limits upstream migration
Bear Creek (SF Tieton)	0.5 (0.8)		Natural barrier limits upstream migration
Bear Creek (Rimrock)	3.7 (5.9)		High sedimentation
NF Tieton River	9.9 (15.9)		Falls at 9.9 mi. limit upstream migration
Clear Creek	2 (3.2)		Barrier falls limit upstream migration
Indian Creek	4.9 (7.8)		Falls at 4.9 miles limit upstream migration
Total	**36.8 (59)**		
Note: Other tributaries to Rimrock Lake were considered too small or steep to support migratory fish			

4.5.3 Summary — If passage were provided for anadromous salmonids at Tieton Dam, potentially accessible habitat in tributaries upstream from Rimrock Lake amounts to about 36.8 miles, out of a total of at least 50 miles in the selected tributaries. Habitat quality in the several tributaries varies, due in some cases to substrate composition, water temperatures, or riparian or stream channel conditions that do not meet USFS Forest Plan standards. Based on a surface spill elevation of Rimrock Lake for water years 1994-2001, spill of Rimrock Lake down to elevation 2918 feet (the elevation of the existing spillway) would provide a limited period of volitional passage of juvenile fish. Increasing spill to elevation 2900 feet would provide additional volitional juvenile fish passage in most years but would not encompass the entire fall juvenile migratory period (see Figure 5 in Appendix D).

B-5. SALMONID BIOLOGY AND LOCAL LIFE HISTORY

5.1 SPRING CHINOOK SALMON

Adult spring chinook salmon return to the upper mainstem Yakima River beginning in May. Adults migrate close to the area where they will spawn and find a place to hold in cover (deep water with woody debris or undercut banks or both) until they spawn in September and October. Depending upon water temperature, the peak of spawning may occur from September 15 to October 1 (NPPC 2001). Most spawning now occurs in the mainstem Yakima River between the Teanaway River and Easton Dam. There are also many adults that spawn in the Cle Elum River and in the Yakima River between the town of Thorp and the Teanaway River. Adults that spawn in the upper reaches of tributaries typically move into the tributaries by the end of June or early July when flows are still high enough for them to traverse the lower reaches of the tributaries (McMichaels, Battelle Pacific Northwest Laboratories, Richland, WA, pers. comm.). Some migrating adult fish will arrive early prior to the time some streams go subsurface to make it past the parts of the streams that eventually go dry for a period of time. Variability in run timing is influenced by high and low flows. Run-timing for spawning runs of all salmon and steelhead is delayed during years of high flow and accelerated in years of low flow.

Naches River spring chinook salmon usually begins spawning in late August, while the upper mainstem Yakima River stock usually begins spawning in early September. The peak of spawning activity for spring chinook salmon in the Naches River ranges from September 8 to September 18 and in the upper mainstem Yakima River from September 15 to October 1 (Fast et al. 1991).

Spring chinook salmon emerge from the gravel in March-May and use slow-water habitat near the edges of the river. Emergence appears to be quite closely synchronized across stocks of spring chinook salmon despite 5 to 7 weeks differences in spawning timing. In the upper Yakima River, fry were captured between March 8 and June 13, with a median capture date of April 16.

Fry from all stocks redistribute themselves downstream the spring and summer after emergence, with highest densities in summer being found well below the major spawning areas, but above Sunnyside Diversion Dam (RM 103.8). The lack of anadromous salmonids rearing in the lower Yakima River is attributed to excessive summertime water temperatures in the mainstem below Sunnyside Diversion Dam (Fast et al. 1991). In some cases juveniles rear in the general area where they were spawned while others migrate up tributary streams to rear for the summer. Upstream juvenile migrations into tributaries for early rearing have been documented in numerous tributaries (NPPC 2001).

All Yakima River stocks of spring chinook salmon exhibit an extensive downstream migration of pre-smolts in the late fall and early winter (Pearsons et al. 1996) Most juvenile spring chinook salmon in the Upper Yakima Basin migrate down river during the fall-winter period and overwinter in the Yakima River somewhere between Roza and Prosser dams (probably in the Zillah/Granger area). This “winter migrant” behavior is presumably triggered by rapidly falling water temperatures in the late fall. This thermal trigger occurs earlier in the upper reaches of the basin. Although 10-35 percent of the juveniles from a given brood year migrate below Prosser Dam (RM 47.1) during the winter, most fish overwinter in the deep slackwater reach of the Yakima River between Marion Drain (RM 82.6) and Prosser Dam (Fast et al. 1991); they begin their smolt outmigration from the lower river the following spring. This “winter migrant” behavior for all wild Yakima spring chinook salmon is contrasted with an "upriver smolt" type, which spend the winter in the upper Yakima system in the mainstem and in tributaries like Badger and Wilson creeks, much closer to natal areas, then outmigrate as smolts during the following spring (NPPC 2001).

The outmigration timing of Yakima River spring chinook salmon smolts is also quite variable. The overall timing of the outmigration does not appear to be shifted earlier or later by flow, although the migration rate of actively migrating smolts is positively correlated with flow. The gross timing of the outmigration seems instead to be a function of water temperature the winter preceding smoltification. Specifically, there is an inverse relationship between the mean outmigration date and the thermal units accumulated over the months of December through March: the more degree-days in the Yakima River through the coldest part of winter, the earlier the outmigration, and vice versa (NPPC 2001).

Studies of radiotagged spring chinook salmon adults released below Prosser Dam in 1991-1992 and monitored through spawning, indicated that there was no interstock difference in the temporal distribution of fish as they arrived at Prosser Dam (Hockersmith et al. 1994). This was true even though there were clear interstock differences in the onset and duration of spawning.

In an EDT analysis of spring chinook salmon in the upper Yakima River basin, parr, wintering parr, and fry were determined to be the most severely impacted life stages, in descending order (NPPC 2001). The most significant environmental impacts in descending order were habitat complexity, flow, and key habitat (NPPC 2001). Although this analysis was for spring chinook salmon downstream from dams, it is reasonable to expect these same life stages and environmental impacts to be the most impacted or significant in tributaries upstream from Yakima Basin reservoirs. *Yakima Subbasin Summary* (NPPC 2001) and Haring (2001) provide additional migration and life history information and a review of passage timing and other information.

5.2 COHO SALMON

All upper Columbia River coho salmon stocks, including those in the Yakima River, are believed to be extinct; endemic coho salmon were extirpated in the early 1980s (NPPC 2001). Beginning in the 1950s and continuing through the 1970s, an extensive network of coho salmon hatcheries was constructed in the lower Columbia River. Fish management agencies allowed harvest rates of 80-90 percent. Although the hatchery runs of coho salmon could withstand such high rates of harvest, wild Columbia River coho salmon stocks were also harvested in the mixed-stock fisheries. As a result of hatchery, harvest, and loss of habitat, most Columbia River coho salmon stocks above Bonneville Dam were lost (Johnson 1991).

Natural reproduction of hatchery-reared coho salmon, outplanted as smolts, is now occurring in the Yakima River and the Naches River. Natural reproduction is evident from the increasing occurrence of age-zero coho salmon parr in samples collected at numerous points in the basin (Yakama Nation, unpublished data, 2000). Coho salmon currently returning to the basin are a mix of hatchery stocks from outside the basin. Efforts are underway to develop a "naturalized" stock. Currently coho salmon enter the Yakima River in the fall and reach the upper watersheds in November and December. Adult passage data at Roza Dam from 1941-1968 indicate that the endemic coho salmon run timing was earlier than now. The vast majority of the hatchery coho salmon smolts outplanted since 1985 have also been early-run. There is also some evidence for a bimodal distribution in the run timing of coho salmon (Pat Monk, fishery biologist, Yakima Basin Joint Board, Ellensburg, WA, October 2002, pers. comm.)

Based on sparse WDFW records of spawner surveys, the endemic stock spawned in the upper Yakima River above the Cle Elum River confluence and in the Naches River, primarily in the lower alluvial reaches downstream from the Tieton River confluence. Bryant and Parkhurst (1950) reported that coho salmon also spawned in smaller tributaries of the upper Yakima, such as Taneum and Umtanum Creeks, in the early years of the 20th century, and affidavits from early settlers of the Wenatchee basin state that "silvers" were found in virtually every perennial creek and river in the basin before extensive development occurred. It is now assumed that coho salmon utilized virtually every low-gradient perennial stream in the basin prior to the extensive habitat alteration that began in the late 19th century (YIN 1990).

Efforts to restore coho salmon within the Yakima Basin rely largely upon releases of hatchery-produced fish. The Yakama Nation has released between 85,000 and 1.4 million coho salmon smolts in the Yakima Basin annually since 1985. However, before 1995, the primary purpose of these releases was harvest augmentation; after 1995, the primary purpose became a test of the feasibility of re-establishing natural production (NPPC 2001).

The current, naturalized run spawns in reaches downstream from the historical areas because, until 1999, the vast majority of hatchery smolts were acclimated and/or released well downstream from historical spawning areas. Radiotag monitoring of adult coho salmon in the fall of 1999 indicated that most coho salmon now spawn in proximity to their acclimation and release points, primarily in the middle Yakima below Sunnyside Diversion Dam, from RM 95 to RM 104 (Dunnigan 2000). In recent years, coho salmon spawning has been documented in side channels of the mainstem Yakima River between Roza Dam and the town of Wapato (about RM 100) and in the Yakima Canyon (RM 129 to RM 146); in Naches River below the Tieton River confluence; and in numerous smaller tributaries.

McNeil and Kreeger (1993) and Yakama Indian Nation (1990) estimated the historical coho salmon run at 44,000 and 150,000 fish, respectively. Coho salmon returns since regular outplanting began in 1985 have increased steadily, climbing from 0 in 1984 to a peak of 5,700 in 2000. Few of the outplanted coho salmon were marked until recently. Therefore, the proportion of natural origin recruits in recent returns is unknown.

The spawning distribution and spawning success of coho salmon returning to the Yakima River is just beginning to be determined (NPPC 2001). Earlier attempts to determine the spatial distribution of spawning coho salmon in the Yakima was compromised by difficulty in finding redds. An indication of the problem is the 25:1 ratio of adults passing Prosser Dam to redds counted later in the season during the period 1989-1996. Thus, assuming a 50 percent sex ratio, only about 8 percent of the potential redds were discovered (YN 1997).

A 3-year radiotelemetry study was initiated in 1999 to determine the spawning distribution of coho salmon in the Yakima Basin (NPPC 2001). Most coho salmon homed back to the general vicinity of the three lowest acclimation sites from which coho salmon smolts were released in the spring of 1998.

5.3 SOCKEYE SALMON

Before the unladdered crib dams were built (1904-1910) at the outlets of the four natural sockeye salmon rearing lakes, the sockeye salmon run was probably larger than any other in the Yakima Basin in terms of numerical abundance (YIN 1990). Prior to water development in the Yakima Basin, historic sockeye salmon run size has been "estimated" as 211,104 fish (YIN 1990). Historically, juvenile sockeye salmon reared in all of the headwaters lakes — Keechelus, Kachess, Cle Elum and Bumping — and adults probably spawned both in the lakes and lake tributaries.

Except for a handful of adult fish returning from experimental Cle Elum Lake research releases of hatchery-reared stock, smolts from Lake Wenatchee stock in the years 1991-1993 and 1995, and a number of experimental releases of smolts in the 1940s, sockeye salmon have not returned to the Yakima Basin since the1920s. Run-timing for sockeye salmon at Rock Island Dam and Rocky Reach Dam peaks in early-mid July, and the Lake Wenatchee adult sockeye salmon migration would peak about the same time.

Juvenile sockeye salmon rear exclusively in lakes, rather than streams as do other Pacific salmon species. Sockeye salmon also exhibit unique spawning behavior. Some populations of adult sockeye salmon spawn in lakes or in tributaries entering lakes. Other populations spawn in rivers flowing out of the lakes, downstream from the lake outlet. Upon emergence, sockeye salmon fry in lake-outlet spawning populations must migrate upstream in order to utilize the rearing habitat in the lake, whereas fry emerging from lake-inlet streams must migrate downstream to the rearing habitat in the lake. The direction sockeye salmon fry migrate is genetically based and is an important consideration for fish passage and hatchery supplementation (Burgner 1991).

5.4 STEELHEAD

5.4.1 Abundance and Distribution — Yakima Basin steelhead are a component of the NMFS-designated Middle Columbia River (MCR) steelhead Evolutionarily Significant Unit (ESU). Adult steelhead return to the upper Yakima River between September and May. Current steelhead abundance is only about 1.3 to 6 percent of historical estimates, averaging 1,256 fish over the brood years 1985 to 2000 (NPPC 2001). Numbers of adults returning above Roza Dam has been very low until about the past 10 years (about 100 to 200 steelhead per year). About 7 percent of the basin-wide steelhead run goes past Roza Dam (Walt larrick, USBR Yakima, February 2003, pers. comm.).

The MCR steelhead ESU was listed as threatened under the Endangered Species Act (ESA) on March 25, 1999 (64 Fed. Reg. 14517). It includes all natural-origin populations in the Columbia River Basin above the Wind River, Washington, and the Hood River, Oregon, including the Yakima River. This ESU includes the only populations of winter inland steelhead in the United States (in the Klickitat River, Washington, and Fifteenmile Creek, Oregon). Both the Deschutes River and Umatilla River hatchery stocks are included in the ESU, but are not listed. Critical habitat is not presently designated for MCR steelhead.

Middle Columbia River steelhead population sizes are substantially lower than historic levels, and at least two extinctions are known to have occurred in the ESU. Based on historic (pre-1960s) estimates, the run size could have been in excess of 300,000 fish (Busby et al. 1996). In recent years, wild fish escapement among the ESU populations has averaged 39,000 and total escapement 142,000. A large proportion of hatchery fish, concurrent with the decline of wild fish, is a major risk to the MCR steelhead ESU (WDFW et al. 1993; Busby et al. 1996; 63 Fed. Reg. 11798, March 10, 1998).

Across the entire ESU, steelhead abundance in larger rivers like the Yakima has also been severely reduced. It is estimated that the Yakima River had annual run sizes from 20,000 to 100,000 steelhead prior to development (WDF et al. 1993). Although historical run size estimates vary, numerous early surveyors and visitors to the Yakima Basin reported a robust and widespread steelhead population (Bryant and Parkhurst 1950; Davidson 1953; Fulton 1970; NPPC 1986; McIntosh et al. 1990).

Within the Yakima River basin, wild adult steelhead returns have averaged 1,488 fish (low of 505 in 1996 to high of 4,461 in 2002) over brood years 1985-2002 as monitored at Prosser Dam (NPPC 2001; brood year 2002 data from Yakima-Klickitat Fisheries Program [YKFP], available at www.ykfp.org). YKFP data showed that 1,362 wild adult steelhead had passed Prosser Dam as of January 7, 2003. This comparatively large return mirrors high numbers of returning salmon and steelhead observed returning to the Columbia basin in the past two years.

5.4.2 Factors for Decline — Several factors have been noted for contributing to the decline of steelhead in the upper mainstem Yakima River basin. These include structural simplification of most of the anastomosing reaches of the mainstem Yakima River, partial or complete blockage of spawning tributaries by irrigation diversion dams, entrainment of smolts in tributary and mainstem irrigation diversions, the release of large volumes of water from storage reservoirs in the summer when steelhead fry are just emerging, and stranding of fry and parr in shallow side channels. For many years, operation of Roza Dam precluded fish access to the ladder during the time period steelhead return to the basin.

5.4.3 Migration and Spawning — Generally, adult MCR steelhead migration into the Yakima Basin peaks in late-October and again from late February or early March. Steelhead adults begin passing Prosser Dam in late summer, suspend movement during the colder parts of December and January, and resume migration from February through June. The relative number and timing of wild adult steelhead returning during the fall and winter-spring migration periods varies from year to year, most likely because of a low-flow induced thermal barrier in the lower Yakima River in the fall (USBR 2000a; NPPC 2001). Most adult steelhead overwinter in the Yakima River between Prosser Dam (RM 47.1) and Sunnyside Diversion Dam (RM 103.8) before moving upstream into tributary or mainstem spawning areas (Hockersmith et al. 1995).

Steelhead spawning varies across temporal and spatial scales in the Yakima Basin, although the current spatial distribution is significantly decreased from historic conditions. Yakima Basin steelhead spawn in intermittent streams, mainstem and side-channel areas of larger rivers, and in perennial streams up to relatively steep gradients (Hockersmith *et al.* 1995; Pearsons *et al.* 1996). Hockersmith *et al.* (1995) identified eleven spawning populations within the Yakima Basin:

- upper Yakima River above Ellensburg
- Teanaway River
- Swauk Creek
- Taneum Creek
- Roza Canyon
- mainstem Yakima River between the Naches River and Roza Dam
- Little Naches River
- Bumping River
- Naches River
- Rattlesnake Creek
- Toppenish Creek
- Marion Drain
- Satus Creek

Of 105 radiotagged fish observed from 1990 to 1992, Hockersmith et al. (1995) found that well over half of the spawning occurs in Satus and Toppenish Creeks (59 percent). A smaller proportion was found in the Naches drainage (32 percent), and the remainder in the mainstem Yakima River below Wapato Dam (4 percent), mainstem Yakima River above Roza Dam (3 percent), and Marion Drain (2 percent), the latter a

Wapato Irrigation Project drain tributary to the Yakima River. Electrophoretic analyses have identified four genetically distinct spawning populations of wild steelhead in the Yakima Basin: the Naches, Satus, Toppenish, and Upper Yakima stocks (Phelps et al. 2000).

Typically, steelhead spawn earlier in lower-elevation warmer waters than in higher-elevation colder waters. Overall, most spawning is completed within the months of January through May (Hockersmith et al. 1995), although WDFW personnel have observed steelhead spawning in July in the Teanaway River (RM 176.1), a tributary to the upper arm of the Yakima River. These steelhead spawn later in the year at higher elevations in the Yakima Basin, and face lethal conditions (in most years) as emigrating kelts (spawned-out adults returning to the ocean) in the lower Yakima River. MCR steelhead that spawn in the Yakima Basin at lower elevations potentially meet the same fate, however earlier spawn timing and emigration may provide increased survival because kelts traverse the lower Yakima River before water quality becomes lethal. High water temperatures, low flows, and degraded water quality from irrigation effluents (a combination of high water temperature, turbidity and pollutant concentrations), contribute to extremely low survival during summer months (Vaccaro 1986; Lichatowich and Mobrand 1995; Lichatowich et al. 1995; Pearsons et al. 1996; Lilga 1998). Steelhead kelts and smolts have been observed at the Chandler Juvenile Enumeration Facility (about ½-mile downstream from Prosser Dam) into the middle of July, but operations at this facility cease around this time because river conditions prove lethal for most salmonids (including smolt, juvenile, and kelt MCR steelhead). Conditions in the lower Yakima River become suitable once again for salmonids in early fall, near the end of the irrigation season (NPPC 2001).

Most Yakima River basin steelhead are tributary spawners, with most currently spawning in the complex, multi-channel reaches of tributaries with a "moderate" gradient, about 1-4 percent (NPPC 2001), such as Naches River and tributaries, Satus Creek or Toppenish Creek.

Steelhead spawning has been documented throughout the mainstem Yakima River and especially between the mouth of the Yakima Canyon and Ellensburg, in the Bristol Flats area to around the mouth of the Teanaway River, and in the area between Easton Dam and the mouth of Big Creek. Steelhead spawning has also been documented in Umtanum, Cherry, Taneum, and Swauk creeks as well as in the West and North forks of the Teanaway River.

Adult steelhead spawn during the spring/early summer period between March and July. As nearly as can be determined, spawning occurs in the middle Yakima River (the reach between Roza Dam and Sunnyside Diversion Dam), the upper main Yakima River and higher elevation upper Yakima River tributaries according to the following approximate schedule (NPPC 2001):

- **middle Yakima River** — late February through early April, peak in late March
- **upper Yakima River mainstem in Yakima Canyon** (including Umtanum and Wilson/Naneum Creeks) — late March to mid May with a peak in late April,
- **upper Yakima River mainstem above the Yakima Canyon** — from mid April to late May with a peak in early May
- **upper Yakima River tributaries** (Big Creek, Teanaway River, Swauk Creek, Taneum Creek, Manastash Creek) — late April through early June, with a peak in late May.

Juvenile steelhead emerge from the gravel between June and August and rear in the areas near where they were spawned. Much less is known about the life cycle of juvenile steelhead in the Yakima River system than for chinook salmon for two reasons; 1) the steelhead are much less abundant, and 2) juvenile steelhead are indistinguishable from resident rainbow trout until they reach the smolt stage.

Juvenile steelhead utilize tributary and mainstem reaches throughout the Yakima Basin as rearing habitat until they begin to smolt and emigrate from the basin. Smolt emigration begins in November, peaking between mid-April and May. Busack et al. (1991) analyzed scale samples from smolts and adult steelhead. They found that smoltification generally occurs after 2 years in the Yakima system, with a few fish maturing after 3 years and an even smaller proportion reaching the smolt stage after one year. When compared to spawning distribution and run timing, these data suggest that various life stages of listed steelhead are present throughout the Yakima Basin and its tributaries virtually every day of the calendar year.

Steelhead smolts have been collected in mainstem Yakima River, all three forks of the Teanaway River, and Swauk, Taneum, Manastash, Dry, Wilson, Naneum, Cherry, Badger, and Umtanum creeks. Steelhead in other streams that are similar to the Yakima River (that is, those in the Deschutes River, Oregon, which are also part of the MCR steelhead ESU) can spawn in small and relatively warm tributaries; some fish even spawn in seasonally intermittent tributaries. Most steelhead smolts migrate from the Yakima River between the ages of 1 and 3, although in some systems steelhead may rear in freshwater for 1 to 7 years before smolting and beginning their seaward migration.

The Upper Yakima River steelhead population was undoubtedly adversely affected by operations at Roza Dam (RM 128) between 1939 and 1958 (USBR 2000a). Although fitted with a ladder, the pool at Roza Dam was kept down from the end of one irrigation season (mid-October) to the beginning of the next (mid-March) during this 20-year period. Hockersmith et al. (1995) found that steelhead passed Roza Dam from November through March, and more recent data suggest that passage occurs from the end of September through May (see www.ykfp.org). Consequently, operations at Roza Dam virtually eliminated fish passage for most of the steelhead migration season and excluded most steelhead bound for the upper Yakima from reaching their destination. A new ladder was installed at Roza Dam in 1989 that allows better passage, but only when the pool is completely up or down. However, the ladder is inoperable at levels between maximum and minimum pool when the reservoir is manipulated to facilitate screen maintenance at the end of October and early November. Additionally, as previously described, MCR steelhead spawn and emergence timing is shifted to later in the year in the Upper Yakima, and emigrating smolts therefore meet hazardous if not lethal water quality conditions in the lower Yakima River. This combination of historic and contemporary seasonal factors could help explain in part the low abundance of MCR steelhead in the Upper Yakima Basin.

Pre-smolt rearing migrations are less well understood for steelhead than they are for spring chinook salmon. The presence of juvenile steelhead in small tributaries throughout the summer, sometimes in high densities, indicates that the fish are apparently less inclined to migrate downstream for early rearing than spring chinook salmon (NPPC 2001).

Yakima Subbasin Summary (NPPC 2001) raises some interesting questions and provides discussion regarding eventual restoration of steelhead populations in the upper Yakima River in light sympatric populations of resident rainbow trout and complex life history attributes of the two ecotypes, including reproductive isolation or the lack thereof. Zimmerman and Reeves (2000) provide additional information on reproductive isolation of steelhead and resident rainbow trout.

5.5 BULL TROUT

5.5.1 Distribution and Status — Bull trout (*Salvelinus confluentus*) occurred historically throughout most of the Yakima Basin. Today, however, they are fragmented into relatively isolated stocks. Although bull trout were probably never as abundant as other salmonids in the Yakima Basin due in part to their requirements for cold, clear water, they were certainly more abundant and more widely distributed than they are today (WDFW 1998).

In June 1998, the U.S. Fish and Wildlife Service (FWS) listed the Columbia River basin "distinct population segment" of bull trout as threatened under the Endangered Species Act (63 Fed. Reg. 31647;

10 June 1998). FWS identified eight bull trout subpopulations in the Yakima River basin in its 1998 final listing rule (63 FR 31647). These subpopulations included:

- Ahtanum Creek
- Naches River
- Rimrock Lake
- Bumping Lake
- North Fork Teanaway River
- Cle Elum Lake
- Kachess Lake
- Keechelus Lake

At the time of listing, only the Rimrock Lake subpopulation was considered stable. The remaining subpopulations were classified as “depressed” and “declining.” The population status for the Naches River subpopulation was classified as “unknown.” With the exceptions of Rimrock Lake and the Naches River, the remaining subpopulations were considered to be at risk of extirpation.

WDFW recognizes nine bull trout stocks in the Yakima River basin (see table B-5-1 below). These stocks are consistent with the subpopulations identified by FWS in its final listing rule; however, it includes one stock (Yakima River) that was not recognized by FWS at the time of listing.[3/] Six stocks are classified as “critical” by WDFW, one is “depressed,” one is “healthy,” and one is “unknown” (classification definitions are in table B-5-1). The status of each of these stocks was largely derived from redd counts that WDFW has been conducting on an annual basis since 1984.

Within each stock one or more local populations may exist. A local population represents a group of bull trout that spawn within a particular stream or portion of a stream system. Thus, a local population could be considered the smallest group of fish that represent an interacting reproductive unit. Gene flow may occur between local populations but is assumed to be infrequent compared to that among individuals within a local population. There are presently thirteen local populations that have been identified in the Yakima River basin. Other local populations may exist but are as yet unrecognized. For example, as recently as the summer of 2002, a juvenile bull trout was captured by Yakama Nation fisheries personnel in a tributary to Cowiche Creek (Eric Anderson, WDFW, pers. comm., June 2002).

3 This exclusion was due to a lack of information which has since been attained.

TABLE B-5-1. YAKIMA RIVER BASIN BULL TROUT STOCKS RECOGNIZED BY WDFW (from WDFW 1998).			
Stock	**Life History Form**	**Status**	**Comments**
Keechelus Lake	adfluvial	Critical	Chronically low redd counts
Kachess Lake	adfluvial	Critical	Chronically low redd counts
Cle Elum/Waptus Lakes	adfluvial	unknown	
Bumping Lake	adfluvial	Depressed	Short-term severe pop. declines
Rimrock Lake	adfluvial	Healthy	
N. Fork Teanaway River	fluvial/resident	Critical	Chronically low redd counts
Naches River	fluvial/resident	Critical	Chronically low redd counts
Yakima River[1/]	fluvial	Critical	Chronically low redd counts
Ahtanum Creek	resident	Critical	Chronically low redd counts

[1/] Stock not recognized by FWS as subpopulation in its 1998 Final Listing Rule (63 FR 31647)

Critical — A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed — A stock of fish whose production is below expected levels based on available habitat and natural variations in survival rates, but above the level where permanent damage to the stock is likely.

Healthy — A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Unknown — There is insufficient information to rate stock status.

5.5.2 Life History — Three bull trout life history forms are present in the Yakima Basin: adfluvial, fluvial and resident. Adfluvial and fluvial fish reside in lakes and mainstem rivers, respectively. Fry and juveniles rear in their natal streams for 1-4 years before migrating downstream into lakes or mainstem river systems. Adults migrate into tributary streams to spawn, after which they return to the lake or river. The resident life-history form resides in a particular stream for its entire life cycle. The life history forms displayed by each of the nine bull trout stocks in the Yakima Basin is presented in Table B-5-1. Adfluvial stocks occur in Rimrock, Bumping, Kachess, Keechelus and Cle Elum/Waptus lakes. A fluvial stock is present in the mainstem Yakima River, fluvial/resident forms are present in the Naches River and North Fork Teanaway River drainages, and a resident stock occurs in Ahtanum Creek (WDFW 1998).

Bull trout are late summer/early fall spawners and most spawning activity in the Yakima Basin, irrespective of life history form, occurs from early September through early October. However, spawning may occur as early as late August (Deep Creek in the Bumping system) or as late as mid-October to early November (Kachess River-Mineral Creek in the Kachess system). For the migratory life history forms, the spawning migration can begin as early as mid-July (Gold Creek in the Keechelus system) when adults move upstream to hold in deep pools or it may occur just prior to spawning (Indian Creek in the Rimrock Lake system).

The incubation period for bull trout is extremely long relative to other salmonids and fry may take up to 225 days to emerge from the gravel (Craig 1997). Adfluvial and fluvial juveniles will generally rear in their natal streams for 1-3 years before emigrating to their adult environments to further mature (Rieman and McIntyre 1993). Sexual maturity is reached in 5-7 years and the species may live up to 12 years, spawning repeatedly. Data from an adfluvial bull trout population in the Flathead Lake system of Montana indicate that between 38 to 69 percent of adults leave the lake each summer to spawn (Fraley and Shepard 1989). However, these are averages and some fish seem to spawn nearly every season, as evidenced by a female from Rimrock Lake that has spawned 5 of the past 6 years at Indian Creek (Paul James, Central Washington University, Ellensburg, WA, pers. comm.).

The primary downstream migration periods for juvenile bull trout from their natal tributaries into lakes or rivers occurs from June through November. The early summer migration appears to be in response to increased flows and may correspond with a switch in prey from invertebrates to fish, whereas the fall migration appears to be primarily in response to decreasing water temperatures and the need to find suitable overwintering habitat (Fraley and Shepard 1989; Murdoch 2002).

Relatively limited data exist on juvenile movement patterns downstream from lakes/reservoirs, or upstream into lakes/reservoirs from fluvial systems. However, it is likely these movements are triggered in response to shifts in food resources, temperature regimes, overwintering habitat or spawning activity or entrainment through dams, in which case the fish may be lost to the system if upstream passage is not provided. In the Lake Wenatchee system, Murdoch (2002) reported observing fish moving into the lake in the fall, apparently to overwinter. Further observations from traps downstream from Lake Wenatchee indicate juvenile bull trout are not frequently seen moving at this time of year in the fluvial environment.

5.5.3 Habitat — Bull trout appear to have unique habitat requirements. While migratory forms may use much of the river basin throughout their life cycle, spawning and rearing fish are often found only in a portion of the available stream reaches; rearing and resident fish often live only in smaller watersheds or second-to-fourth order tributaries (Armstrong and Morrow 1980; Fraley and Graham 1981; Platts 1974; Platts and Partridge 1983; Thurow 1987; Ziller 1992). Among the most important habitat attributes affecting bull trout distribution and abundance are suitable water temperatures, channel stability, clean substrates, adequate cover, and the presence of migration corridors (Allan 1980; Fraley and Graham 1981; Thurow 1987; Ziller 1992). Little is known regarding migration timing in the Yakima Basin.

Bull trout are extremely temperature sensitive. Water temperatures in excess of about 15 °C are thought to limit bull trout distribution (Allan 1980; Fraley and Shepard 1989; Goetz 1991; Pratt 1985; Shepard et al. 1984, Selong et al. 2001). Numerous studies have cited various temperatures as optimal for the different life stages of bull trout. Temperature data from archival temperature tags placed on adult bull trout in the summer of 2002 in the Wenatchee River system indicate maximum temperatures experienced were 15-16 ºC (De La Vergne 2002). In general, spawning is initiated when water temperatures drop below 10 °C. Optimal temperatures for incubation are between 2-4 °C, and those for rearing are in the range of 4-10 °C (Fraley and Shepard 1989; Goetz 1989; McPhail and Murray 1979).

Channel stability and clean substrates are closely associated habitat elements necessary for successful reproduction, fry and juvenile survival, and growth. As mentioned above, bull trout embryos and alevins spend an extended period of time beneath redd gravels. After emergence, young bull trout remain closely associated with stream channel substrates. The evidence suggests that channel instability and resultant increases in bedload movement and sediment deposition decreases bull trout survival (Goetz 1989; Weaver 1985). The species also demonstrates an affinity for complex forms of cover (woody debris, undercut banks, pools). Numerous studies have shown a positive correlation between bull trout densities and cover (Rieman and McIntyre 1993).

Open migratory corridors are essential to allow bull trout populations to move between seasonal habitats, exploit seasonal food resources, experience gene flow between populations, refound populations after local extirpations, and gain support from stronger populations. Disruption of migratory corridors will increase stress, reduce growth and survival, and possible lead to the loss of the migratory life-history types (Rieman and McIntyre 1993).

5.6 PACIFIC LAMPREY

5.6.1 Distribution and Status — Pacific lamprey (*Lampetra tridentata*) are currently recognized as a Category 2 candidate species as listed by FWS. Pacific lamprey are declining in most, if not all, areas of the Columbia River Basin (Close et al. 1995, 2002). In January 2003, a coalition of conservation groups petitioned FWS to list four species of lamprey (including the Pacific lamprey) as threatened or endangered. Historically, Native Americans fished for lamprey in the Yakima Basin, which suggests that they were quite abundant (Hunn 1990). The distribution of the two other species, river lamprey (*Lampetra ayresi*) and western brook lamprey (*Lampetra richardsoni*) is unknown in the Yakima Basin, however western brook lamprey have been found in the lower reaches of the Yakima River. Currently, lamprey are not harvested in the Yakima River because of their scarcity. Since so little information is available regarding lamprey abundance and distribution in the upper Yakima River basin and their ability to use fish passage facilities, these species will not be considered any further in this Phase I report.

5.6.2 Life History — Pacific lamprey spend the early part of their life burrowed in fine silt. After 4 to 6 years they undergo a metamorphosis that changes their physical appearance and physiological abilities. Juveniles then outmigrate to the ocean and spend between 20-40 months in a free swimming stage. Adults then return to their natal freshwater streams in June and July to spawn and die (Close et al. 2002; Wydoski and Whitney 1979). Unlike the other two species of lamprey, western brook lamprey spend their entire life in fresh water, and spawn from April through July with a peak in May.

5.6.3 Habitat — Although no historic records of lamprey above the Yakima River dams are known, there were several sightings just below the dams. WDFW Division of Non-Game Fish has a record of a river lamprey at the base of Easton Diversion Dam. There are also several reports by Todd Pearsons (WDFW, pers. comm.) of Pacific lamprey in the upper reaches of the mainstem Yakima River, but downstream from storage reservoirs. Juveniles typically rear in side channel areas of the mainstem of the Yakima River, and are often found in areas with well developed silt and aquatic plants.

5.6.4 Ecological Significance — Lampreys historically represented a significant percentage of the biomass in some streams and as such acted as important processors of stream nutrients. Lampreys also facilitate the processing of detritus and algae; they are poor digesters, thereby making this semi-digested material available to other aquatic organisms and enriching the aquatic ecosystem. Lamprey also act as a food source for other animals, including juvenile salmon (Pfeiffer and Pletcher 1964).

5.6.5 Cultural Significance — Traditionally, lamprey have been harvested by tribal peoples of the Columbia River Basin for subsistence, ceremonial, and medicinal purposes. They are important in celebrations (Close et al. 1995).

B-6. DATA DESCRIBING HABITAT CONDITIONS

6.1 KEECHELUS LAKE SUPPORT DATA

6.1.1 Meadow Creek — The *Yakima Watershed Assessment* (USFS 1999) reports three culverts on road crossings of Meadow Creek that exceed gradient criteria for fish passage design (located in T21N, R11E, Sections 8 and 16). The reaches sampled in Meadow Creek did not meet the *Northwest Forest Plan* (USFS 1994) standards for LWD presence or pool frequency (USFS 1997).

The standards are 100 pieces of large wood, 36 inches in diameter and 50 feet long; 100 pieces of small wood, 24 inches in diameter and 50 feet long; NMFS large-wood standard is 20 pieces of large wood. High water temperatures due to past logging likely preclude significant bull trout use until regrowth provides riparian shade.

Figures B-6-1 and B-6-2 show stream discharge and water temperature in Meadow Creek from early to mid June to late November.

Figure B-6-1. Meadow Creek discharges (cfs)

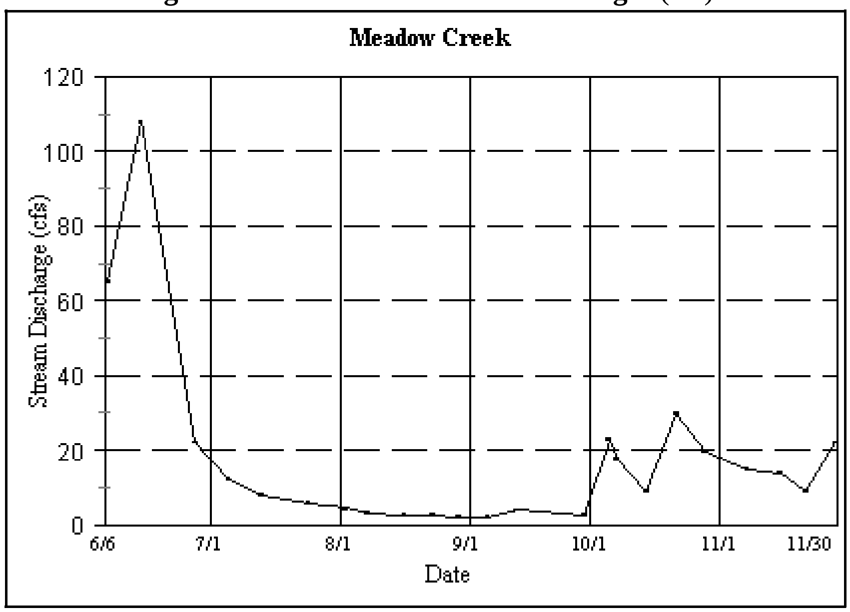
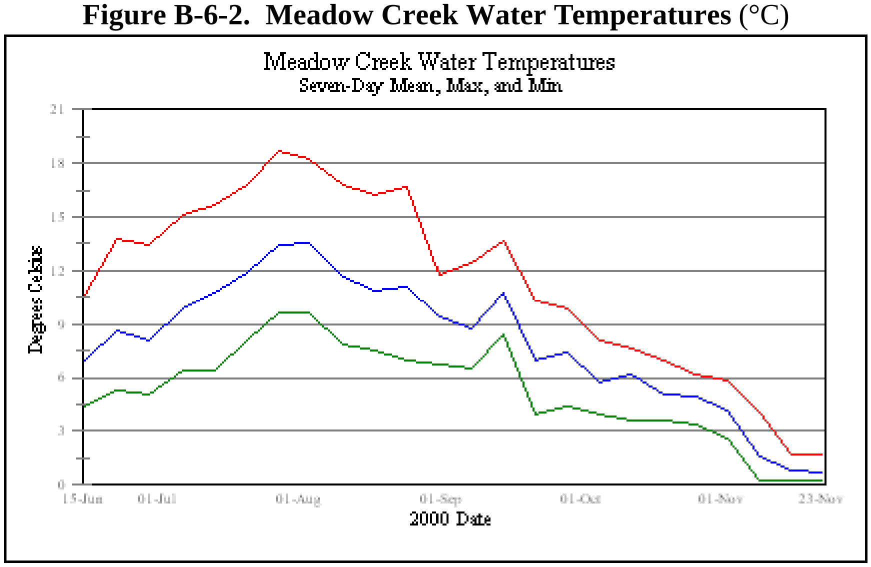
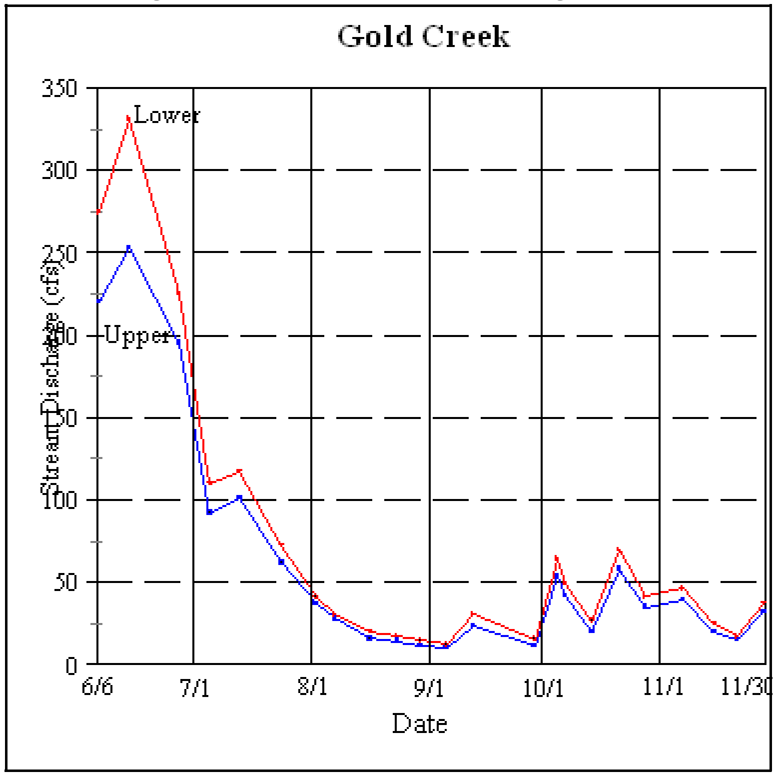


Figure B-6-2. Meadow Creek Water Temperatures (°C)



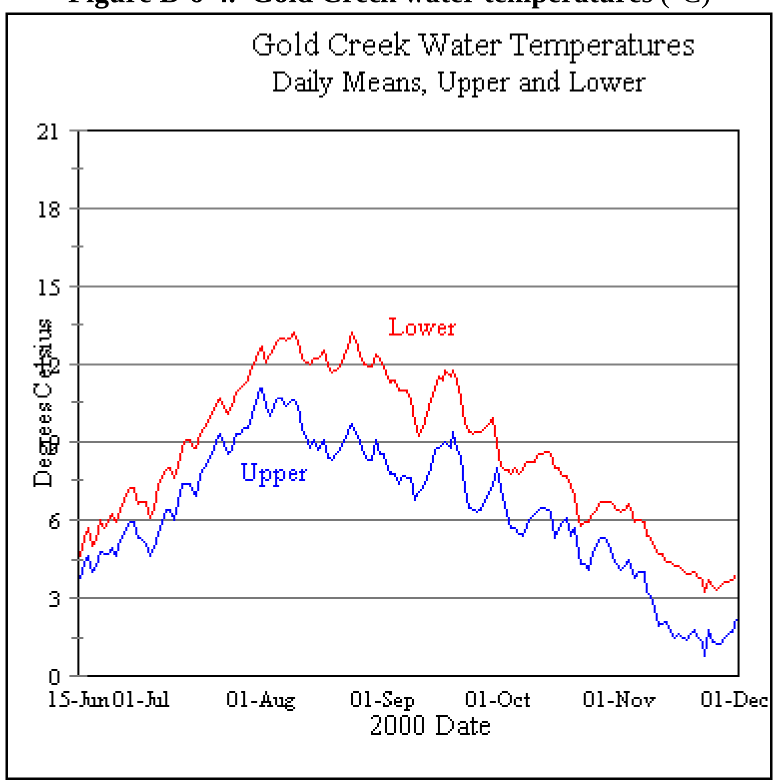
6.1.2 Gold Creek— Gold Creek has a natural falls at RM 7.1 that is a barrier to upstream fish passage (Craig 1997, cited in USBR 2000a). Adult bull trout migration into Gold Creek begins in mid to late July and continues into August until the creek becomes impassable due to dewatering (Anderson 2001; James et al. 2000; Meyer 2002). Gold Creek routinely stays dewatered for a month or two, typically lasting into late September (Wissmar and Craig 1997). The dewatering typically begins in reaches above Gold Creek Pond and can be intermittent for over 1.5 miles. Complete dewatering of portions of the Gold Creek channel upstream from the maximum lake elevation has been noted in most recent years. At times, when the channel above the lake is dewatered, that portion of the channel traversing the reservoir bottom may also be impassable due to low Gold Creek flows, shallow water conditions, and the poor stream habitat conditions created by periodic inundation of the stream channel by the reservoir.

Figure B-6-3. Gold Creek discharges (cfs)



Migrating fish commonly can swim through the channel across the exposed lakebed, but cannot swim up the channel above Gold Pond (Brent Renfrow, WDFW, pers. comm.). Adults that haven't migrated into the upper watershed prior to dewatering frequently move into and hold in the flowing reaches of Gold Creek, between Gold Creek Pond and the reservoir. There is evidence that some of the adult fish holding in this lower area move into the upper watershed upon the streams rewatering in the fall, although a few adults are known to spawn in the lower reaches. Redd counts from 1984 to 2001 have ranged from 2 to 51 with an average of 18 (s.d. = 13.3). A rough population estimate for this stock is between 100-200 adult fish and the stock is currently considered at a critically low level. Figures B-6-3 and B-6-4 show Gold Creek flows and water temperatures at two locations from early-to-mid June to late November. Maximum water temperatures

Figure B-6-4. Gold Creek water temperatures (°C)



are less than 15 °C during the warmest part of the summer. Low flow was about 10-12 cfs around the beginning of September 2000.

Gold Creek only met the Forest Plan standard for LWD in one of the six reaches sampled. Historically LWD in Gold Creek included large old growth trees, which would serve as stable key pieces in debris jams. In-channel wood likely was a critical channel roughness element, dissipating stream energy and maintaining the stability of the alluvial channel. All of the large, old growth timber in the lower watershed was logged by 1990; there is now little or no residual key-piece size LWD in-channel and no opportunity for recruitment of new LWD key pieces. Although there is a substantial amount of small and medium sized woody debris in Gold Creek (and more is recruited from the banks with each flood), most all of it is readily mobilized by flood flows. Pieces are not large enough to provide bank protection, stable debris jams and stable LWD-related channel features. Bank erosion is occurring throughout lower Gold Creek and the resulting bedload has caused the channel to become broad and braided. During late summer low flow, the stream flows subsurface within these gravels. Potentially, the reintroduction of stable LWD features would restore bank stability and aid in the return of deep pools and prolong the period when upstream fish passage is possible.

Gold Creek and Meadow Creek are on the Clean Water Act 303(d) impaired water quality list for water temperature.

6.1.3 Cold Creek — The culvert at the old Milwaukee Railroad grade crossing of Cold Creek (about 100 yards upstream from the mouth) is perched and is a total barrier to fish passage. Habitat conditions in Cold Creek upstream from the fish barrier are rated as good (Brent Renfrow, WDFW, 2002, pers. comm..; Tina Mayo, USFS, 2002, pers. comm.) with good LWD presence, riparian shade, and cold water, but none of the reaches sampled in Cold Creek upstream from the culvert met the Forest Plan standards for LWD presence or pool frequency (USFS 1997). Reclamation is in the process of removing or replacing this barrier, which would open up about two additional miles of spawning and rearing habitat for anadromous salmonids. As shown in Figures B-6-5 and B-6-6, Cold Creek has essentially no flow in late August-early September, with maximum water temperature of about 17 °C in late July-early August.

Figure B-6-5. Cold Creek discharges (cfs)

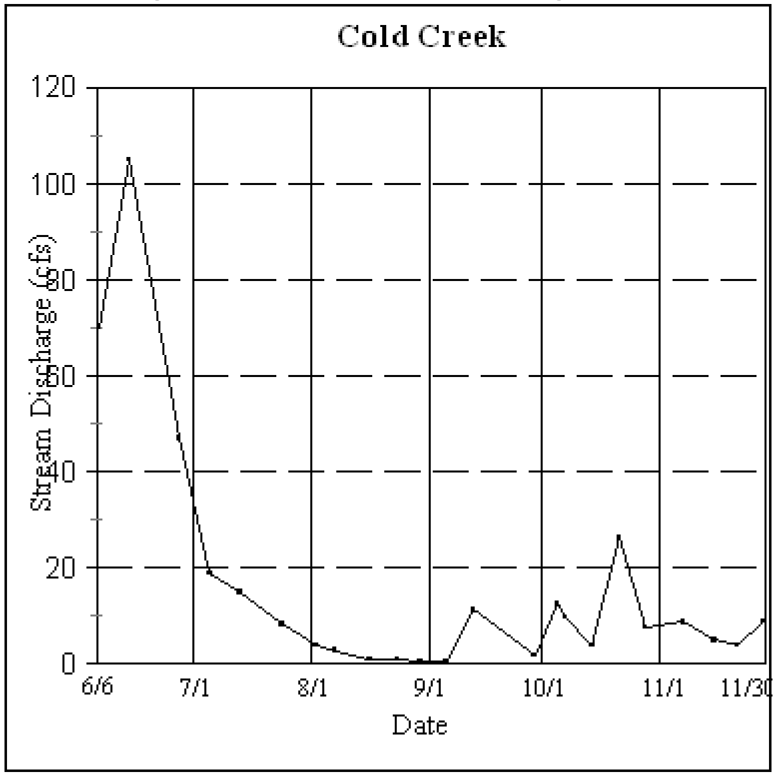
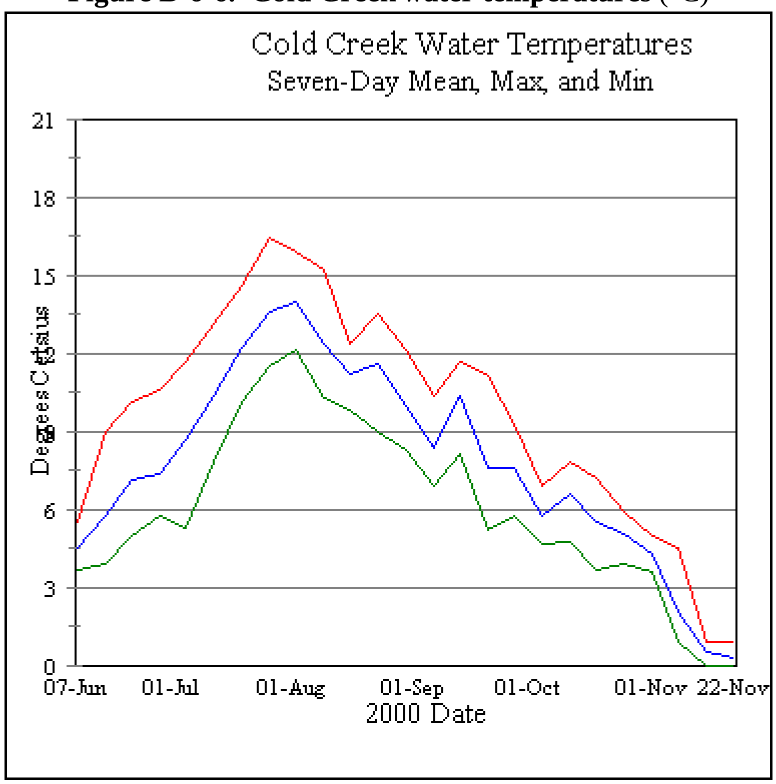


Figure B-6-6. Cold Creek water temperatures (°C)



6.1.4 Coal Creek — Coal Creek has at least two culvert fish passage barriers (one round corrugated metal pipe and one twin concrete box culvert) at crossings under Interstate Highway I-90 upstream from the Hyak interchange (Brent Renfrow, WDFW, 2002, pers. comm.). Natural floodplain function in Coal Creek is highly altered by I-90. The channel has been relocated, confined and straightened as it runs adjacent to the highway (Brent Renfrow, WDFW, 2002, pers. comm.). Much of the drainage is developed (highways, ski areas, and residential development) or clearcut, altering the water storage and runoff characteristics. Habitat conditions in Coal Creek are fair/poor, since much of the stream has been straightened or channelized (or both) along I-90. The daily range of water temperatures observed on Coal Creek during the summer was broad, which is undoubtably the result of extensive stream-side development and degraded riparian conditions. The daily average stream temperature for Coal Creek was the highest of four streams studied by Thomas (2000), although the 7-day average temperatures typically remained below 15 °C throughout most of the study, except for about a one-week period around the end of July-beginning of August. Based on the relatively poor habitat conditions and passage barriers, Coal Creek would not provide suitable spawning and rearing habitat for anadromous salmonids. Figures B-6-7 and B-6-8 show streamflows and water temperatures for Coal Creek from early June to late November. Streamflows are nearly zero in August and early September, while the 7-day average water temperature was greater than 15 °C around the end of July and the maximum water temperature was up to 21 °C during this time period, which would seriously stress bull trout.

Figure B-6-7. Coal Creek discharges (cfs)

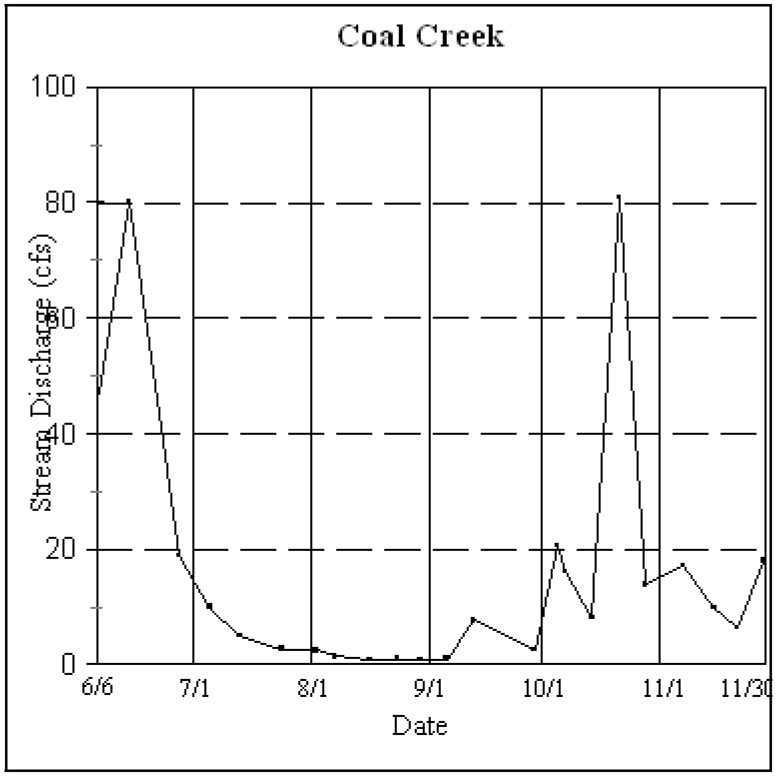
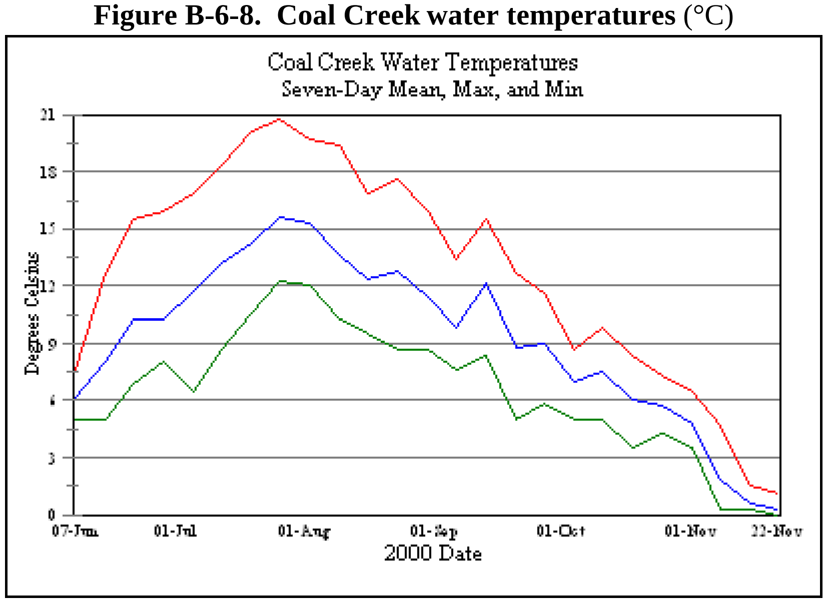


Figure B-6-8. Coal Creek water temperatures (°C)



6.1.5 Mill Creek — Mill Creek is about 2 miles long. A large culvert about RM 0.2 blocks fish passage. As a result, Mill Creek would provide little spawning and rearing habitat for anadromous salmonids even if fish passage was provided at Keechelus Dam.

6.1.6 Keechelus Lake limnology — Self-sustaining runs of kokanee salmon are present in Keechelus Lake, so clearly some food is available re-establish runs of sockeye salmon. Food may be a temporary limiting factor in juvenile growth and survival until anadromous salmonids runs return sufficient marine-derived nutrients to enhance reservoir productivity. Large fluctuations in the water level in the reservoirs may flush out zooplankton or limit primary productivity. Mongillo and Faulconer (1982) noted the reservoir was oligotrophic and suggested that artificial fertilization as a technique to temporarily increase productivity. Recent research conducted by Steve Hiebert (USBR, Denver, CO, 2002, pers. comm.) also preliminarily classifies Keechelus Lake as oligotrophic.

6.2 KACHESS LAKE SUPPORTING DATA

6.2.1 Kachess River — The Kachess River is 5.5 miles long with a natural fish passage barrier 0.9 mile upstream from Kachess Lake (Steve Croci, FWS, Yakima, September 2002, pers. comm.). WDFW found bull trout actively spawning in late-October/early-November 2000 and 2001 in the upper Kachess River upstream from the confluence with Mineral Creek, but not in Mineral Creek (Anderson and Cummins 1992). The Kachess River supports spring chinook salmon, coho (historic) salmon, and summer steelhead spawning and rearing downstream from Kachess Dam, as well as other resident salmonids and non-salmonids. The Kachess River is dry near its confluence with Kachess Lake in late summer through mid-to-late October, depending on fall precipitation. In 2000 and 2001, bull trout were found spawning in the Kachess River after fall rains restored flow. USFS (1997) has identified five fish-passage-barrier culverts in miscellaneous tributaries to the Kachess River and one on Gale Creek (tributary to Kachess Lake). These barriers may impact resident salmonids, but no anadromous salmonids presently occur upstream from Kachess Dam, and bull trout are not known to utilize the streams on which the barriers are located. The *Yakima Watershed Analysis* (USFS 1999) has the specific locations of these barriers.

6.2.2 Box Canyon Creek — Box Canyon Creek is 7.7 miles long (USFS 1995b), with a barrier falls at RM 1.6 (Haring 2001); USFS (1995b) reported that a waterfalls also occurs at about RM 4.5. Stream gradient near this area approaches 40 percent. Historically, the Box Canyon Creek supported sockeye salmon, bull trout, and cutthroat trout (USFS 1995b), with sockeye salmon presumed to have occupied Box Canyon Creek up to the barrier at RM 1.6. Bull trout occur in the mainstem to the barrier at RM 1.6 and may have extended higher into the watershed prior to the washout of a logjam below the falls during the 1990 Thanksgiving flood. The adult bull trout that overwinter in Kachess Lake appear to utilize Box Canyon Creek as their primary spawning ground (Anderson 1995 cited in USFS 1995b). Box Canyon Creek has excellent bed and bank stability due to bedrock and small boulder dominated substrate. LWD abundance and pool frequency were below USFS Forest Plan standards (USFS 1995b). Riparian conditions in Box Canyon Creek have declined between 1942 and 1992 as indicated by aerial surveys. Summertime water temperatures have exceeded Forest Plan standards and ranged as high as 20 °C. Box Canyon Creek has a high risk of road-related sediment problems. The bull trout population is considered at high risk of extirpation (Mongillo 1993, as cited in USFS 1995b), with an estimate of 50 adults in Kachess Lake (Brown 1992, as cited in USFS 1995b).

Other potential spawning streams around Kachess Lake have extensive alluvial aggradations and are highly impacted by lowering of Kachess Lake in late summer and early fall. The combination of reservoir drawdown and aggradation causes these streams to go subsurface at the critical time when adult bull trout are beginning their spawning migration. As the lake is drawn down, the exposed Box Canyon Creek channel on the lake bottom lacks definition as it flows across the permeable lake sediments and may become too shallow for adult bull trout passage (NPPC 2001). Reclamation attempted to correct this in 1996 with construction of a single channel through the inundation zone, but passage problems may still persist under some circumstances. Similar passage problems for bull trout also occur in the Kachess River as it annually dewaters upstream from the reservoir inundation zone.

6.2.3 Mineral Creek — Mineral Creek is 19 miles long, with a natural blockage at 0.25 miles. USFS (1997, cited in Haring 2001) rated 2 miles of spawning habitat, 3 miles of summer rearing habitat, and 3 miles of winter rearing habitat as good in Mineral Creek. The 16 to 17 miles remaining were rated fair or poor.

Bull trout were found in Mineral Creek in 1998 (WDFW 1998, cited in USBR 2000a). WDFW found bull trout actively spawning in late-October/early-November 2000 and 2001 in the upper Kachess River upstream from the confluence with Mineral Creek, but not in Mineral Creek (Anderson and Cummins 1992). In October 2001, one adult bull trout and no redds were found in the lower 0.25 mile of Mineral Creek. Although further investigation is required, a series of cascades on Mineral Creek may block upstream migration of bull trout beyond the lower 0.25 mile, and spawning gravel in the lower end of the creek is scarce.

6.2.4 Gale Creek — Gale Creek is 4 miles long. The 1991 USFS survey delineated four reaches in Gale Creek; there is a waterfall in Reach 3 above RM 1.5. The stream was subsurface for the first 165 feet as a result of lake drawdown during an October 1991 USFS stream survey. The Gale/Thetis Forest Planning Unit has a high total road or open road density, as well as road-related sediment problems (USFS 1997, cited in Haring 2001). Teaches 1, 2, 3, and 4 were 0.75, 0.75, 1.50, and 0.50 miles in length, respectively. Stream gradients in reaches 1, 2, 3, and 4 were 4, 6, 11, and 2 percent, respectively. Substrate composition was cobble/small boulder in reaches 1, 2, and 3 and gravel/cobble in Reach 4. Gale Creek is on the Clean Water Act “303(d)” impaired water quality list for water temperature. During the period 2 July to 10 September 1991, water temperatures ranged from 8 to 20 °C, which exceeded the 7-day average of 14.4 °C recommended by the Forest Plan. However, during the 2-8 October 1991 USFS survey, the stream met the Forest Plan standards for water temperature of 16 °C. The stream does not meet the Forest Plan standards for large woody debris or primary pools. The stream is embedded due to landslides, clearcuts, and recreation (USFS 1991). Riparian conditions vary among reaches, with reach 1 having the lowest percent canopy closure, ranging from 0 to 19 percent. No bull trout were documented in Gale Creek. With impaired water quality conditions especially as related to water temperature, habitat conditions may not be suitable for bull trout.

6.2.5 Thetis Creek — Thetis Creek is 2.7 miles long. In later summer, the creek commonly goes subsurface in he lakebed and upstream.

6.2.6 Lodge Creek — Lodge Creek is a small stream that provides a mix of habitat conditions in about 1.25 miles of accessible habitat. Habitat components include woody debris and wetlands. Brook trout are the most common species of fish observed.

6.2.7 Kachess Lake limnology — Self-sustaining runs of kokanee salmon are present in Kachess Lake, so clearly some food is available in the reservoir for re-establishing runs of sockeye salmon. Food may be a temporary limiting factor in juvenile growth and survival until anadromous runs return sufficient marine-derived nutrients to enhance reservoir productivity. Large fluctuations in the water level in the lake may flush out zooplankton or limit primary productivity. Mongillo and Faulconer (1982) noted the reservoir was oligotrophic and suggested artificial fertilization as a technique to temporarily increase productivity. Hiebert (USBR, Denver, CO, 2002, pers. comm.) classified Kachess Lake as oligotrophic.

6.3 CLE ELUM LAKE SUPPORTING DATA

6.3.1 Cle Elum River — The Cle Elum River is about 21 miles long with a potential barrier to fish migration between Camp and Fortune creeks at about RM 9. Slatick and Park (2000) indicated that "Cle Elum falls" (considered by local fisheries biologists as a series of cascades) would be a barrier to fish movement. But, Renfrow and Thomas (2002, pers. comm.) suggest that larger, stronger adult salmonids could negotiate the falls at least seasonally, which would make the Cle Elum River accessible up to Hyak Lake. Spawning habitat in the reach just above reservoir full pool was judged to consist of intermediate quality substrate, while the next 9 miles (15 km) upstream to the area near Fortune Creek had a combination of intermediate-to-large cobble spawning substrates; however, the river narrows after its confluence with the Cooper and Waptus rivers, so potential spawning habitat is reduced (Slatick and Park 2000).

6.3.2 French Cabin Creek — French Cabin Creek is about 3.7 miles long.

6.3.3 Thorp Creek — Thorp Creek is reported by the Forest Service to be 5.3 miles long. In a 1992 stream survey, USFS segmented the stream into three reaches. Its principal findings were that anadromous salmonids did not use this stream; average gradient was 10%, 12%, and >30% in reaches 1, 2, and 3, respectively; and there were 23 falls, 5 falls, and 7 falls in reaches 1, 2, and 3, respectively. The substrate in Reach 1 was bedrock and cobble; riparian conditions were fair due in part to impacts from previous timber harvest; and large woody debris and pools did not meet Forest Plan standards. Therefore, this creek is unlikely to provide any benefit to anadromous salmonids if fish passage is provided at Cle Elum Dam.

6.3.4 Cooper River — The Cooper River is 6.8 miles long with an impassable falls at RM 0.6. Slatick and Park (2000) reported that spawning conditions in the area of the Cooper River potentially accessible to anadromous salmonids had less spawnable gravel than the river upstream, and would thus not provide substantial benefit to anadromous salmonids if passage were provided at Cle Elum Dam.

6.3.5 Waptus River — The Waptus River is 13.2 miles long, including reaches upstream from Waptus Lake. There is an impassable falls at RM 7.2. Reach 1 (from the mouth to RM 7.2) has a 3.6 percent gradient, with a substrate of bedrock and cobble, while Reach 2 has a 3.8 percent gradient, with a substrate of cobble and gravel. Slatick and Park (2000) indicated that the Waptus River from its confluence with the Cle Elum River to Waptus Falls had poor spawning potential for anadromous salmonids, since the river bed had large cobble and rocks with few pockets of spawnable gravel. Since the falls block upstream fish migration, the potentially better spawning conditions they reported as occurring upstream would not be usable. USFS (1990) reported that the Waptus River is in generally healthy condition, with only large woody debris needing improvement for enhancing bull trout habitat. Reach 1 contained bull trout, rainbow trout, cutthroat trout, and brook trout, and sculpin. Reach 1 had an estimated 8,543 square yards of spawning habitat (USFS

1990). The river has been moderately impacted by recreational use. This river would not provide substantial benefit to anadromous salmonids if passage were provided at Cle Elum Dam due to the poor spawning habitat available in the accessible reach.

6.3.6 Paris Creek — Paris Creek is 1.4 miles long, with an impassable barrier about 0.25 miles upstream from the mouth, and gradient is steep (Jeff Thomas, FWS, October 2002, pers. comm.). It would therefore provide little or no benefit to anadromous salmonids.

6.3.7 Big Boulder Creek — Big Boulder Creek is 2.5 miles long, with an impassable barrier about 0.5 miles upstream from the mouth; in addition, the gradient is steep (Thomas 2002).

6.3.8 Camp Creek — Camp Creek is 0.8 mile long, with an impassable barrier about 0.25 mile upstream from the mouth (Thomas 2002). There a 36 percent gradient at the mouth; at some flows, it is a barrier to fish migration. There is also a high-gradient area at RM 0.6, which also delineates the upstream boundary of Reach 1. Overall gradient in the upper part of Reach 1 ranges from 11 to 20 percent. The substrate is cobble/gravel/small boulders. None of these three creeks (Paris, Big Boulder, and Camp) would benefit anadromous salmonids if passage were provided at Cle Elum Dam.

6.3.9 Fortune Creek — Fortune Creek is 4.5 miles long. Two reaches were surveyed by the Forest Service; Reach 1 was 2.4 miles long and Reach 2 was 0.48 mile long. Reach 2 has numerous falls and a relatively steep gradient of 14 percent. In addition, there is a fish passage barrier downstream from the mouth of Fortune Creek in the mainstem Cle Elum River. The presence of a potential fish passage barrier at Cle Elum RM 9 might prevent use of Fortune Creek by anadromous salmonids and would not benefit anadromous salmonids that would otherwise have access to the reservoir and upstream tributaries if fish passage was provided at Cle Elum Dam.

6.3.10 Cle Elum Lake limnology — Self-sustaining runs of kokanee salmon are present in Cle Elum Lake, so clearly some food is available for re-establishing runs of sockeye salmon. Food may be a temporary limiting factor in juvenile growth and survival until anadromous runs return sufficient marine-derived nutrients to enhance reservoir productivity. Large fluctuations in the water level in the reservoirs may flush out zooplankton or limit primary productivity. Mongillo and Faulconer (1982) noted the reservoir was oligotrophic and suggested artificial fertilization as a technique to temporarily increase productivity. The carcasses of spawned-out salmon in streams entering Cle Elum Lake historically provided a substantial and reliable source of marine-derived nutrients, which was greatly reduced once the crib dam obstructed the salmon runs (Flagg et al. 2000). Bioassays conducted by Mongillo and Faulconer (1982) found growth of algal mass to be phosphorous limited. Statistical analysis of sediment cores in the lake indicate that prior to 1906 (the year of initial crib dam construction that blocked fish passage), there was an average of 19 percent more phosphorous deposited in lake sediments each year than there has been since 1906. These results suggest that salmon runs were probably eliminated by construction of the crib dam in 1906, rather than by the 1933 storage dam, and that salmon carcasses once contributed appreciably to the phosphorous load of Cle Elum Lake. Recent research conducted by Steve Hiebert (USBR, Denver, CO, 2002, pers. comm.) classified Cle Elum Lake as oligotrophic.

6.4 BUMPING LAKE SUPPORTING DATA

6.4.1 Bumping River — Bumping River is 8.2 miles long, with a natural barrier to fish passage about 1 mile upstream. Watson (cited in Haring 2001) noted that the Bumping River/Bumping Lake watershed might provide the best opportunity to restore sockeye salmon in the Yakima Basin.

6.4.2 Deep Creek — Deep Creek is 8.5 miles long, with a natural barrier 5 miles upstream from the confluence with Bumping Reservoir and approximately 300 m (1,000 feet) upstream from Forest Road 2008 crossing. The lower 0.5 mile of Deep Creek goes subsurface during low water years. Bull trout currently occupy Deep Creek (WDFW 2002), which is essential spawning and rearing habitat for the Deep Creek local population.

6.4.3 Bumping Lake limnology — Bumping Lake is a relatively small irrigation storage reservoir. Annual water level fluctuation and the rapid flushing rate likely reduce primary and secondary production, resulting in an oligotrophic reservoir. Hiebert (USBR, Denver, CO, 2002, pers. comm.) classified Bumping Lake as oligotrophic.

6.5 RIMROCK LAKE SUPPORTING DATA

6.5.1 South Fork Tieton River — The South Fork Tieton River is 17.5 miles long (USFS 2000) from the confluence with Rimrock Reservoir. It has a falls at RM 13.5 (and a natural barrier at RM 16.8), so potential habitat accessible to anadromous salmonids is about 13.5 miles if passage were provided at Tieton Dam. Bull trout currently occupy the South Fork Tieton River (WDFW 2002), which is essential spawning and rearing habitat for this population.

Stream surveys were conducted by the USFS in 1991 and 2000, in which the river was divided into reaches; however, they designated the reaches differently for each survey. In the 2000 survey, reaches 1, 2, and 3 were upstream from those with the same designation in the earlier survey. Gradients for these three reaches ranged from 1 to about 3 percent. Water temperature during the surveys met the Forest Plan standards, while pools and large woody debris did not meet standards. During the 2000 survey, 85 bull trout redds were identified, indicating relatively good conditions for spawning.

6.5.2 Short and Dirty Creek — Short and Dirty Creek is 3.0 miles long with a natural barrier approximately 0.1 miles upstream from the confluence with the South Fork Tieton River. Bull trout currently occupy Short and Dirty Creek (WDFW 1998), which is essential rearing habitat for the South Fork Tieton River local population. Anderson (1997) cited in Craig (1997) noted that juvenile bull trout and cutthroat trout have been recorded in the creek, but no adult spawners.

6.5.3 Corral Creek — Corral Creek is 2.5 miles long, with a falls at RM 2.2. There are also culverts on Forest Roads 1000 and 1040. Water temperature ranged from 45 to 61 °F during the 7 July-25 September 1998 survey. Stream gradient is 2-5 percent near the mouth and increases progressively upstream to about 17 percent. Timber harvest, livestock grazing, and mining have occurred in this drainage and have impacted the riparian zone. Hunting, motorized ORV (off-road vehicle) travel, and dispersed camping are recent activities in the drainage.

6.5.4 Bear Creek (South Fork Tieton) — Bear Creek (South Fork Tieton River) is 1.9 miles long with a natural barrier approximately 1.1 miles upstream from the confluence with the South Fork Tieton River. Bull trout currently occupy Bear Creek (South Fork Tieton) (WDFW 2002), which is essential spawning and rearing habitat for the South Fork Tieton River local population. Craig (1997) noted that bull trout spawning is restricted to 0.56 miles of habitat downstream from a natural falls.

6.5.5 Bear Creek (Rimrock) — Bear Creek (Rimrock) has a culvert at 3.7 miles from the mouth. The mean stream gradient is 3 percent. The stream has high sedimentation, and does not meet Forest Plan standards for pool frequency.

6.5.6 North Fork Tieton River — The North Fork Tieton River is about 12 miles long from its confluence with Clear Lake Reservoir, with a natural barrier 9.8 miles upstream from the confluence with Clear Lake Reservoir (Craig 1997). Bull trout currently occupy the North Fork Tieton River (Craig 1997), which is essential spawning and rearing habitat for the North Fork Tieton River local population. This local population is not monitored annually. The ladder on Clear Lake Dam is ineffective in providing fish passage.

6.5.7 Clear Creek — Clear Creek has a large spring located about 1.8 mile upstream from the lake that provides the majority of the discharge during baseflow periods (Craig 1997). The creek upstream from the springs is seasonally dewatered, which restricts spawning habitat to the area downstream from the springs.

6.5.8 Indian Creek — Indian Creek is 6 miles long, with a natural barrier 4.9 miles upstream from the confluence with Rimrock Reservoir (Craig 1997). Bull trout currently occupy Indian Creek (Craig 1997; WDFW 2002) up to the falls, which is essential spawning and rearing habitat for the Indian Creek local population. Spawning substrate is extremely limited upstream from the falls (Craig 1997). The unconstrained alluvial valley of Indian Creek subjected the creek to massive channel changes (Craig 1997).

6.5.9 Clear Lake — Bull trout currently occupy Clear Lake (WDFW 1998) but probably in extremely low abundance. Clear Lake has a capacity of 5,300 acre-feet and provides essential foraging and overwintering habitat for the North Fork Tieton River local bull trout population. The existing fish ladder at Clear Lake Dam is ineffective in providing fish passage. If fish passage at Clear Lake Dam is improved, it will provide a migratory corridor to other local populations within the Yakima River.

6.5.10 Rimrock Lake limnology — Rimrock Lake is more productive than the other four reservoirs in the Yakima Basin, based on an analysis of chlorophyll *a* and nutrients (Davine Lieberman, USBR, Denver, CO, 2003, pers. comm.), and is classified as mesotrophic.

Table B-6-1 shows the tributary habitat conditions upstream from the five reservoirs as summarized in the Habitat Limiting Factors (Haring 2001). Some of the information in this summary as well as the information compiled in this appendix and Appendix C, were used to assign a “good” composite rating to the assemblage of tributaries upstream from the reservoirs.

Table B-6-1. Summary comparison of tributary habitat conditions upstream from five Yakima basin storage dams and reservoirs										
Tributaries upstream from	**Fish access**	**Floodplain connectivity**	**Channel Conditions**		**Substrate**	**Riparian Conditions**	**Water Quality**		**Hydrology**	
			LWD	**Pools**			**Temp/DO**	**Toxics**	**Peak Flow**	**Low Flow**
Keechelus Dam	P	P-G	P	P	P-G	P-G	F-G	DG	G	P-G
Kachess Dam	P	F	P	P	F	F	F	G	G	G
Cle Elum Dam	P	G	G	F	G	G	DG	G	G	G
Bumping Dam	P	G	G	F	G	G	G	G	G	G
Tieton Dam	P	P-G	G	G	F	F-G	P	G	G	G

Habitat condition rating information extracted and modified from Table 39 (p 313-314) of *Habitat Limiting Factors, Yakima River Watershed, Water Resource Inventory Areas 37-30, Final Report* (Haring 2001) report for the Yakima River Watershed

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APPENDIX C.

HABITAT PARAMETER MATRICES

APPENDIX TABLE C-1. MATRIX FOR HABITAT PARAMETERS FOR SEVERAL TRIBUTARIES TO KEECHELUS LAKE							
Keechelus Lake watershed	**Tributary**						
Parameter	**Coal Creek**	**Cold Creek**	**Gold Creek**	**Meadow Creek**	**Roaring Creek**	**Mill Creek**	**Total**
Overall stream length (with tributaries) [miles]	2.95 (3.0)	2.2 (2.6)	5.8 (7.1)	4.2 (4.8)	2.0 (4.1)	2	
1) Blockages, dams, culverts 2) waterfalls	2 culvert barriers under I-90	1913 culvert w/ 8-ft drop at RR, ≈0.25 mi. definite barrier	Falls at about RM 7.1	1) culverts at road crossing are barriers; 2) falls in Reach 2, ≈4 mi. upstream		Blocked by large culvert	
Stream length potentially accessible to migratory fish	2.5	0	7	3.9		0.2	13.6
Watershed area [sq. mi.]	7.1	12.4	35.5	16.5	5.6	2.1	
Mean annual streamflow on a daily basis [cfs]	33.07	23.32	66.21	42.01			
Mean monthly streamflow on a daily basis [cfs]							
Average monthly water temperature		57 °F, 15Jun-11Sep92		58.37 °F, 21Jul-27Sep99; 57.37 °F (7-day max; high temps)			
Max. elevation [feet]	3666	3121	3929	3361	3112	3413	
Min. elevation [feet]	2657.1	2499	2534.5	2678.1	2677	2905	
Max. elevation in watershed [feet]	4511	4263	5350	3937	3321	3914	
Max. slope [feet]	16.5	9.9	16.3	11.6	13.1	15.1	
Min. slope [feet]	2.3	0.4	0.8	3.4	3.3	4.6	
Mean gradient				1=3% 2=3% 3=3%			
Reaches		3 surveyed		1=B3 2=B1 3=B4			
Gradient by reach							
Substrate composition							
• Fines/sediment							
• Sand				8 %			
• Gravel				29%			
• Cobble				32%			

Keechelus Lake watershed	Tributary						
Parameter	**Coal Creek**	**Cold Creek**	**Gold Creek**	**Meadow Creek**	**Roaring Creek**	**Mill Creek**	**Total**
• Boulder				17%			
• Bedrock				14%			
Extent of pools, riffles, glides				Good pool presence			
Percent cover in pools							
Length, width, depth, area, substrate measurements in the discrete habitat units (pools, riffles, glides) downstream from barriers	Habitat conds poor, stream has been straightened and channelized along I-90						
Large woody debris		Good WD presence	Little or no key-piece size LWD in channel; no opportunity for recruitment of new key-pieces	Good LWD			
Estimated quantity of spawning and rearing habitat							
Does stream go subsurface at any time during the year, if so, where? Impediment to fish production?		Yes, below culvert, before Lake Keechelus					
Current operations • Flip-Flop • Impacts on adult or juvenile salmonids							
Land ownership in basin							
Land use in the subbasin							
• Livestock grazing				No allotments			
• Timber harvest				Clearcuts w/ some buffer strips			
• Irrigated agriculture							
• Non-irrigated agriculture							
• Mining activity							
• Roads, proximity and density		USFS roads and trail	High risk of road related sediment problems	Heavily roaded, entire stream accessible			

Keechelus Lake watershed	Tributary						
Parameter	**Coal Creek**	**Cold Creek**	**Gold Creek**	**Meadow Creek**	**Roaring Creek**	**Mill Creek**	**Total**
• Recreation, vacation development				Dispersed camping			
• Other anthropogenic activity				Power line			
Biological information							
• Macroinvertebrate surveys				Stoneflies Mayflies Caddisflies			
• Salmonids present			Historically supported anadromous salmonids and bull trout	1 cutt in #1 some YOY salmonids			
• Forage fish species composition and abundance							
• Primary production							
• Riparian conditions		Good riparian shade, riparian area generally intact		Little overstory, loss of riparian shade due to heavy logging			
Cultural and archeological information							
• Old camps, middens, fish bones							

Note

Roaring Creek, Resort Creek and Rocky Run were considered to be too small and steep to support anadromous salmonids.

References and data/information sources:

- Limnological information from Hiebert (USBR, TSC, Denver, CO, 2002, pers. comm.)
- Cold Creek Stream Survey Report, 1992, USFS, Wenatchee National Forest, Cle Elum Ranger District.
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- Rocky Run Creek Stream Survey Report, 1995, USFS, Wenatchee National Forest, Cle Elum Ranger District.
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Appendix Table C-2. Matrix for Habitat Parameters for Several Tributaries to Kachess Lake						
Kachess River watershed	**Tributary**					
Parameter	**Kachess River**	**Box Canyon Creek**	**Mineral Creek**	**Gale Creek**	**Thetis Creek**	**Total**
Stream length [miles]	5.5	6.1	19	7	2.7	
Blockages, waterfalls, dams, culverts	Barrier 0.5 mi upstream from Lake Kachess	Barrier falls at RM 1.6	Blockage at 0.25 mi.	Culvert barrier		
Stream length potentially accessible to migratory fish	0.5	1.6	0.25			2.35
Watershed area (with tributaries) [sq. mi.]	13.9 (19.4)	18.0 (21.8)		6	2.1	
Mean annual streamflow on a daily basis [cfs]						
Mean monthly streamflow on a daily basis [cfs]						
Average monthly water temperature		Summer temps 57-68 °F, (1990-94)				
Max. elevation (with tributaries) [feet]	2796	3431 (3475)		4034	3240	
Min. elevation (with tributaries) [feet]	2264	2457 (2457)		2735	2510	
Max. elevation in watershed (with tributaries) [feet]	4223	4966 (4966)		4596	4147	
Max. slope (with tributaries) [feet]	11.6 (15.5)	22.1 (22.1)		16.9	15.1	
Min. slope (with tributaries) [feet]	0.4	3.2 (5.5)		3.3	4.1	
Mean gradient						
Reaches						
Gradient by reach						
Substrate composition						
• Fines/sediment						
• Sand						
• Gravel						
• Cobble						
• Boulder						
• Bedrock						
Extent of pools, riffles, glides		Low # of pools				
Percent cover in pools						
Length, width, depth, area, substrate measurements in the discrete habitat units (pools, riffles, glides) downstream from barriers						

Kachess River watershed	Tributary					
Parameter	**Kachess River**	**Box Canyon Creek**	**Mineral Creek**	**Gale Creek**	**Thetis Creek**	**Total**
Large woody debris	Low in LWD	LWD below Forest Plan standard		Low in LWD	Low in LWD	
Estimated quantity of spawning and rearing habitat		Poor spawning habitat; better summer and winter rearing habitat	Poor spawning and summer and winter rearing habitat			
Does stream go subsurface at any time during the year, if so, where? Impediment to fish production?						
Current operations • Flip-flop • Impacts on adult or juvenile salmonids						
Land ownership in basin						
Land use in the subbasin						
• Livestock grazing						
• Timber harvest		Yes-reduced canopy cover				
• Irrigated agriculture						
• Non-irrigated agriculture						
• Mining activity						
• Roads, proximity and density						
• Recreation, vacation development		Impacts riparian veg				
• Other anthropogenic activity						
Biological information						
• Macroinvertebrate surveys						
• Salmonids present						
• Forage fish species composition and abundance						
• Primary production						
• Riparian conditions		Impacted				
Cultural and archeological information						
• Old camps, middens, fish bones						
Limnological information from Hiebert (USBR, Denver, CO, 2002, pers. comm.)						

Appendix Table C-3. Matrix for Habitat Parameters for Several Tributaries to Cle Elum Lake										
Cle Elum watershed	**Tributary**									
Parameter	**Cle Elum River**	**French Cabin Creek**	**Thorp Creek**	**Cooper River**	**Waptus River**	**Paris Creek**	**Big Boulder Creek**	**Camp Creek**	**Fortune Creek**	**Total**
Stream length [miles]	18.4 (21.0 sc)	3.7	3.8 (5.3 FS)	6.8 (14.1 sc)	9.6 (13.2sc) (10.4 FS)	1.4	2.5	0.8	4.5 (sc)	51.0 ?
Blockages, waterfalls, dams, culverts	Cle Elum Falls ≈ RM9 between Camp and Fortune Creeks		1) 23 falls 2) 5 falls 3) 7 falls	Impassab le falls at RM 0.6	Waptus Falls at 7.2 impassable				2) steep w/ many falls	
Stream potentially accessible to migratory fish [miles (km)]	9 (21.6)		0	0.6 (1 km)	7.2, but poor quality			0	0 (above barrier in Cle Elum River)	16.8 (29.4)
Watershed area [sq.mi.]	1,030.8 (1,489.7)	10.6 (12.0)	6.5	112.7	54	2.8	4.3	1.7		
Mean annual streamflow on a daily basis [cfs]										
Mean monthly streamflow in cfs on a daily basis										
Average monthly water temperature			49-64 °F 23 Jun-09 Jul 92							
Max. elevation (with tributaries) [feet]	4222 (5643)	3593 (3593)	3796	2808	4000	3531	4787	3593		
Min. elevation (with tributaries) [feet]	2233 (2233)	2936 (2936)	3143	2338	2578	2846	3788	3268		
Max. elevation in watershed (with tributaries) [feet]	4494 (6491)	4572 (4572)	4723	4487	5430	4812	5705	5175		
Max. slope (with tributaries) [feet]	19.1 (32.1)	10.2 (11.5)	20.5	15.8	18.6	22.8	19	14.5		
Min. slope (with tributaries) [feet]	0.7 (0.7)	5.0 (5.0)	7.2	0.7	1.7	10.3	9.9	8.2		
Mean gradient										
Reaches			1=2.8 mi 2=1.8 mi 3=0.25 mi		1=7.2 mi 2=1.2 mi			1=0.6 mi	1=2.4 mi 2=0.48 mi	
Gradient by reach			1=10% 2=12% 3=>30%		1=3.6% 2=3.8%			36% at mouth	2=14%	

Cle Elum watershed	Tributary								
Parameter	**Cle Elum River**	**French Cabin Creek**	**Thorp Creek**	**Cooper River**	**Waptus River**	**Paris Creek**	**Big Boulder Creek**	**Camp Creek**	**Fortune Creek**	**Total**
Substrate composition			1=bedrock /cobble 2=cobble/ cobble 3=gravel/ gravel		1=bedrock /cobble 2=cobble/ gravel			cobble/ gravel/ small boulder s		
• Fines/sediment										
• Sand										
• Gravel										
• Cobble										
• Boulder										
• Bedrock										
Extent of pools, riffles, glides			1=39% P 2=37% P 3=24% P FPS?-NO							
Percent cover in pools										
Length, width, depth, area, substrate measurements in the discrete habitat units (pools, riffles, glides) downstream from barriers										
Large woody debris (large/small)			1) 97/74 2) 126/78 3) 11/6		Could be improved					
Estimated quantity of spawning and rearing habitat			Not used by anadro-mous salmonids		Poor spawning potential from mouth to Waptus Falls					
Does stream go subsurface at any time during the year, if so, where? Impediment to fish production?										
Current operations • Flip-Flop • Impacts on adult or juvenile salmonids										
Land ownership in basin			1/3 private		USFS, mostly wilderness			private; USFS		
Land use in the subbasin										
• Livestock grazing										

Cle Elum watershed	Tributary									
Parameter	**Cle Elum River**	**French Cabin Creek**	**Thorp Creek**	**Cooper River**	**Waptus River**	**Paris Creek**	**Big Boulder Creek**	**Camp Creek**	**Fortune Creek**	**Total**
• Timber harvest			Clearcut to riparian R2 andR3							
• Irrigated agriculture										
• Non-irrigated agriculture										
• Mining activity										
• Roads, proximity and density	4.48 mi/mi²		R1-FS Road 4309							
• Recreation, vacation development					FS Trail 1310			campin g		
• Other anthropogenic activity										
Biological information										
• Macroinvertebrate surveys										
• Salmonids present			BRK, CTT							
• Forage fish species composition and abundance										
• Primary production										
• Riparian conditions			Fair		20% shading			Genera lly good		
Cultural and archeological information										
• Old camps, middens, fish bones										
General comments					River generally healthy					

- Limnological information from Hiebert (USBR, TSC, Denver, CO, 2002, pers. comm.)
- SC = Steve Croci;
- FS = Forest Service;

Cle Elum River includes the following tributaries

- Cooper Creek
- Waptus Creek
- Thorp Creek
- Salmon la Sac Creek
- Little Salmon La Sac Creek
- Paris Creek
- Big Boulder Creek
- Camp Creek
- Scatter Creek
- Unnamed Creek

Appendix Table C-4. Matrix for Habitat Parameters for Several Tributaries to Bumping Lake				
Bumping Lake watershed	**Tributary**			
Parameter	**Bumping River**	**Deep Creek**	**Copper Creek**	**Total**
Stream length [miles (km)]	8.2 (14.8)	8.5 (12.8)		
Blockages, waterfalls, dams, culverts				
Stream length potentially accessible to migratory fish	1 (1.6)	5 (8)		
Watershed area (with tributaries) [sq. mi.]	70.0 (87.0)	54.4 (65.8)		
Mean annual streamflow on a daily basis [cfs]				
Mean monthly streamflow on a daily basis [cfs]				
Average monthly water temperature				
Max. elevation (with tributaries) [feet]	4884 (5015)	5020 (5020)		
Min. elevation (with tributaries) [feet]	3483 (3483)	3486 (3486)		
Max. elevation in watershed (with tributaries) [feet]	5221 (5411)	5333 (5705)		
Max. slope (with tributaries) [feet]	9.9 (14.4)	26.9 (26.9)		
Min. slope (with tributaries) [feet]	0.5 (0.5)	1.5 (1.5)		
Mean gradient				
Reaches				
Gradient by reach				
Substrate composition				
• Fines/sediment				
• Sand				
• Gravel				
• Cobble				
• Boulder				
• Bedrock				
Extent of pools, riffles, glides				
Percent cover in pools				
Length, width, depth, area, substrate measurements in the discrete habitat units (pools, riffles, glides) downstream from barriers				
Large woody debris				
Estimated quantity of spawning and rearing habitat				
Does stream go subsurface at any time during the year, if so, where? Impediment to fish production?		Lower 0.5 miles goes subsurface in low water years		
Current operations • Flip-flop • Impacts on adult or juvenile salmonids				
Land ownership in basin	All USFS			

Bumping Lake watershed	Tributary			
Parameter	**Bumping River**	**Deep Creek**	**Copper Creek**	**Total**
Land use in the subbasin				
• Livestock grazing				
• Timber harvest				
• Irrigated agriculture				
• Non-irrigated agriculture				
• Mining activity				
• Roads, proximity and density				
• Recreation, vacation development				
• Other anthropogenic activity				
Biological information				
• Macroinvertebrate surveys				
• Salmonids present		bull trout		
• Forage fish species composition and abundance				
• Primary production				
• Riparian conditions				
Cultural and archeological information				
• Old camps, middens, fish bones				
Limnological information from Hiebert (USBR, Denver, CO, 2002, pers. comm.)				

APPENDIX TABLE C-5. MATRIX FOR HABITAT PARAMETERS FOR SEVERAL TRIBUTARIES TO RIMROCK LAKE									
Rimrock Lake watershed	**Tributary [miles (km)]**								
Parameter	**South Fork Tieton River**	**Short And Dirty Creek**	**Corral Creek**	**Bear Creek (SF Tieton)**	**Bear Creek (Rimrock)**	**North Fork Tieton River**	**Clear Creek**	**Indian Creek**	**Total**
Stream length [miles	17.5		2.5		1.9	12	4.2	8.2	
Blockages, waterfalls, dams, culverts	Falls at RM13.5 barrier to bull trout. Culverts on tribs		falls at RM 2.2; culverts on FS roads 1000 and 1040		Culvert at 3.7 mi.; 7 culvert, 3 possible fish barriers	Falls at RM 9.9		Falls at RM 4.9 barrier to fish	
Stream length potentially accessible to migratory fish	≈ 13.5 mi.	0.1	2.2	3.7	0.5	9.9	2	4.9	36.8
Watershed area [sq. mi.]	73.6		2.4	6.4	6.2	49.3		19.7	
Mean annual streamflow on a daily basis [cfs]									
Mean monthly streamflow on a daily basis [cfs]									
Average monthly water temperature	43-55°F min-max for 6 months. Meets FPS		45-61°F 7Jul -25 Sep 1998		Meets FPS	46-56°F 7Jul - 25 Sep 1998	45-48°F Aug 1997	45-56°F 12-30 Aug 99	
Max. elevation (with tributaries) [feet]	4507 (5942)			4964	3077	5426 (5426)		4993 (4993)	
Min. elevation (with tributaries) [feet]	2950 (2950)			4343	2981	2943 (2943)		3131 (3131)	
Max. elevation in watershed (with tributaries) [feet]	5604 (6816)			6175	3932	6745 (6745)		5289 (5289)	
Max. slope (with tributaries) [feet]	18.4 (29.4)			19.6	10.9	23.5 (34.3)		16.9 (33.0)	
Min. slope (with tributaries) [feet]	1.7 (1.7)			8.3	2.0	0.8		2.0	
Mean gradient					3%	1) <1% 2) 2.1% 3) 0.01-3.5+%	1=3% 2=3%		
Reaches	7					1) 3.65 mi. 2) 2.9 mi. 3) 3.4 mi.		1=3.5 mi.	
Gradient by reach	1=1% 2=1% 3=2-3%		17% 2-5% near mouth					1=<3%	

Rimrock Lake watershed	Tributary [miles (km)]								
Parameter	**South Fork Tieton River**	**Short And Dirty Creek**	**Corral Creek**	**Bear Creek (SF Tieton)**	**Bear Creek (Rimrock)**	**North Fork Tieton River**	**Clear Creek**	**Indian Creek**	**Total**
Substrate composition									
• Fines/sediment					High sedimentat ion				
• Sand						1) 46% in pools; does not meet FPS 2) 27.5 % in pools; 3) 45.3 % in pools	2) sand, gravel	1) 16.7% in pools; meets FPS	
• Gravel							1) gravel, sand		
• Cobble									
• Boulder									
• Bedrock									
Extent of pools, riffles, glides	Pools 0.08-0.43 (<FPS)				Pool freq does not meet FPS			Pool freq does not meet FPS	
Percent cover in pools									
Length, width, depth, area, substrate measurements in the discrete habitat units (pools, riffles, glides) downstream from barriers						1) 51.9% P 2) 40.8% 3) 43.4%	1)28% P 2) 41%	1) 4.57% Pools	
Large woody debris	1=<FPS 2=meets FPS 3=<FPS				Meets FPS	1, 2, 3 meet FPS	1, 2 meet FPS	1 does not meet FPS	
Estimated quantity of spawning and rearing habitat	Good spawning; 85 redds in 2000 survey								
Does stream go subsurface at any time during the year, if so, where? Impediment to fish production?							braided channel , some channel s go dry		

Rimrock Lake watershed	Tributary [miles (km)]								
Parameter	**South Fork Tieton River**	**Short And Dirty Creek**	**Corral Creek**	**Bear Creek (SF Tieton)**	**Bear Creek (Rimrock)**	**North Fork Tieton River**	**Clear Creek**	**Indian Creek**	**Total**
Current operations • Flip-flop • Impacts on adult or juvenile salmonids									
Land ownership in basin	Mostly Fed., some private upstream		USFS						
Land use in the subbasin									
• Livestock grazing	Some impact on riparian		In riparian and adjacent meadows			No allotmen ts		Historica lly heavily grazed	
• Timber harvest			Some in last 20 yrs		Some	Some in R2; R3=non e		Some limited early	
• Irrigated agriculture									
• Non-irrigated agriculture									
• Mining activity			Some in mid 1800s			Prospect ed in mid 1800s			
• Roads, proximity and density			nearby		Close to stream	FS Road 1207par alles stream		Parallele d by FS Road 1308	
• Recreation, vacation development	ORV use, some fishing, hunting, hiking		ORV, hunting, travel, dispersed camping		Summer homes	Hiking, camping , fishing, trail riding		Campsit es, summer homes	
• Other anthropogenic activity									
Biological information									
• Macroinvertebrate surveys									
• Salmonids present	RBT, CTT BRK, bull trout					1=RBT, CTT	BRK		
• Forage fish species composition and abundance	*Cottus* spp.						*Cottus* spp.	*Cottus* spp.	
• Primary production									

Rimrock Lake watershed	Tributary [miles (km)]								
Parameter	**South Fork Tieton River**	**Short And Dirty Creek**	**Corral Creek**	**Bear Creek (SF Tieton)**	**Bear Creek (Rimrock)**	**North Fork Tieton River**	**Clear Creek**	**Indian Creek**	**Total**
• Riparian conditions	Poor - livestock grazing				Heavily vegetated - alder				
Cultural and archeological information								Part of Cowlitz Trail	
• Old camps, middens, fish bones									
General comments	R4,5, 6 =good bull trout spawning habitat			Habitat pristine		Partly in Goat Rocks Wildern ess		Large no. of spawnin g bull trout	
Sources	FS Reports					FS 1999	FS 1997	FS 1999	

Limnological information from Hiebert (USBR, TSC, Denver, CO, 2002, pers. comm.)

FPS = Forest Plan Standards
FS = Forest Service

South Fork Tieton River tributaries
- Short and Dirty Creek
- Conrad Creek
- Bear Creek
- Corral Creek
- Tenday Creek

APPENDIX D

FISH PASSAGE ENGINEERING CONCEPTS

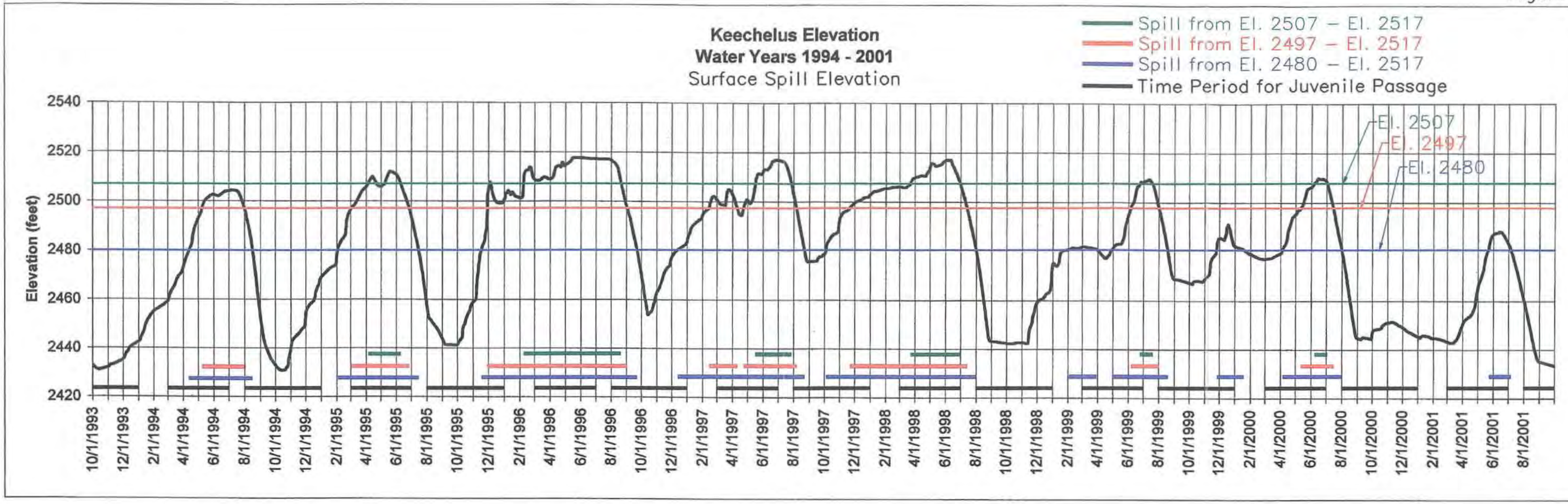
FIGURES AND DRAWINGS

CONTENTS

FIGURES *(© = with color)*

DRAWINGS *(© = with color)*

Figure 1



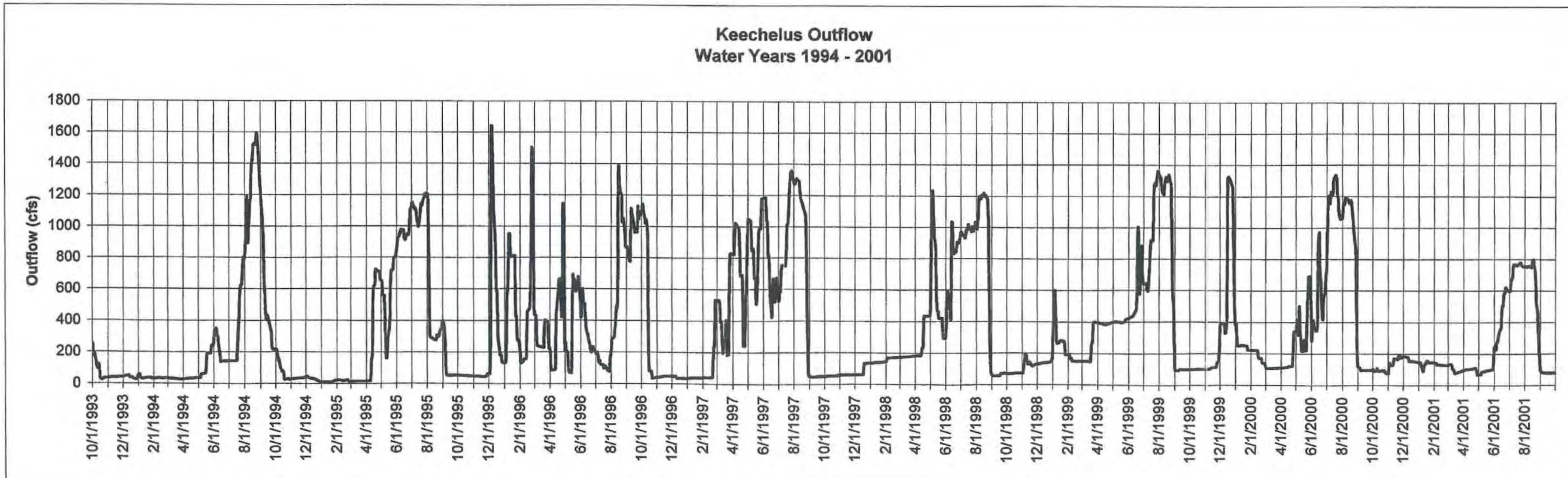
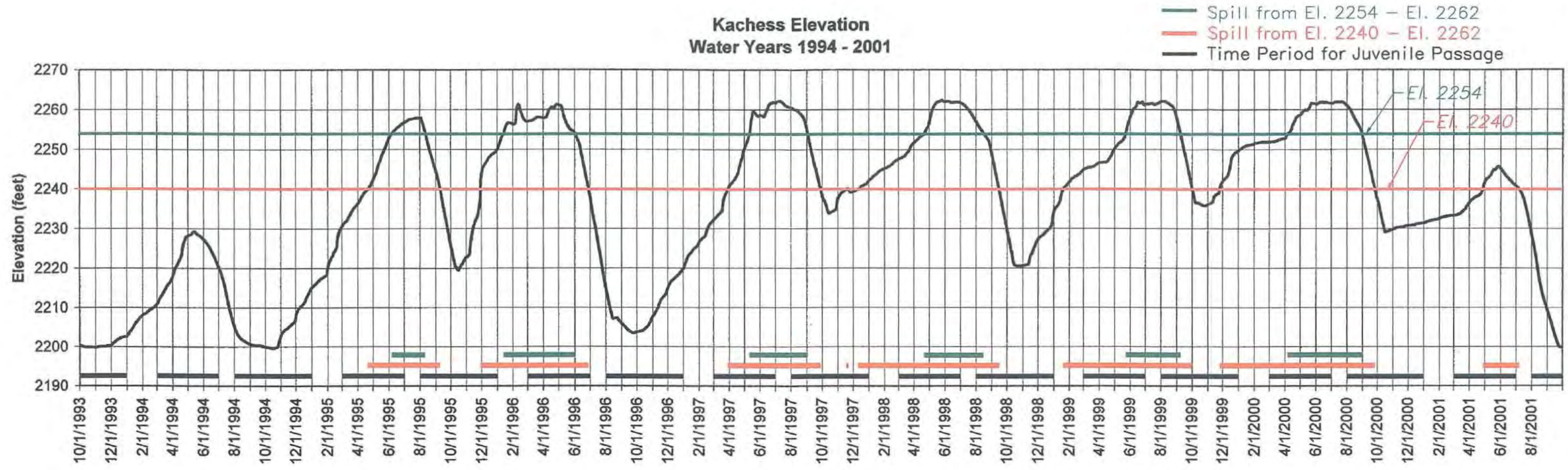


Figure 1



Kachess Elevation
Water Years 1994 - 2001
Spill from El. 2254 – El. 2262
Spill from El. 2240 – El. 2262
Time Period for Juvenile Passage
El. 2254
El. 2240
Elevation (feet)
2190
2200
2210
2220
2230
2240
2250
2260
2270
10/1/1993
12/1/1993
2/1/1994
4/1/1994
6/1/1994
8/1/1994
10/1/1994
12/1/1994
2/1/1995
4/1/1995
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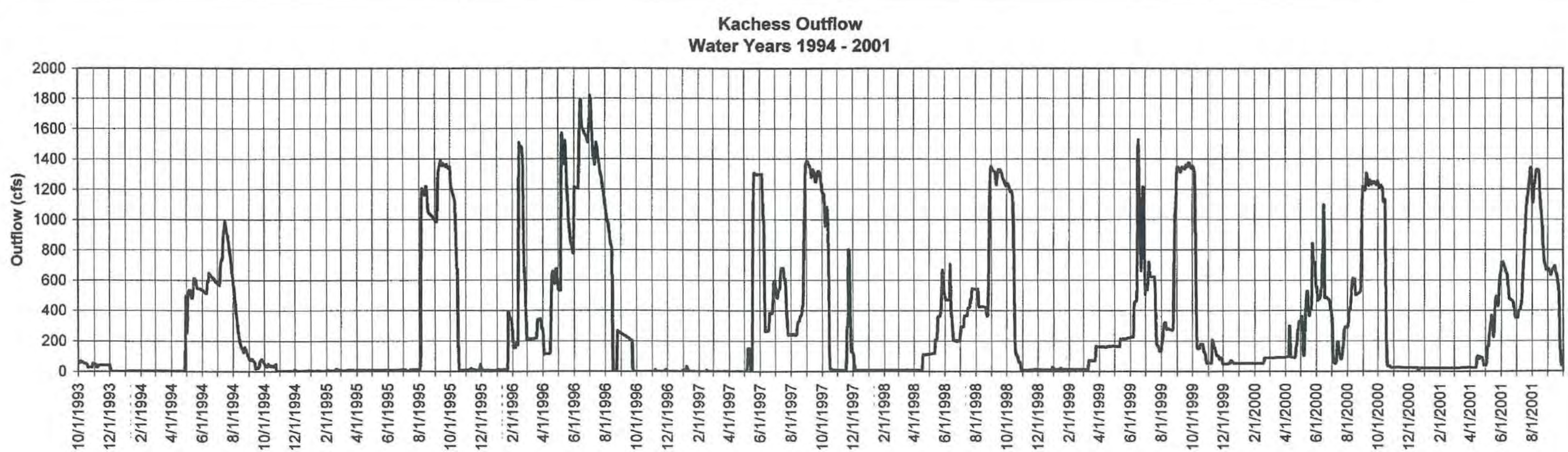
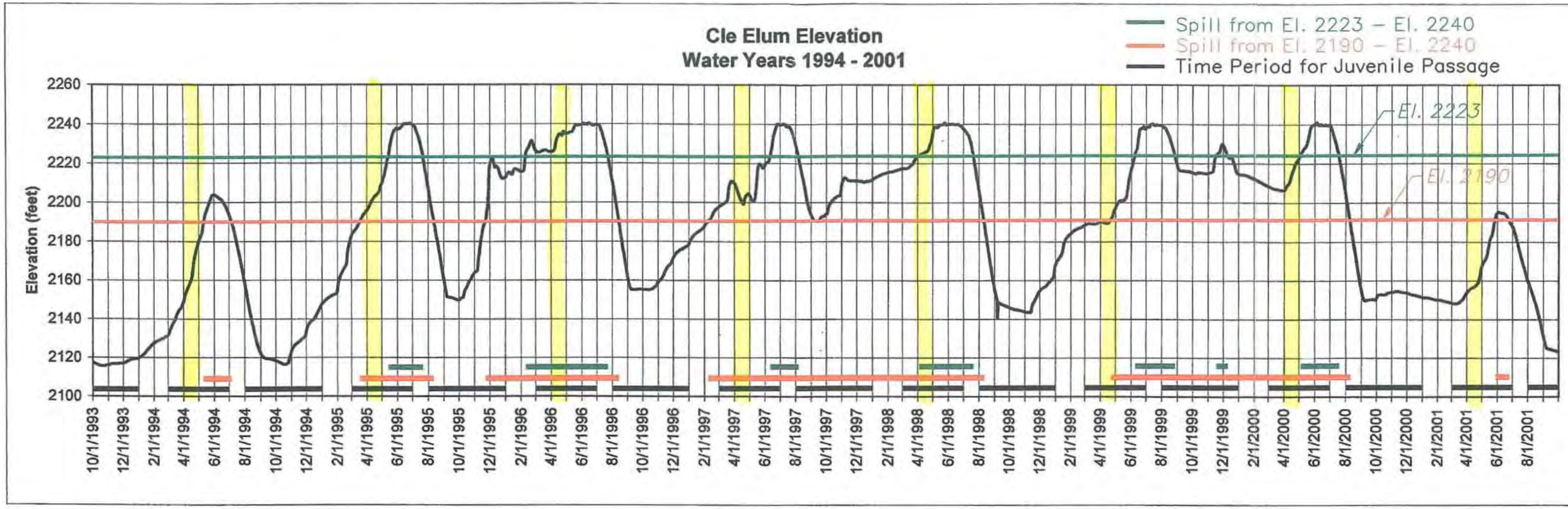
6/1/2001
8/1/2001



Kachess Outflow
Water Years 1994 - 2001
Outflow (cfs)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
10/1/1993
12/1/1993
2/1/1994
4/1/1994
6/1/1994
8/1/1994
10/1/1994
12/1/1994
2/1/1995
4/1/1995
6/1/1995
8/1/1995
10/1/1995
12/1/1995
2/1/1996
4/1/1996
6/1/1996
8/1/1996
10/1/1996
12/1/1996
2/1/1997
4/1/1997
6/1/1997
8/1/1997
10/1/1997
12/1/1997
2/1/1998
4/1/1998
6/1/1998
8/1/1998
10/1/1998
12/1/1998
2/1/1999
4/1/1999
6/1/1999
8/1/1999
10/1/1999
12/1/1999
2/1/2000
4/1/2000
6/1/2000
8/1/2000
10/1/2000
12/1/2000
2/1/2001
4/1/2001
6/1/2001
8/1/2001

Figure 2

Figure 3



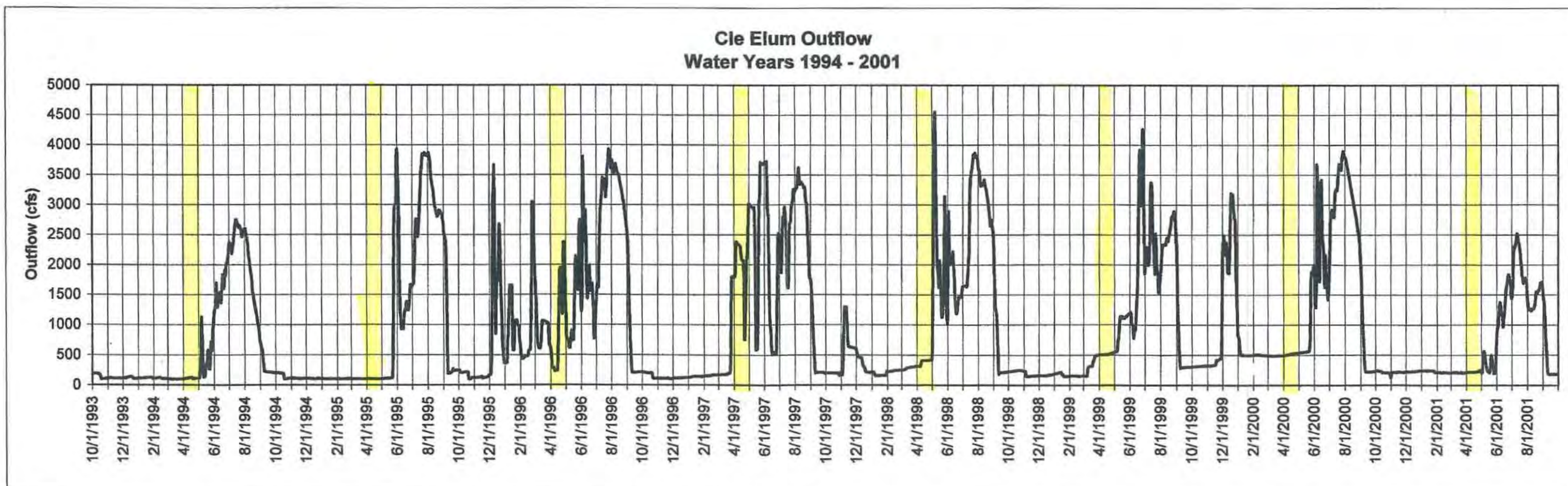
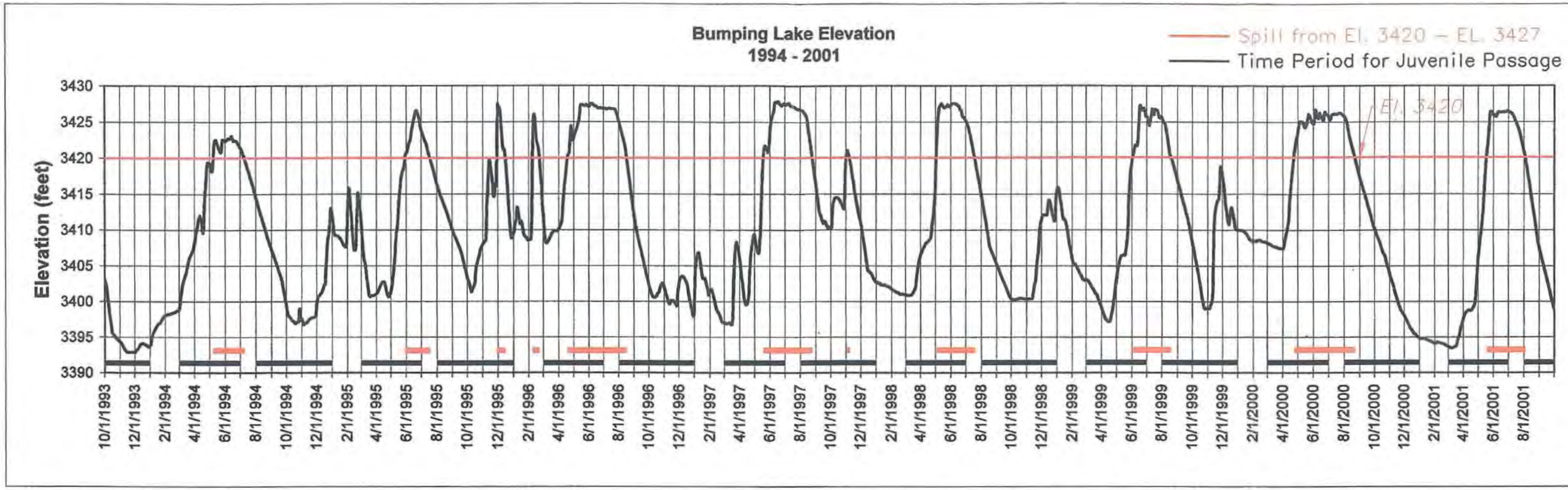


Figure 3

Figure 4



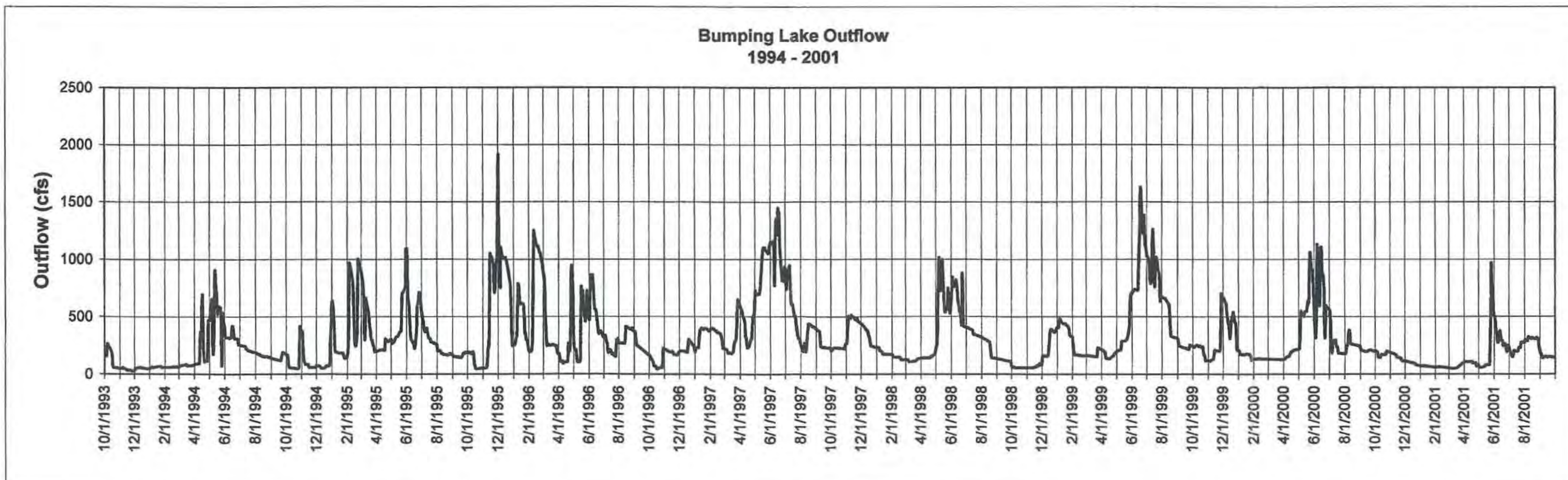
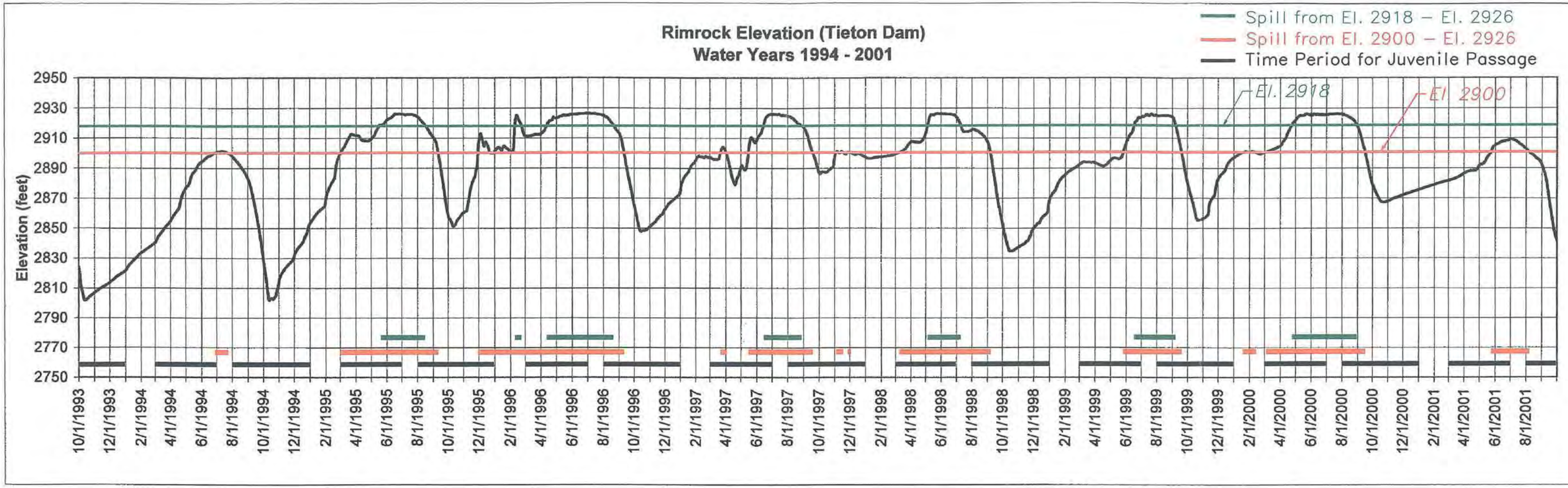
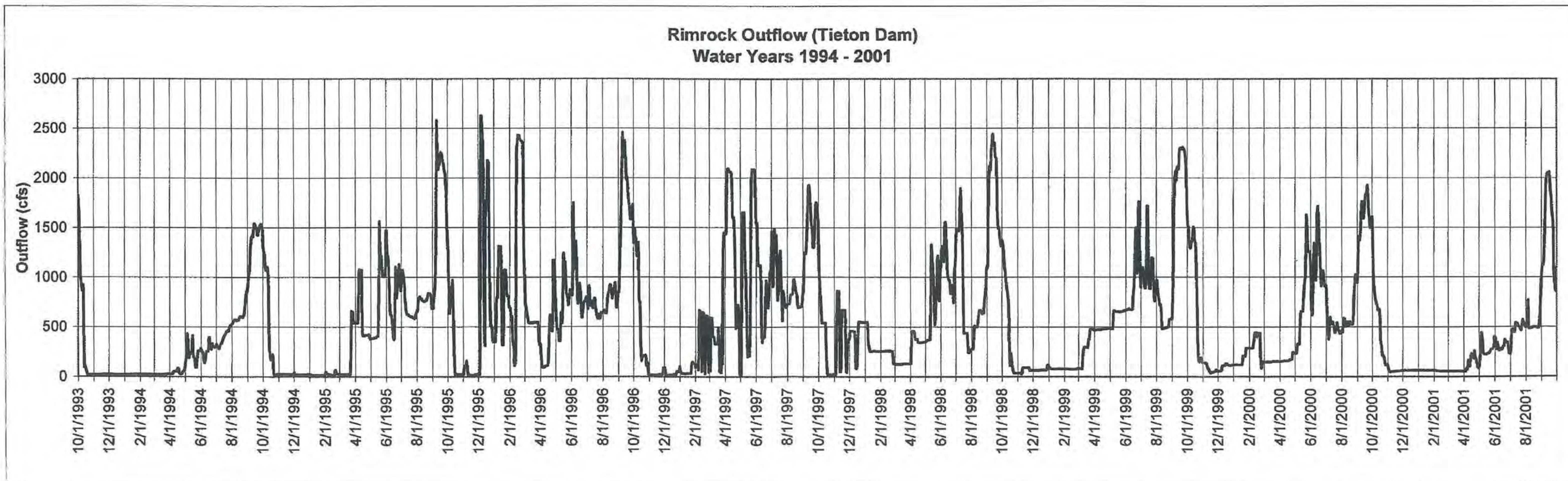


Figure 4



Rimrock Elevation (Tieton Dam)
Water Years 1994 - 2001
Spill from El. 2918 – El. 2926
Spill from El. 2900 – El. 2926
Time Period for Juvenile Passage
El. 2918
El. 2900
Elevation (feet)
2950
2930
2910
2890
2870
2850
2830
2810
2790
2770
2750
10/1/1993
12/1/1993
2/1/1994
4/1/1994
6/1/1994
8/1/1994
10/1/1994
12/1/1994
2/1/1995
4/1/1995
6/1/1995
8/1/1995
10/1/1995
12/1/1995
2/1/1996
4/1/1996
6/1/1996
8/1/1996
10/1/1996
12/1/1996
2/1/1997
4/1/1997
6/1/1997
8/1/1997
10/1/1997
12/1/1997
2/1/1998
4/1/1998
6/1/1998
8/1/1998
10/1/1998
12/1/1998
2/1/1999
4/1/1999
6/1/1999
8/1/1999
10/1/1999
12/1/1999
2/1/2000
4/1/2000
6/1/2000
8/1/2000
10/1/2000
12/1/2000
2/1/2001
4/1/2001
6/1/2001
8/1/2001



Rimrock Outflow (Tieton Dam)
Water Years 1994 - 2001
Outflow (cfs)
3000
2500
2000
1500
1000
500
0
10/1/1993
12/1/1993
2/1/1994
4/1/1994
6/1/1994
8/1/1994
10/1/1994
12/1/1994
2/1/1995
4/1/1995
6/1/1995
8/1/1995
10/1/1995
12/1/1995
2/1/1996
4/1/1996
6/1/1996
8/1/1996
10/1/1996
12/1/1996
2/1/1997
4/1/1997
6/1/1997
8/1/1997
10/1/1997
12/1/1997
2/1/1998
4/1/1998
6/1/1998
8/1/1998
10/1/1998
12/1/1998
2/1/1999
4/1/1999
6/1/1999
8/1/1999
10/1/1999
12/1/1999
2/1/2000
4/1/2000
6/1/2000
8/1/2000
10/1/2000
12/1/2000
2/1/2001
4/1/2001
6/1/2001
8/1/2001

Figure 5

RESERVOIR OUTFLOW DATA

Keechelus Dam - Exceedance Flows
Water Years 1950 - 2001

Reservoir Elevation Range	Reservoir Outflow (cfs) Max.	Exceedance Percent 90%	75%	50%	25%	10%
El.2510 - El.2517	1940	81	286	509	747	957
El.2500 - El.2510	1950	8	61	344	716	936
El.2490 - El.2500	1730	2	13	240	674	953
El.2480 - El.2490	2092	2	13	143	519	922
El.2470 - El.2480	2370	1	8	101	444	824
El.2460 - El.2470	2205	1	6	68	374	804
El.2450 - El.2460	1651	1	5	71	370	900
El.2440 - El.2450	1550	1	6	66	184	707
El.2430 - El.2440	942	1	1	53	165	595

Cle Elum Dam - Exceedance Flows
Water Years 1950 - 2001

Reservoir Elevation Range	Reservoir Outflow (cfs) Max.	Exceedance Percent 90%	75%	50%	25%	10%
El.2230 - El.2240	5980	308	1150	1850	2390	2951
El.2220 - El.2230	3880	78	222	932	2365	3020
El.2210 - El.2220	4084	39	114	540	1805	2840
El.2200 - El.2210	4180	34	60	380	1413	2700
El.2190 - El.2200	4060	27	51	156	1270	2650
El.2180 - El.2190	3750	19	44	128	1140	2690
El.2170 - El.2180	3461	1	44	132	1130	2576
El.2160 - El.2170	3139	2	35	125	974	2152
El.2150 - El.2160	2818	23	58	168	276	1887
El.2140 - El.2150	2417	1	19	105	271	1970

Bumping Lake Dam - Exceedance Flows
Water Years 1950 - 2001

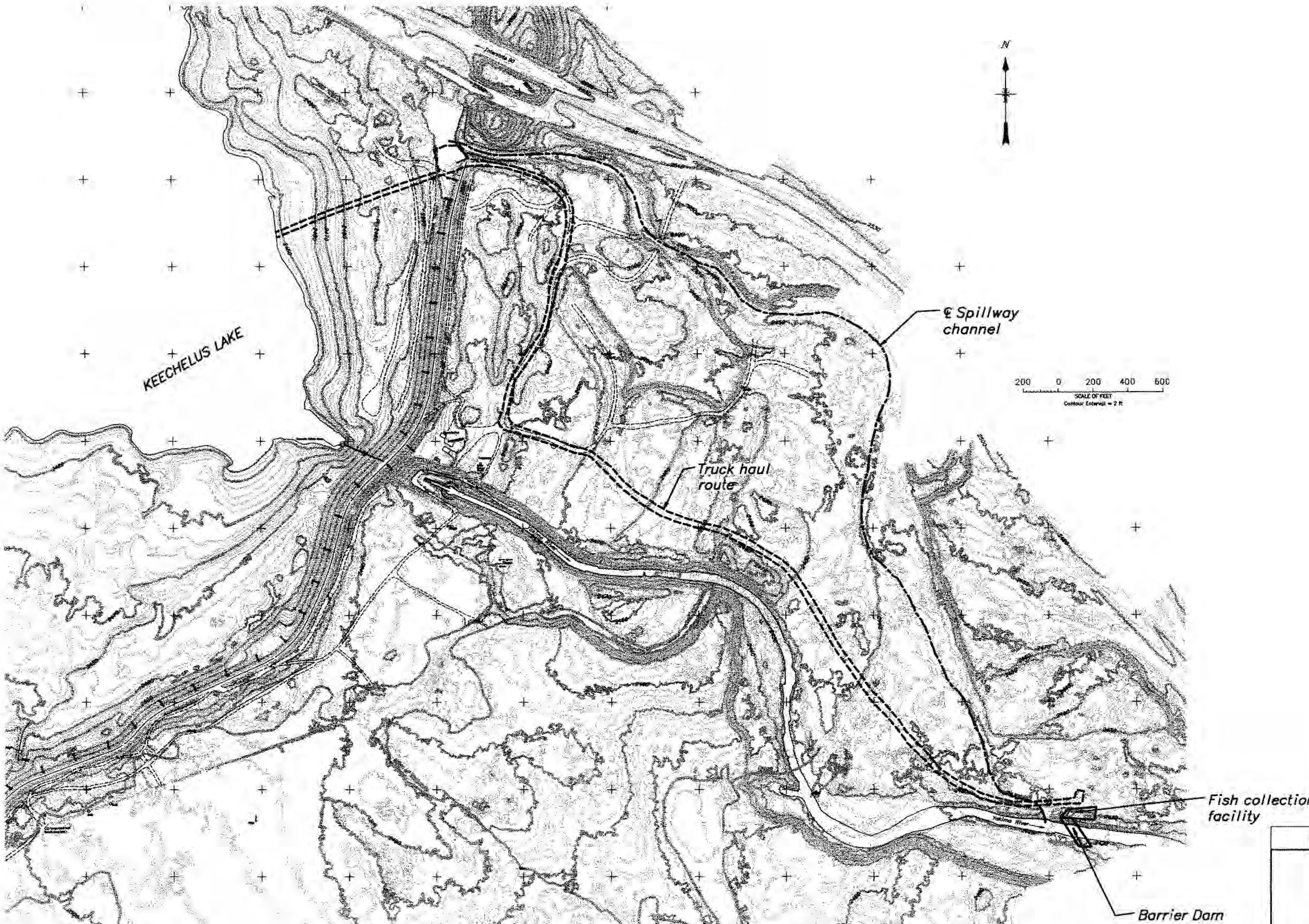
Reservoir Elevation Range	Reservoir Outflow (cfs) Max.	Exceedance Percent 90%	75%	50%	25%	10%
El.3420 - El.3427	2486	148	248	450	740	1066
El.3410 - El.3420	1200	80	157	251	410	650
El.3400 - El.3410	950	61	128	190	288	428
El.3390 - El.3400	562	56	80	118	174	238

Tieton Dam - Exceedance Flows
Water Years 1950 - 2001

Reservoir Elevation Range	Reservoir Outflow (cfs) Max.	Exceedance Percent 90%	75%	50%	25%	10%
El.2920 - El.2927	3340	388	567	836	1169	1453
El.2910 - El.2920	2628	101	308	597	1030	1360
El.2900 - El.2910	2670	19	135	396	860	1350
El.2890 - El.2900	2613	8	86	265	644	1139
El.2880 - El.2890	2454	7	33	172	669	1246
El.2870 - El.2880	2513	3	39	114	681	1280
El.2860 - El.2870	2548	0	8	44	573	1389
El.2850 - El.2860	2439	0	7	19	191	1307
El.2840 - El.2850	2294	0	8	56	246	981
El.2830 - El.2840	2006	2	18	47	365	868

Kachess Dam - Exceedance Flows
Water Years 1950 - 2001

Reservoir Elevation Range	Reservoir Outflow (cfs) Max.	Exceedance Percent 90%	75%	50%	25%	10%
El.2250 - El.2260	1764	5	14	274	607	881
El.2240 - El.2250	2060	2	4	15	436	850
El.2230 - El.2240	2083	2	3	9	382	880
El.2220 - El.2230	1880	1	2	6	343	1048
El.2210 - El.2220	1324	1	2	4	452	946
El.2200 - El.2210	907	1	2	21	189	539
El.2190 - El.2200	122	27	31	38	48	53



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BUREAU OF RECLAMATION

YAKIMA PROJECT – WASHINGTON

KEECHELUS DAM

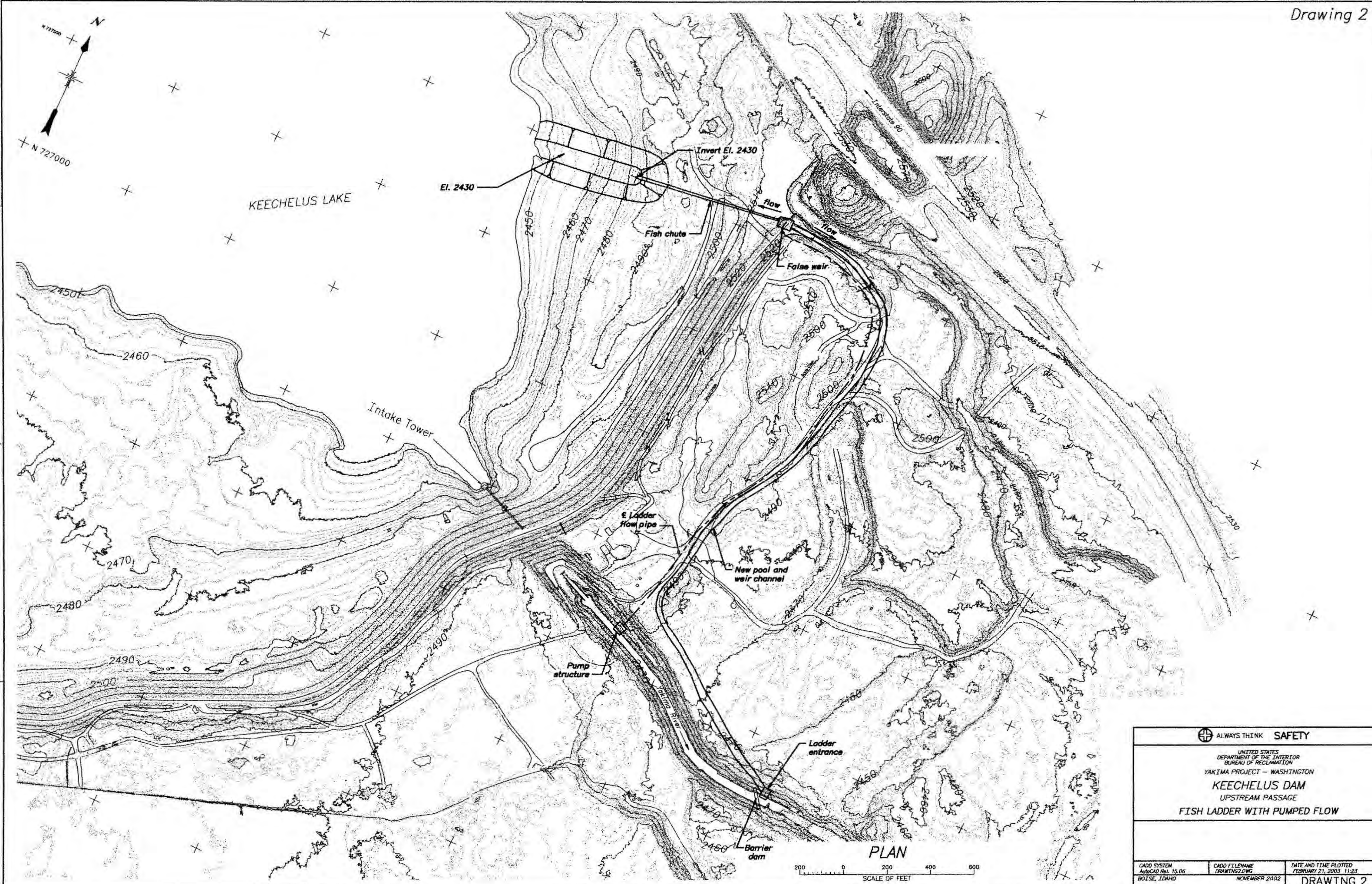
UPSTREAM PASSAGE

TRAP AND HAUL

CADD SYSTEM AutoCAD Rel. 15.06	CADD FILENAME DWG-1.dwg
BOISE, IDAHO NOVEMBER 2002	DRAWING 1

Specification #

FEBRUARY 19, 2003 09:28
PLOTTED BY



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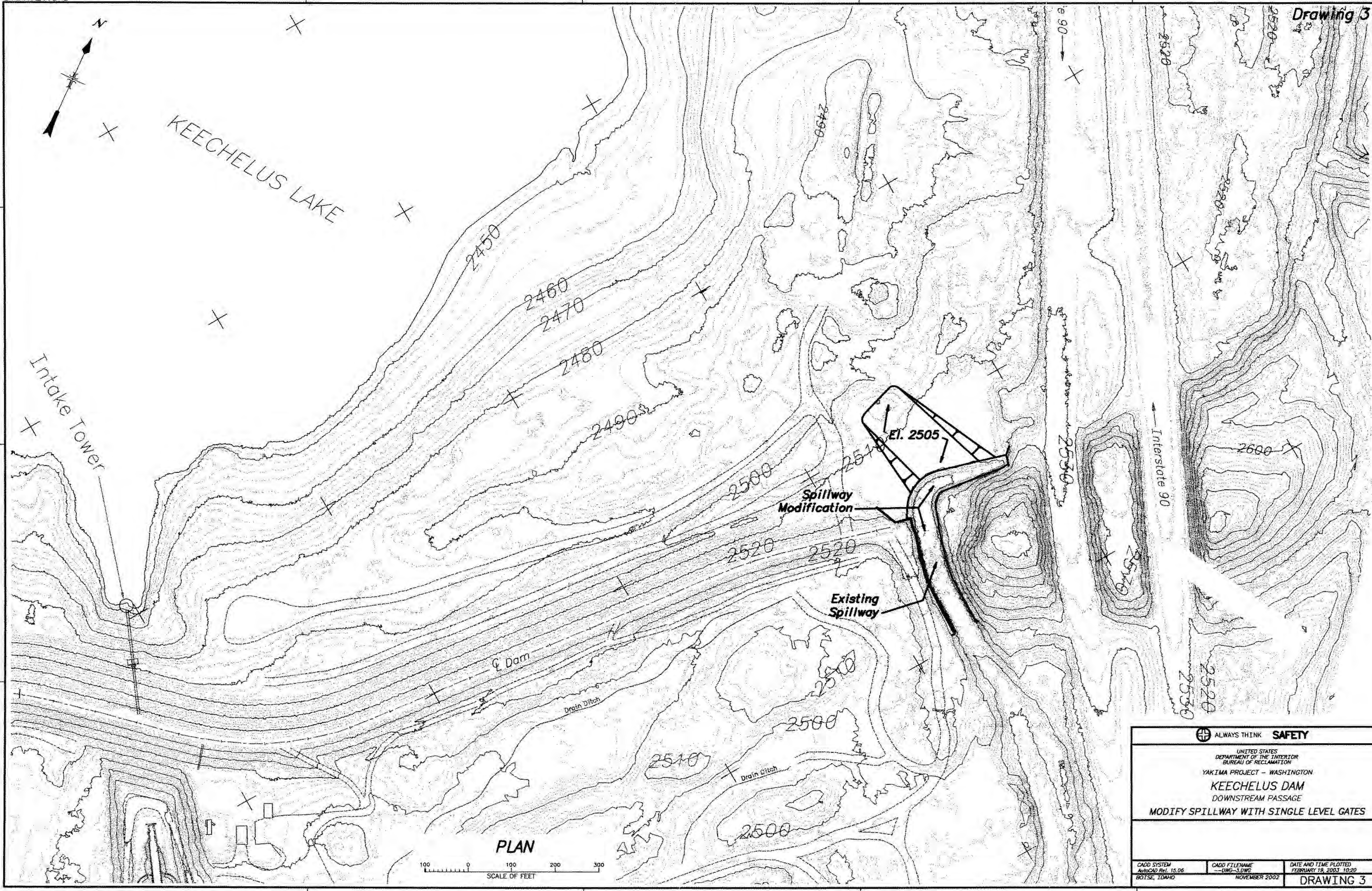
KEECHELUS DAM
UPSTREAM PASSAGE
FISH LADDER WITH PUMPED FLOW

CADD SYSTEM AutoCAD Rel. 15.06	CADD FILENAME DRAWING2.DWG	DATE AND TIME PLOTTED FEBRUARY 21, 2003 11:23
BOISE, IDAHO	NOVEMBER 2002	DRAWING 2


DRAWING 3
No.
Drawing 3
N
KEECHELUS LAKE
Intake Tower
2450
2460
2470
2480
2490
2500
2510
2520
2520
El. 2505
Spillway
Modification
Existing
Spillway
Interstate 90
2600
2530
2520
2510
2500
2510
2500
2520
2530
℄ Dam
Drain Ditch
Drain Ditch
PLAN
100 0 100 200 300
SCALE OF FEET
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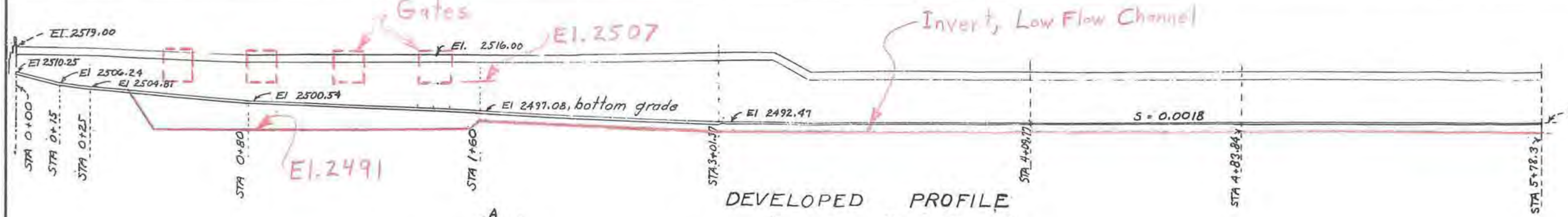
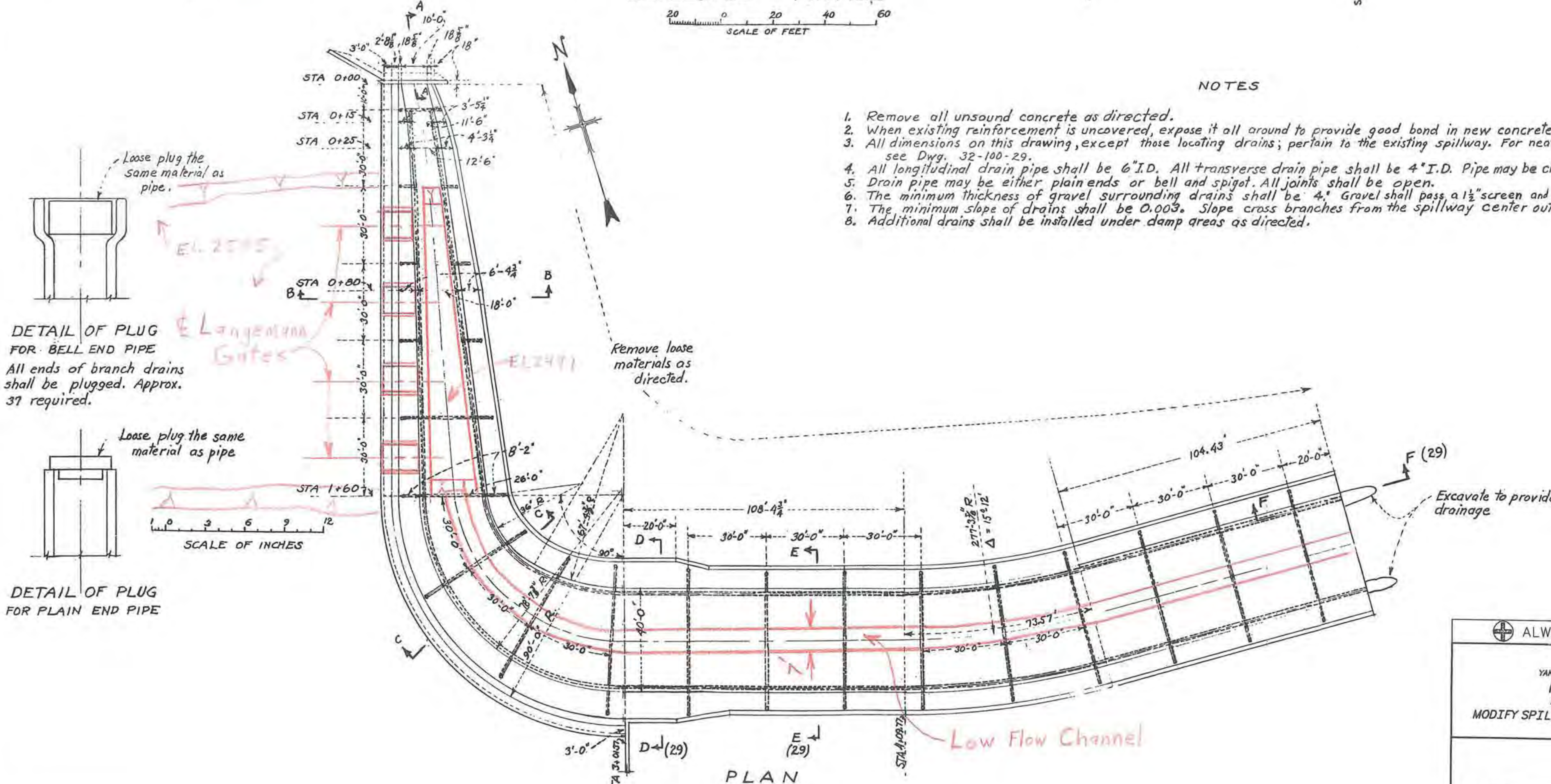
YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH SINGLE LEVEL GATES
CADD SYSTEM AutoCAD Rel. 15.06
CADD FILENAME --DWG-3.DWG
DATE AND TIME PLOTTED FEBRUARY 19, 2003 10:20
BOISE, IDAHO
NOVEMBER 2002
DRAWING 3
No.

DRAWING 4





NOTES

1. Remove all unsound concrete as directed.
2. When existing reinforcement is uncovered, expose it all around to provide good bond in new concrete.
3. All dimensions on this drawing, except those locating drains; pertain to the existing spillway. For neat lines of new concrete, see Dwg. 32-100-29.
4. All longitudinal drain pipe shall be 6"I.D. All transverse drain pipe shall be 4"I.D. Pipe may be clay tile or concrete.
5. Drain pipe may be either plain ends or bell and spigot. All joints shall be open.
6. The minimum thickness of gravel surrounding drains shall be 4". Gravel shall pass a 1½" screen and be retained on a ½" screen.
7. The minimum slope of drains shall be 0.003. Slope cross branches from the spillway center outward to the main drains.
8. Additional drains shall be installed under damp areas as directed.

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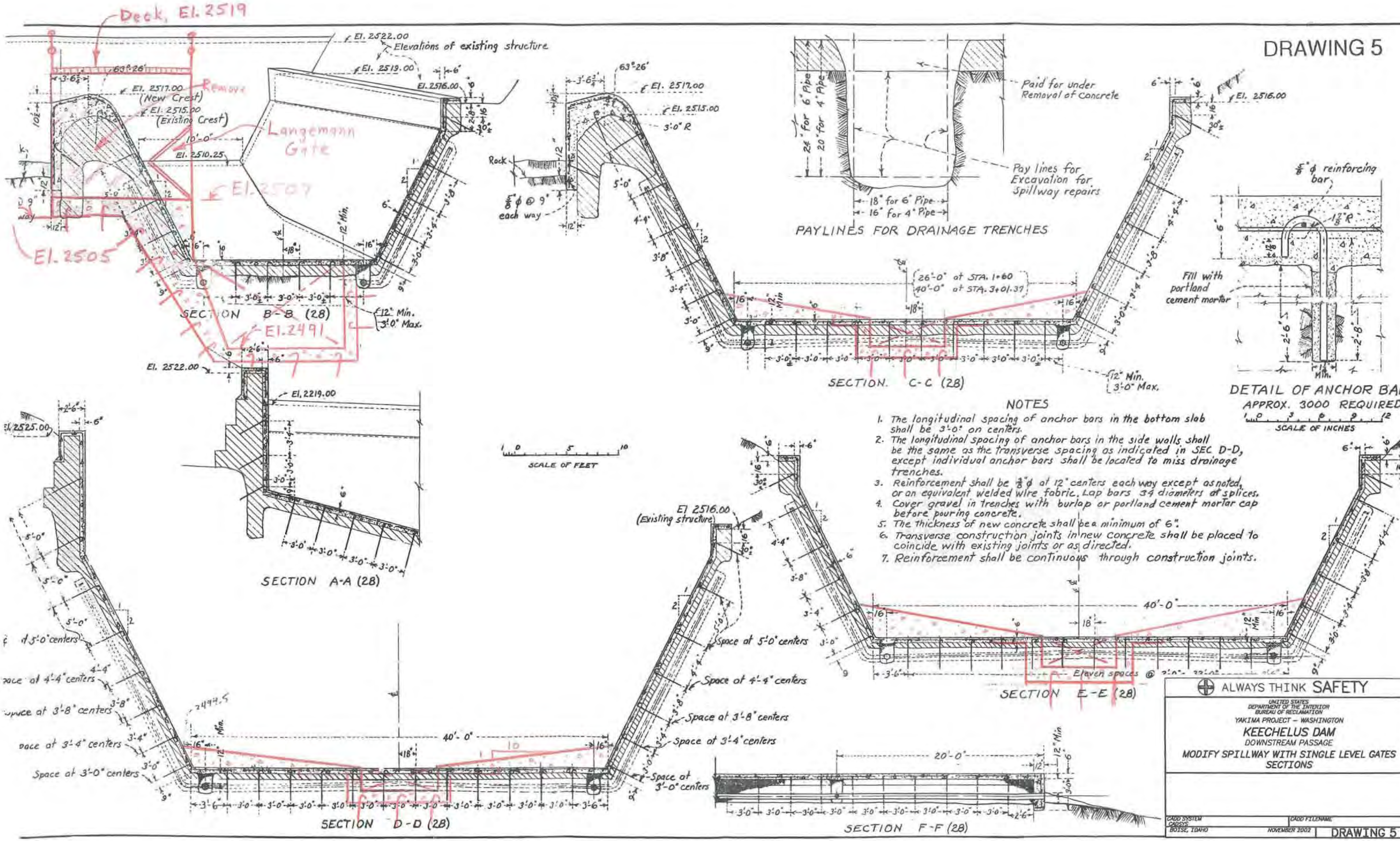
KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH SINGLE LEVEL GATES
DETAIL

CADD SYSTEM CADSYS | CADD FILENAME
BOISE, IDAHO | NOVEMBER 2002 | DRAWING 4

DRAWING 5



NOTES

1. The longitudinal spacing of anchor bars in the bottom slab shall be 3'-0" on centers.
2. The longitudinal spacing of anchor bars in the side walls shall be the same as the transverse spacing as indicated in SEC D-D, except individual anchor bars shall be located to miss drainage trenches.
3. Reinforcement shall be 5/8"φ at 12" centers each way except as noted, or an equivalent welded wire fabric. Lap bars 34 diameters at splices.
4. Cover gravel in trenches with burlap or portland cement mortar cap before pouring concrete.
5. The thickness of new concrete shall be a minimum of 6".
6. Transverse construction joints in new concrete shall be placed to coincide with existing joints or as directed.
7. Reinforcement shall be continuous through construction joints.

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YAKIMA PROJECT – WASHINGTON

KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH SINGLE LEVEL GATES
SECTIONS

CADD SYSTEM | CADD FILENAME
BOISE, IDAHO | NOVEMBER 2002 | DRAWING 5

DRAWING 6

No.
Drawing 6
N
AKE
Interstate 90
Existing spillway
El. 2484.0
Approach channel
Spillway modification
Drain Ditch
℄ Dam
Intake Tower
2450
2460
2470
2480
2490
2500
2510
2520
2530
2540
PLAN
100 0 100 200 300
SCALE OF FEET
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YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH MULTIPLE LEVEL GATES
CADD SYSTEM AutoCAD Rel. 15.06
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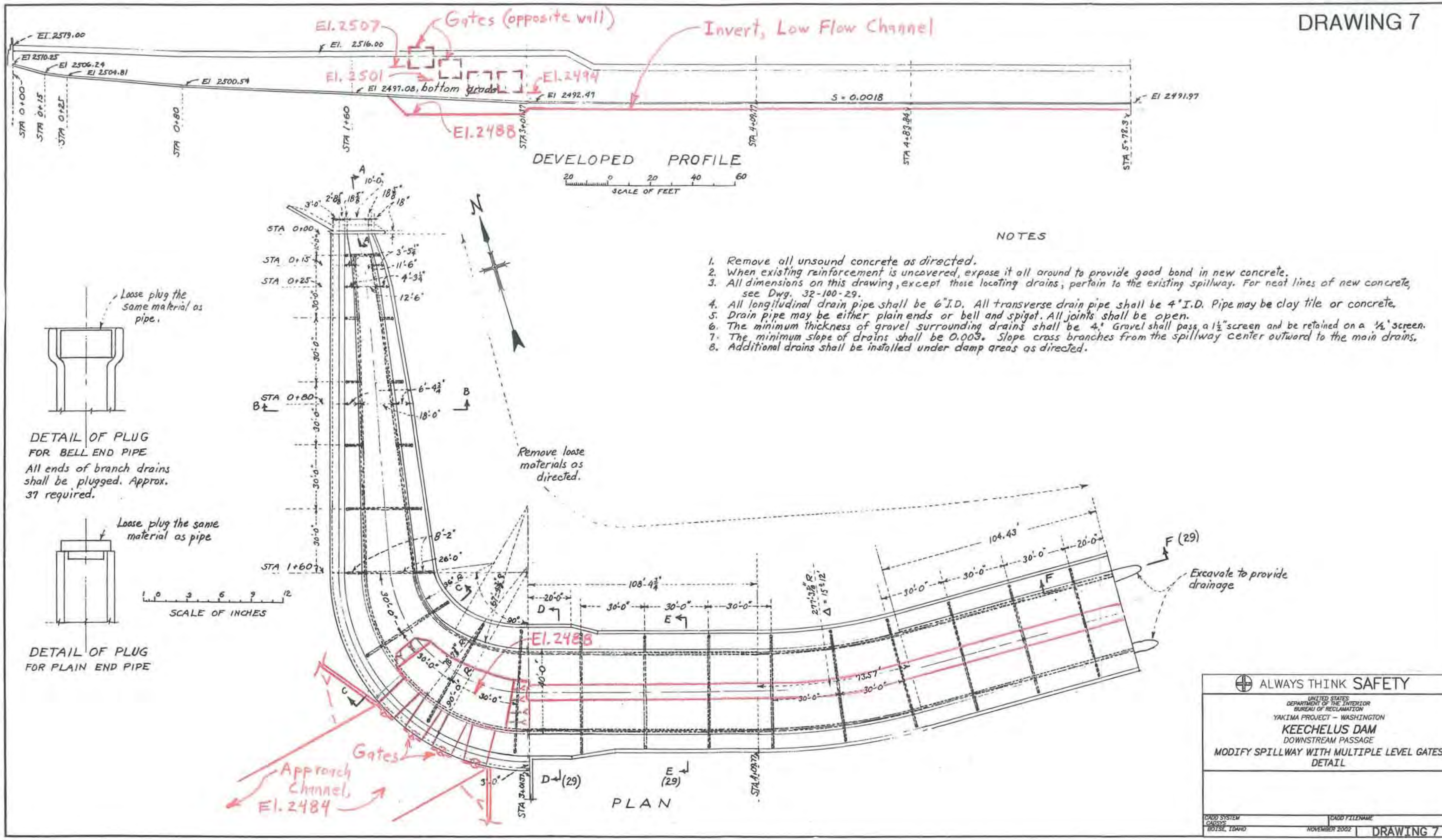
BOISE, IDAHO
NOVEMBER 2002
DRAWING 6
No.



DRAWING 7
El. 2507
Gates (opposite wall)
Invert, Low Flow Channel
El. 2501
El. 2494
El. 2488
El 2519.00
El 2510.25
El 2506.24
El 2504.81
El 2500.54
El. 2516.00
El 2497.08, bottom grade
El 2492.49
S = 0.0018
El 2491.97
STA 0+00
STA 0+15
STA 0+25
STA 0+80
STA 1+60
STA 4+09.17
STA 4+83.84
STA 5+72.3
DEVELOPED PROFILE
SCALE OF FEET
NOTES
1. Remove all unsound concrete as directed.
2. When existing reinforcement is uncovered, expose it all around to provide good bond in new concrete.
3. All dimensions on this drawing, except those locating drains, pertain to the existing spillway. For neat lines of new concrete, see Dwg. 32-100-29.
4. All longitudinal drain pipe shall be 6" I.D. All transverse drain pipe shall be 4" I.D. Pipe may be clay tile or concrete.
5. Drain pipe may be either plain ends or bell and spigot. All joints shall be open.
6. The minimum thickness of gravel surrounding drains shall be 4". Gravel shall pass a 1½" screen and be retained on a ½" screen.
7. The minimum slope of drains shall be 0.003. Slope cross branches from the spillway center outward to the main drains.
8. Additional drains shall be installed under damp areas as directed.
Loose plug the same material as pipe.
DETAIL OF PLUG FOR BELL END PIPE
All ends of branch drains shall be plugged. Approx. 37 required.
Loose plug the same material as pipe
SCALE OF INCHES
DETAIL OF PLUG FOR PLAIN END PIPE
Remove loose materials as directed.
Excavate to provide drainage
104.43'
108'-4¾"
El. 2488
Gates
Approach Channel, El. 2484
PLAN
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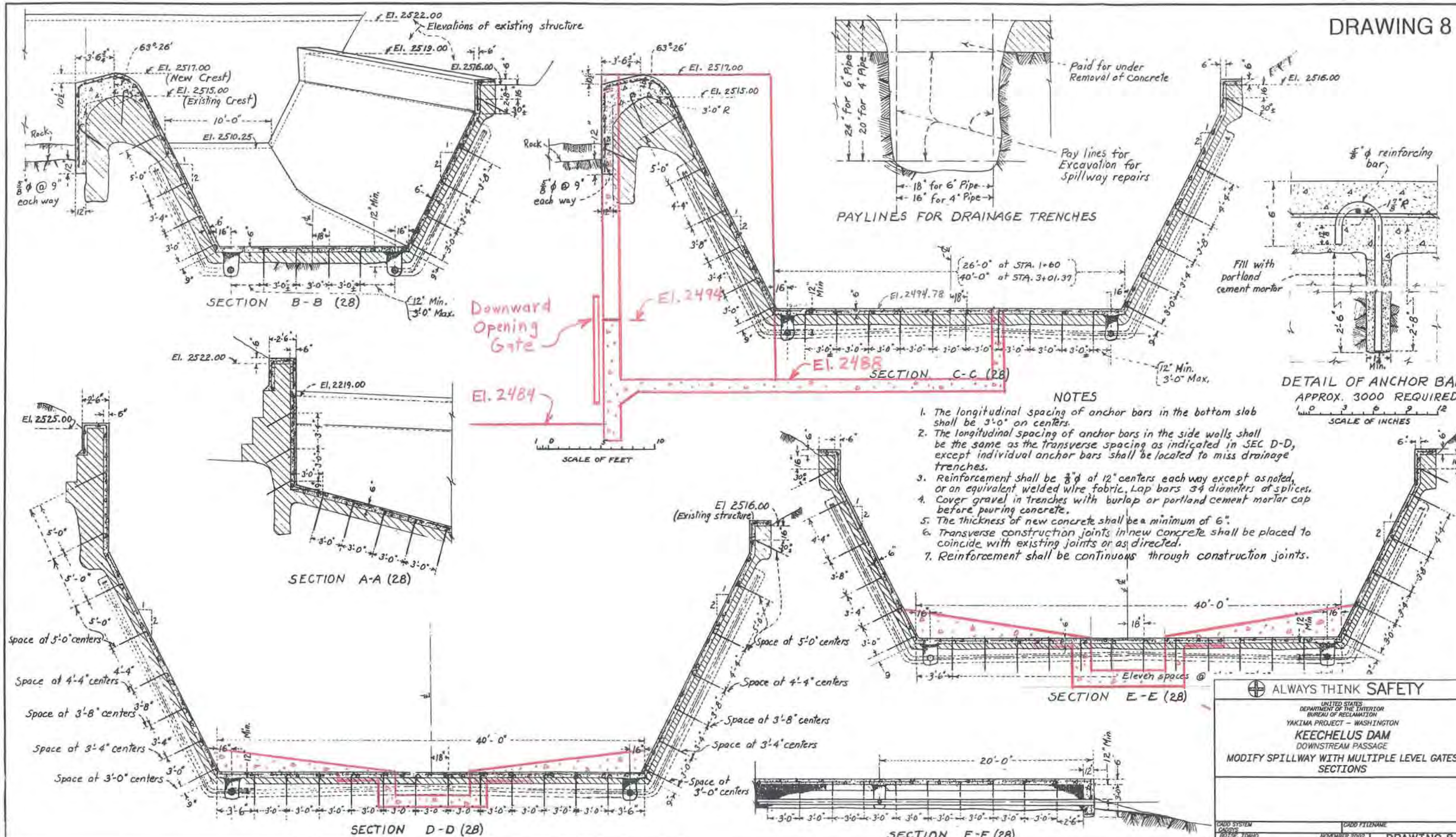
YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH MULTIPLE LEVEL GATES DETAIL
BOISE, IDAHO
NOVEMBER 2002
DRAWING 7



NOTES

1. The longitudinal spacing of anchor bars in the bottom slab shall be 3'-0" on centers.
2. The longitudinal spacing of anchor bars in the side walls shall be the same as the transverse spacing as indicated in SEC D-D, except individual anchor bars shall be located to miss drainage trenches.
3. Reinforcement shall be ⅜"ϕ at 12" centers each way except as noted, or an equivalent welded wire fabric. Lap bars 34 diameters at splices.
4. Cover gravel in trenches with burlap or portland cement mortar cap before pouring concrete.
5. The thickness of new concrete shall be a minimum of 6".
6. Transverse construction joints in new concrete shall be placed to coincide with existing joints or as directed.
7. Reinforcement shall be continuous through construction joints.

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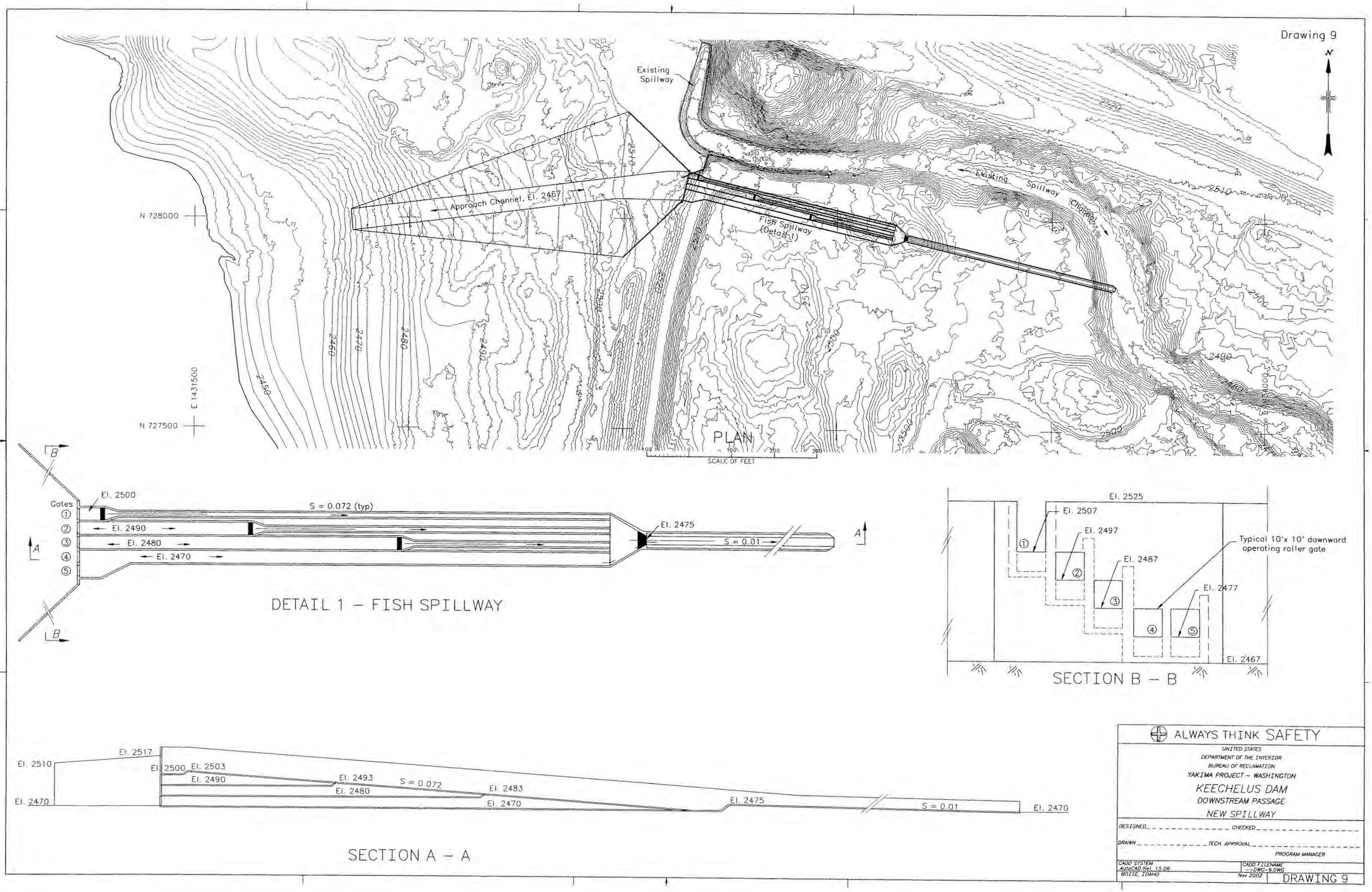
KEECHELUS DAM
DOWNSTREAM PASSAGE
MODIFY SPILLWAY WITH MULTIPLE LEVEL GATES SECTIONS

CADD SYSTEM CADSYS | CADD FILENAME
BOISE, IDAHO | NOVEMBER 2002 | DRAWING 8


Drawing 9
N
Existing Spillway
Approach Channel, El. 2467
Fish Spillway (Detail 1)
Existing Spillway Channel
N 728000
N 727500
E 1431500
2450
2460
2470
2480
2490
2500
2510
2520
PLAN
SCALE OF FEET
100
0
100
200
300
Gates
①
②
③
④
⑤
El. 2500
El. 2490
El. 2480
El. 2470
S = 0.072 (typ)
El. 2475
S = 0.01
A
B
DETAIL 1 – FISH SPILLWAY
El. 2525
El. 2507
El. 2497
El. 2487
El. 2477
El. 2467
Typical 10'x 10' downward operating roller gate
SECTION B – B
El. 2510
El. 2517
El. 2500
El. 2503
El. 2490
El. 2493
El. 2480
S = 0.072
El. 2483
El. 2470
El. 2475
S = 0.01
El. 2470
SECTION A – A
ALWAYS THINK SAFETY
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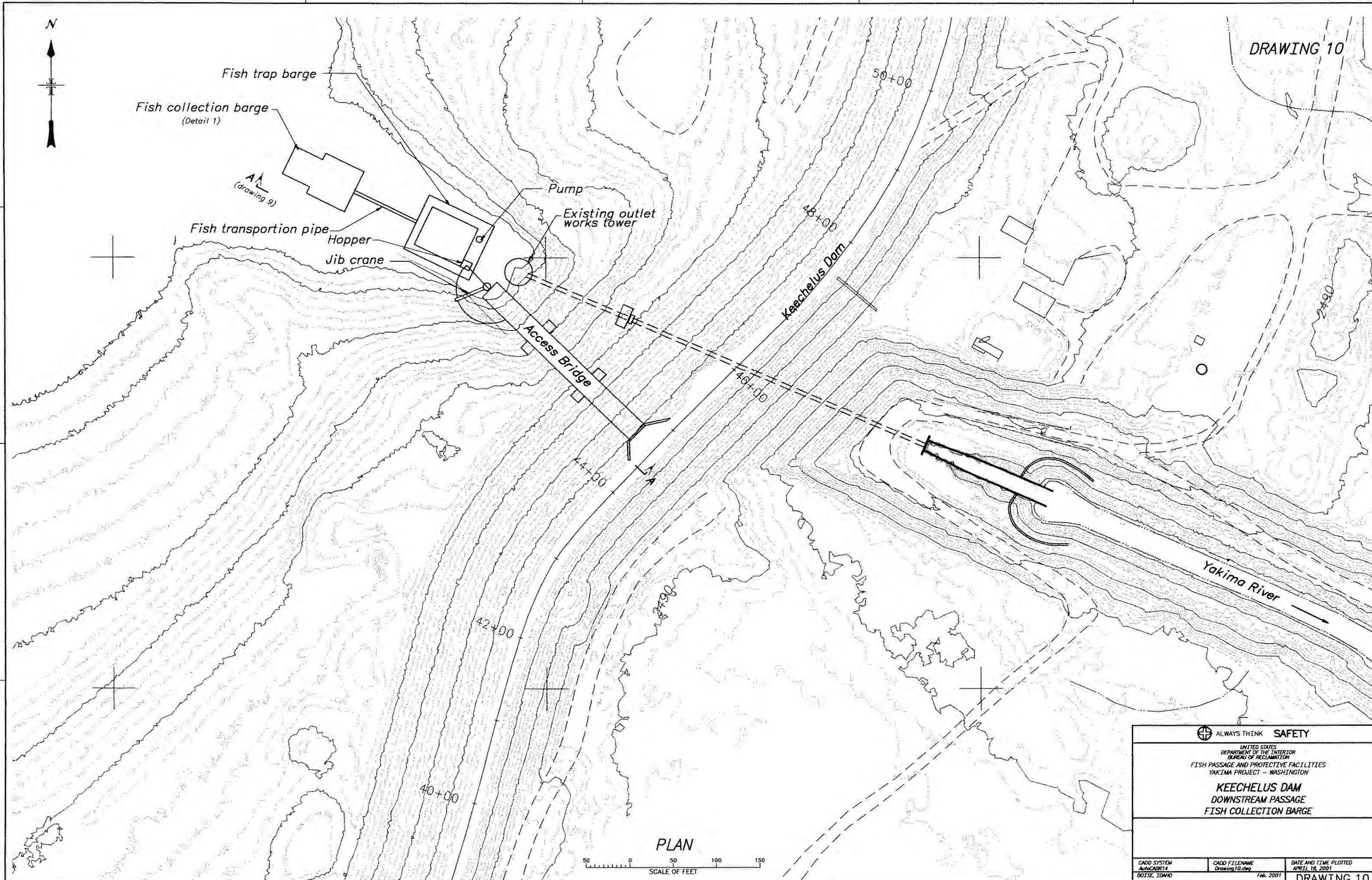
YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
NEW SPILLWAY
DESIGNED
CHECKED
DRAWN
TECH. APPROVAL
PROGRAM MANAGER
CADD SYSTEM
AutoCAD Rel. 15.06
BOISE, IDAHO
CADD FILENAME
--DWG-9.DWG
Nov 2002
DRAWING 9


DRAWING 10
N
Fish trap barge
Fish collection barge
(Detail 1)
A
(drawing 9)
Pump
Existing outlet works tower
Fish transportion pipe
Hopper
Jib crane
Access Bridge
Keechelus Dam
50+00
48+00
46+00
44+00
42+00
40+00
2490
Yakima River
PLAN
50 0 50 100 150
SCALE OF FEET
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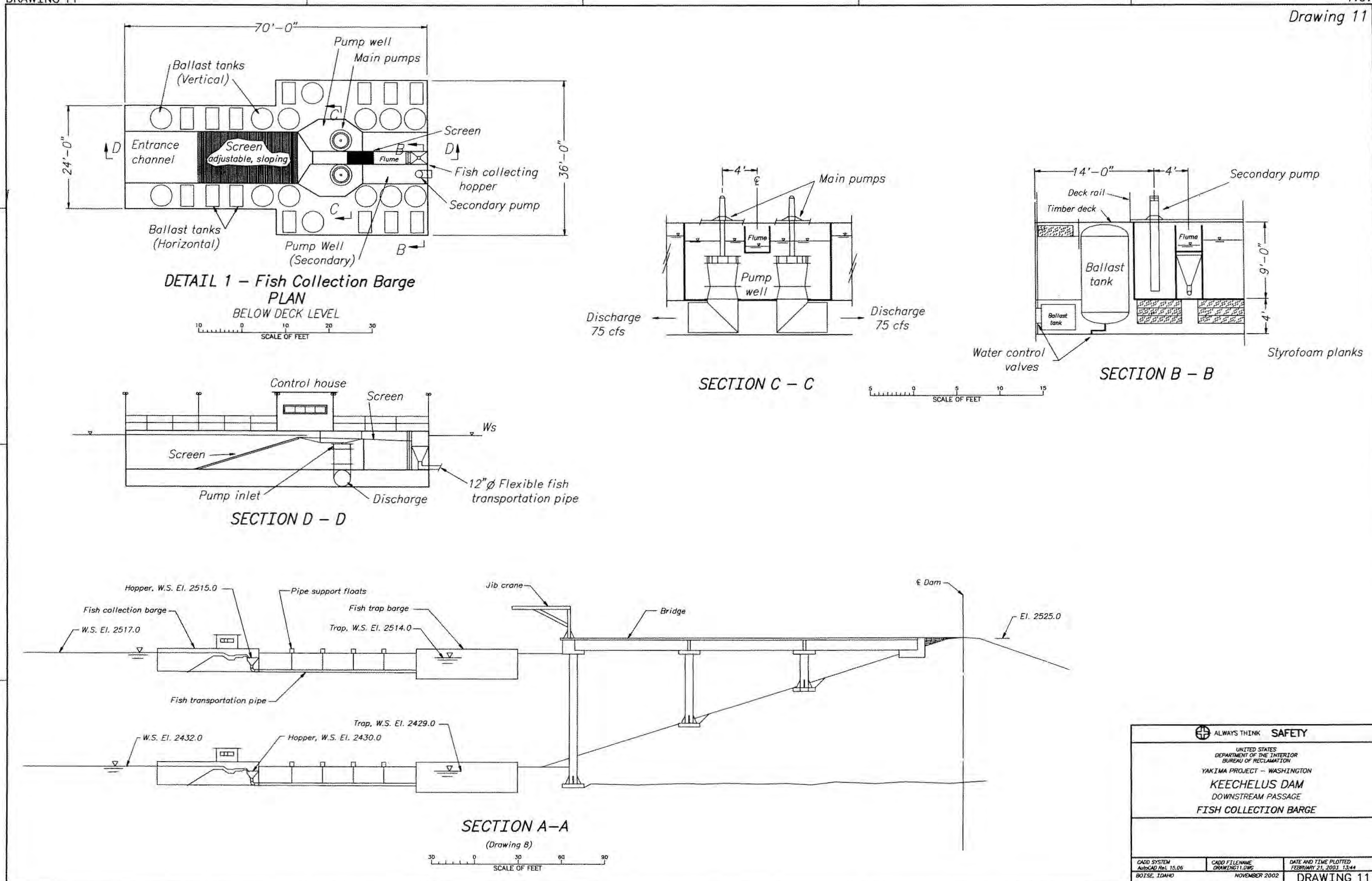
FISH PASSAGE AND PROTECTIVE FACILITIES
YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
FISH COLLECTION BARGE
CADD SYSTEM
AutoCADR14
CADD FILENAME
Drawing10.dwg
DATE AND TIME PLOTTED
APRIL 18, 2001
BOISE, IDAHO
Feb. 2001
DRAWING 10


70'-0"
Pump well
Main pumps
Ballast tanks (Vertical)
24'-0"
36'-0"
Entrance channel
Screen adjustable, sloping
Flume
Screen
Fish collecting hopper
Secondary pump
Ballast tanks (Horizontal)
Pump Well (Secondary)
DETAIL 1 – Fish Collection Barge PLAN
BELOW DECK LEVEL
SCALE OF FEET
4'
Main pumps
Flume
Pump well
Discharge 75 cfs
Discharge 75 cfs
SECTION C – C
SCALE OF FEET
14'-0"
4'
Secondary pump
Deck rail
Timber deck
Flume
Ballast tank
Ballast tank
9'-0"
4'
Water control valves
Styrofoam planks
SECTION B – B
Control house
Screen
Ws
Screen
Pump inlet
Discharge
12"Ø Flexible fish transportation pipe
SECTION D – D
Hopper, W.S. El. 2515.0
Pipe support floats
Fish collection barge
Fish trap barge
W.S. El. 2517.0
Trap, W.S. El. 2514.0
Jib crane
Bridge
℄ Dam
El. 2525.0
Fish transportation pipe
Trap, W.S. El. 2429.0
W.S. El. 2432.0
Hopper, W.S. El. 2430.0
SECTION A–A
(Drawing 8)
SCALE OF FEET
ALWAYS THINK SAFETY
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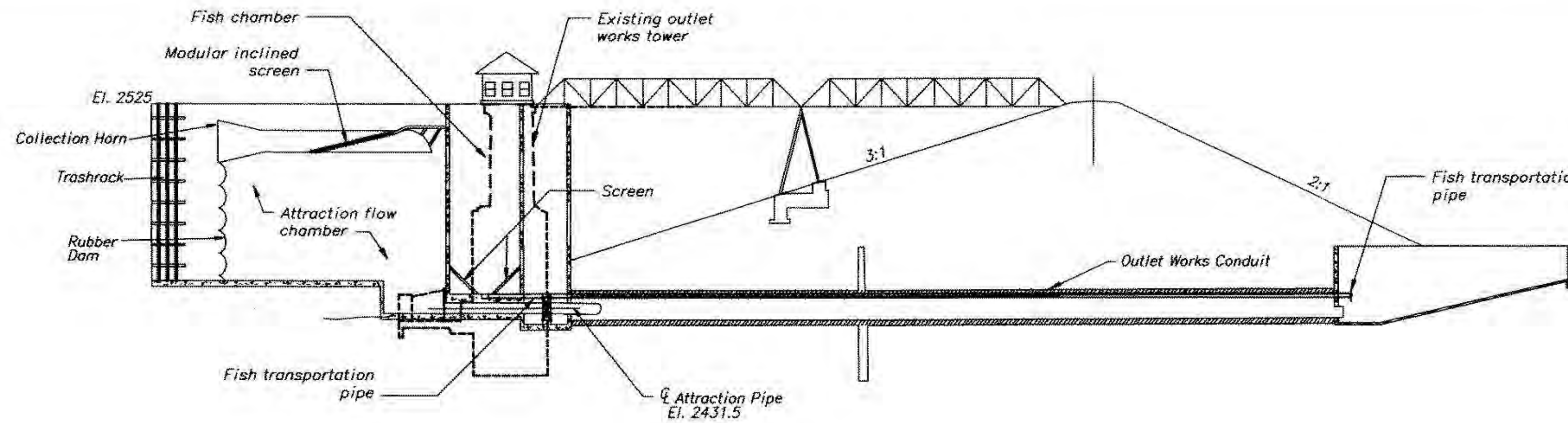
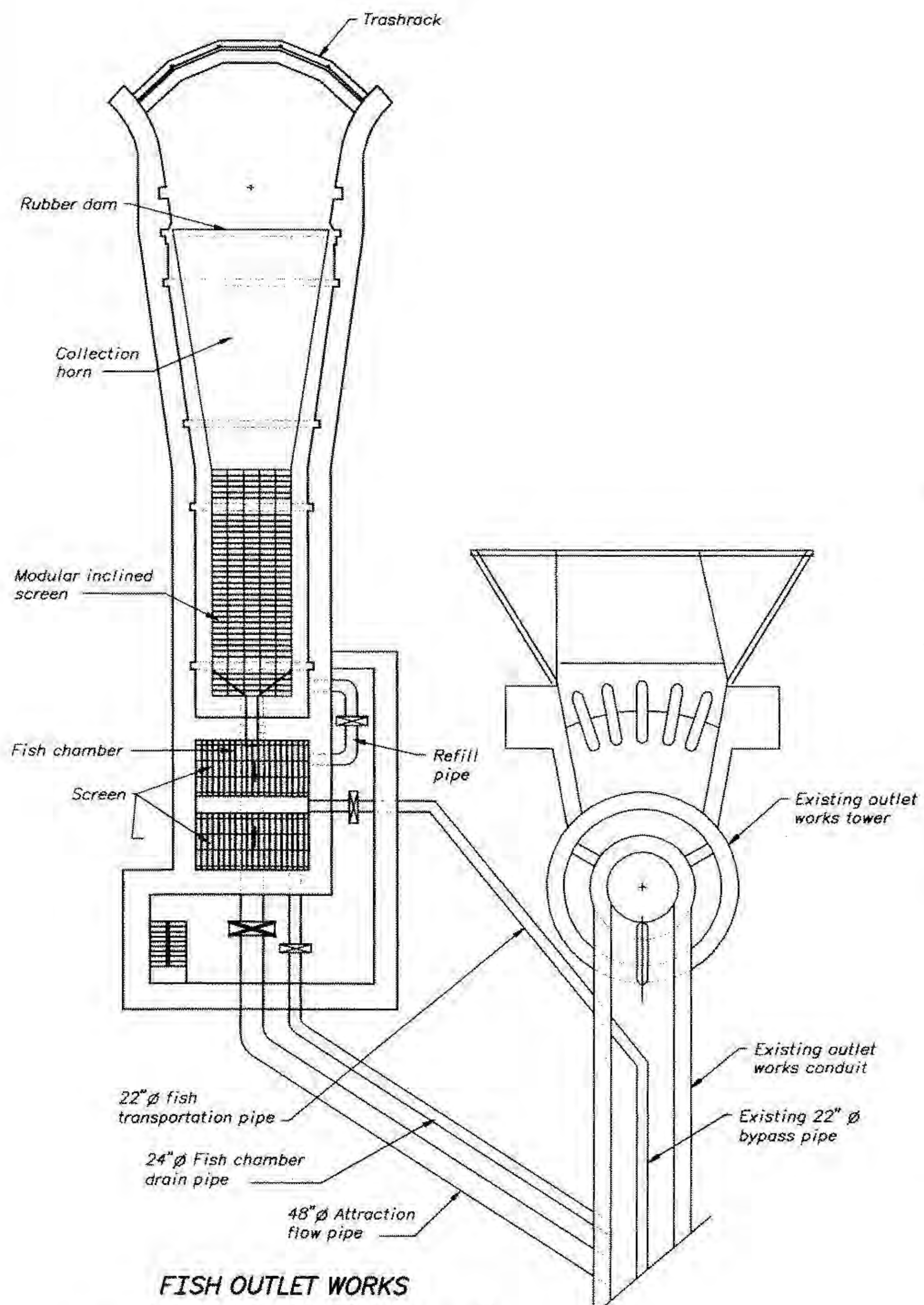
YAKIMA PROJECT – WASHINGTON
KEECHELUS DAM
DOWNSTREAM PASSAGE
FISH COLLECTION BARGE
CADD SYSTEM AutoCAD Rel. 15.06
CADD FILENAME DRAWING11.DWG
DATE AND TIME PLOTTED FEBRUARY 21, 2003 13:44
BOISE, IDAHO
NOVEMBER 2002
DRAWING 11

DRAWING 12



SECTION A–A

1 0 1 2 3 4 5 6 7 8
SCALE OF FEET



FISH OUTLET WORKS

1 0 1 2 3 4 5
SCALE OF FEET

PLAN

100 0 100 200 300
SCALE OF FEET

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YAKIMA PROJECT – WASHINGTON

KEECHELUS DAM
DOWNSTREAM PASSAGE

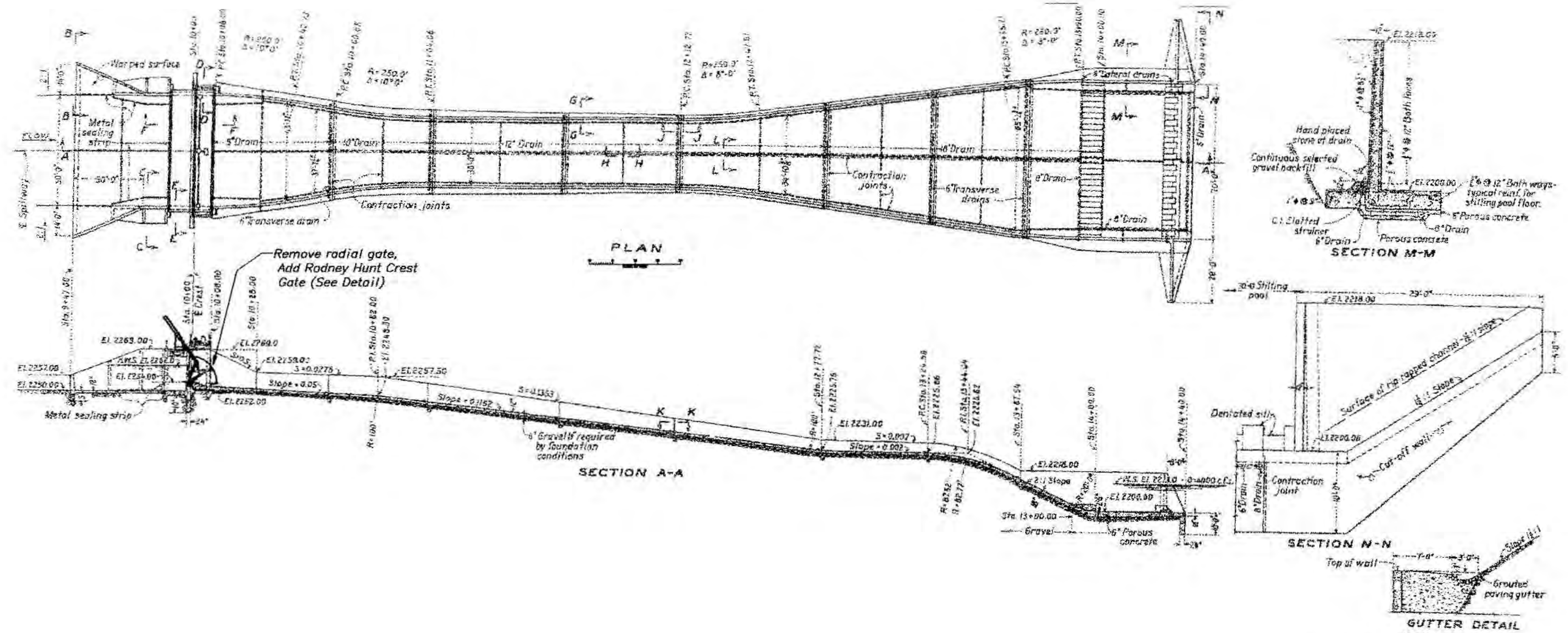
NEW OUTLET WORKS

CADD SYSTEM AutoCAD Rel. 15.06
BOISE, IDAHO
CADD FILENAME drawing12.dwg
7-1-2002

DRAWING 12

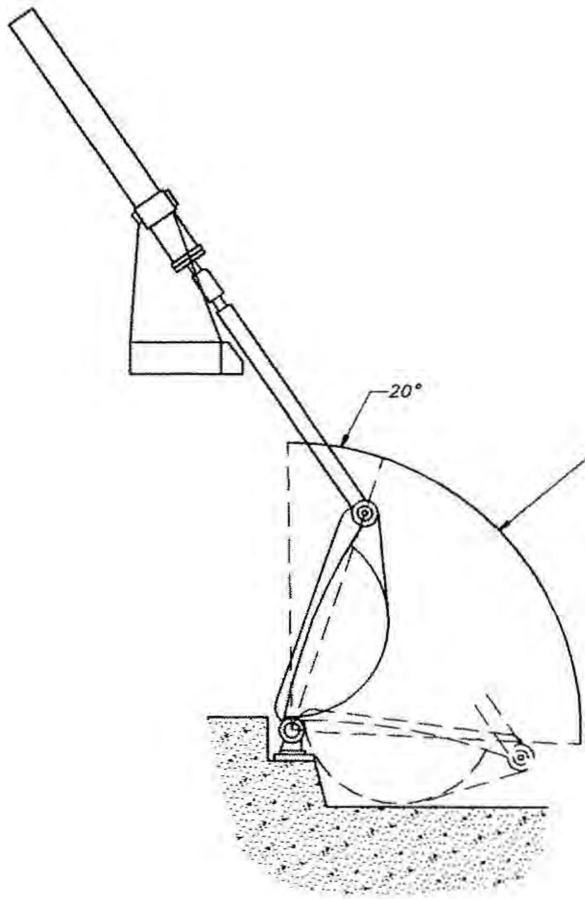
Specification #

DRAWING 13



NOTES

All drains to be open joint sewer pipe and are to be laid in selected gravel except as otherwise shown.



CREST GATE DETAIL

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YAKIMA PROJECT – WASHINGTON

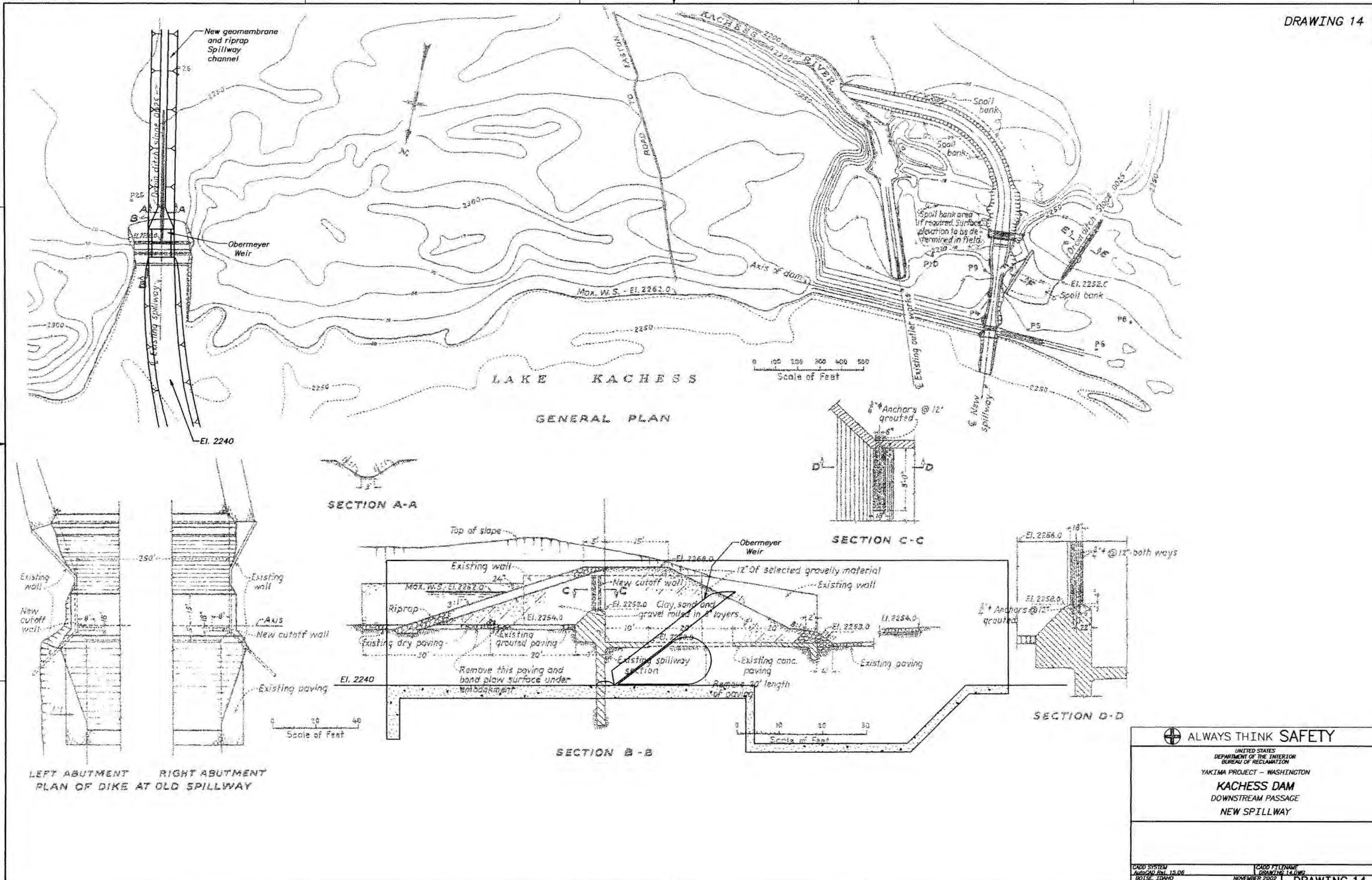
KACHESS DAM

DOWNSTREAM PASSAGE

MODIFY SPILLWAY WITH NEW GATE

CADD SYSTEM AutoCAD Rel. 15.06 | CADD FILENAME DRAWING 13.DWG
BOISE, IDAHO | NOVEMBER 2002 | DRAWING 13

SPECIFICATION #


DRAWING 14
New geomembrane and riprap Spillway channel
Obermeyer Weir
El. 2240
Max. W.S. - El. 2262.0
Axis of dam
KACHESS RIVER
ROAD TO EASTON
Spoil bank
Spoil bank area if required. Surface elevation to be determined in field.
Existing outlet works
New spillway
Drain ditch
Spoil bank
El. 2252.0
Scale of Feet
LAKE KACHESS
GENERAL PLAN
SECTION A-A
Anchors @ 12" grouted
SECTION C-C
Existing wall
New cutoff wall
Axis
Existing paving
LEFT ABUTMENT
RIGHT ABUTMENT
PLAN OF DIKE AT OLD SPILLWAY
Scale of Feet
Top of slope
Obermeyer Weir
El. 2268.0
12" Of selected gravelly material
Existing wall
Max. W.S. El. 2262.0
New cutoff wall
El. 2258.0 Clay, sand and gravel rolled in 6" layers
Riprap
El. 2254.0
Existing dry paving
Existing grouted paving
Existing spillway section
Existing conc. paving
El. 2253.0
Existing paving
Remove this paving and band plow surface under embankment
Remove 20' length of paving
El. 2240
Scale of Feet
SECTION B-B
El. 2266.0
@ 12" both ways
El. 2258.0
Anchors @ 12" grouted
SECTION D-D
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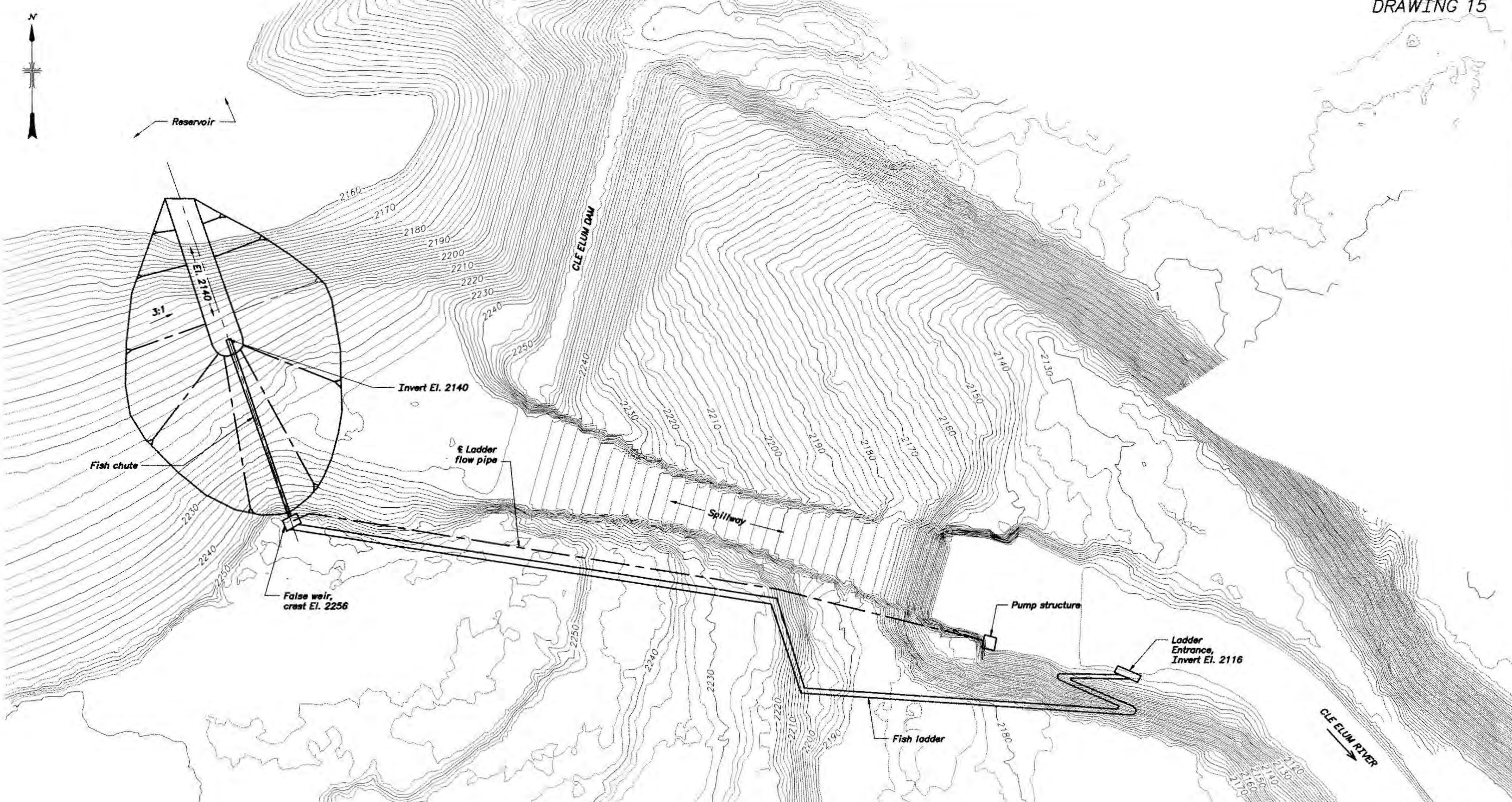
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON
KACHESS DAM
DOWNSTREAM PASSAGE
NEW SPILLWAY
CADD SYSTEM AutoCAD Rel. 15.06
BOISE, IDAHO
CADD FILENAME DRAWING 14.DWG
NOVEMBER 2002
DRAWING 14

DRAWING 15



PLAN

100 0 100 200 300
SCALE OF FEET

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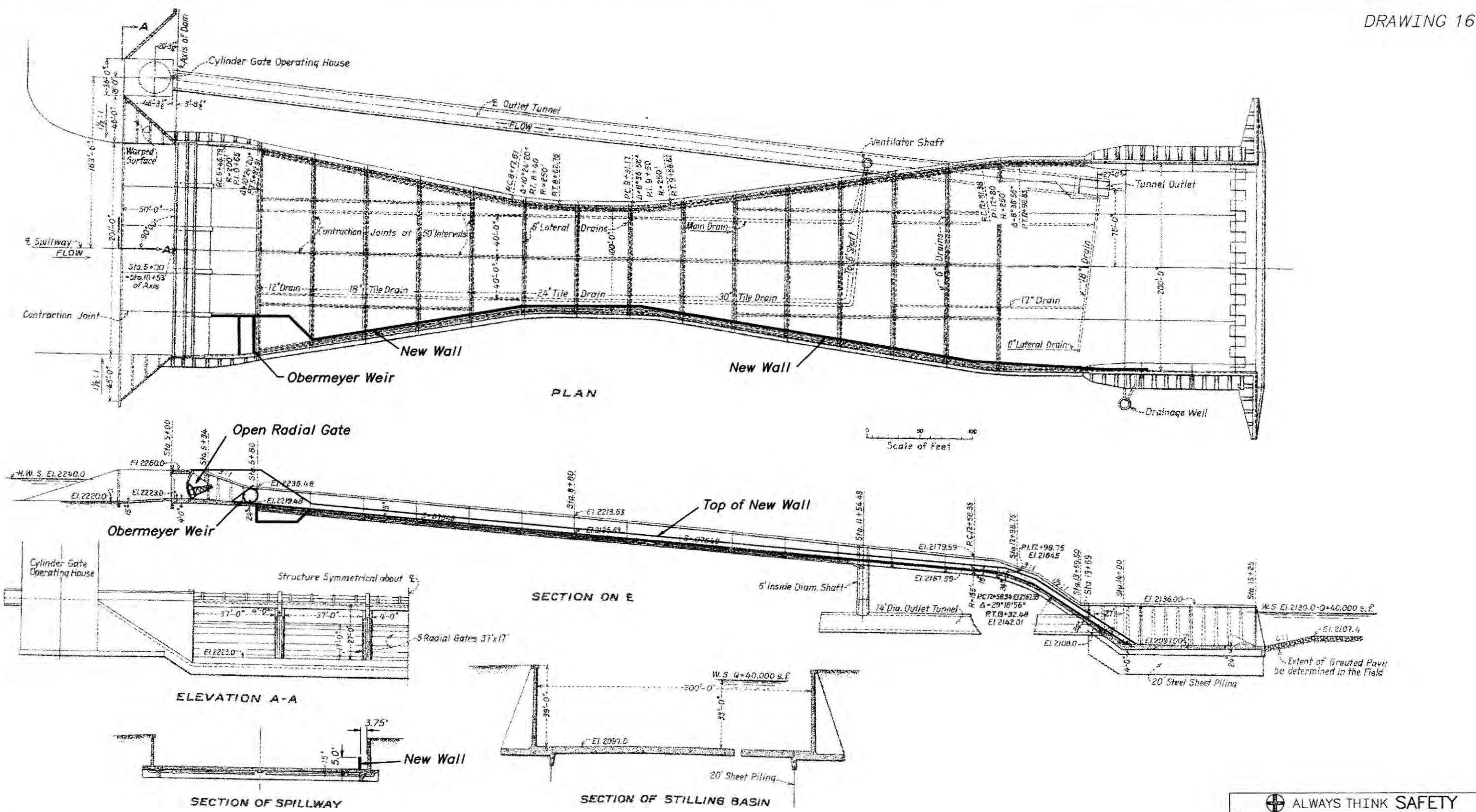
YAKIMA PROJECT – WASHINGTON

CLE ELUM DAM
UPSTREAM PASSAGE
FISH LADDER WITH PUMPED FLOW

CADD SYSTEM AutoCAD Rel. 15.06 | CADD FILENAME Drawing13.dwg
BOISE, IDAHO | NOVEMBER 1, 2002 | DRAWING 15

Specification #



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YAKIMA PROJECT – WASHINGTON

CLE ELUM DAM

DOWNSTREAM PASSAGE

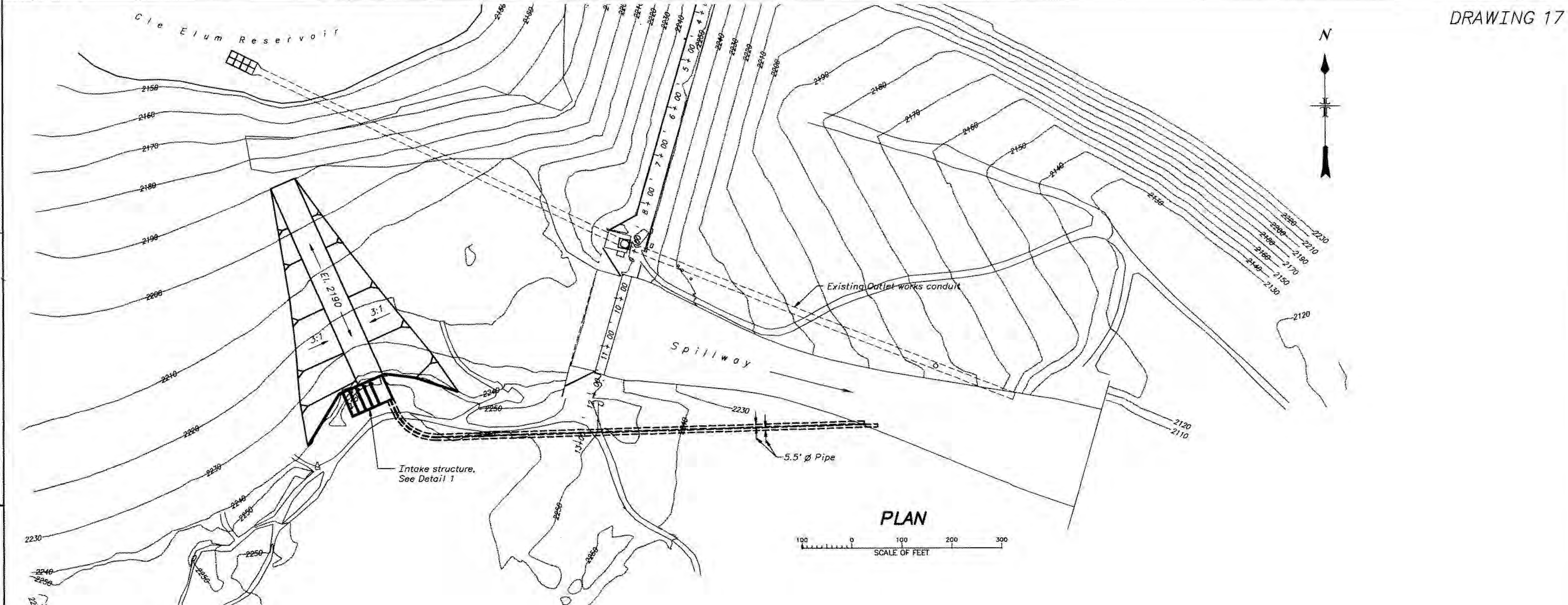
MODIFY SPILLWAY WITH NEW GATE

CADD SYSTEM AutoCAD Rel. 15.06 BOISE, IDAHO	CADD FILENAME DRAWING14.DWG NOV 2002

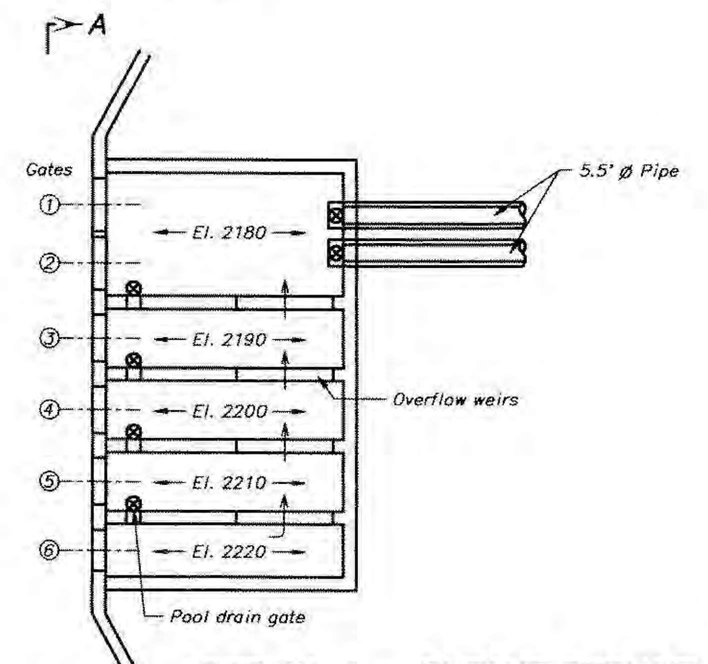
DRAWING 16

Specification #

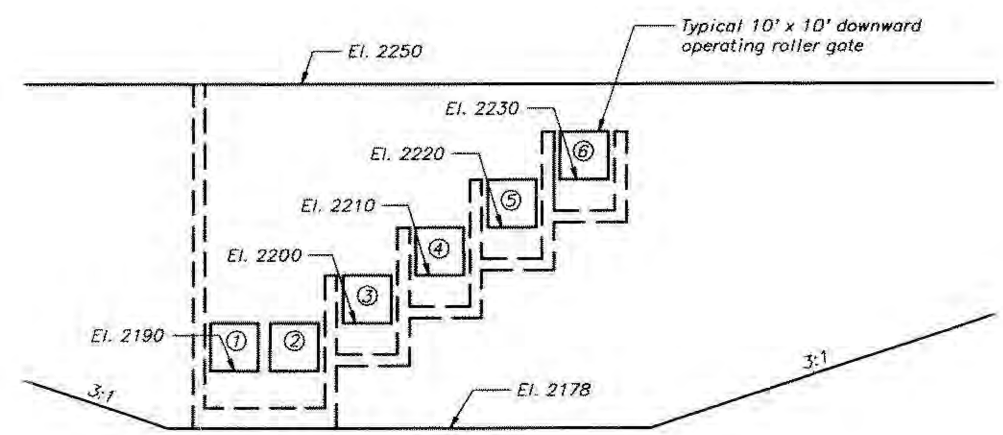
DRAWING 17



PLAN



DETAIL 1 – INTAKE STRUCTURE



SECTION A–A

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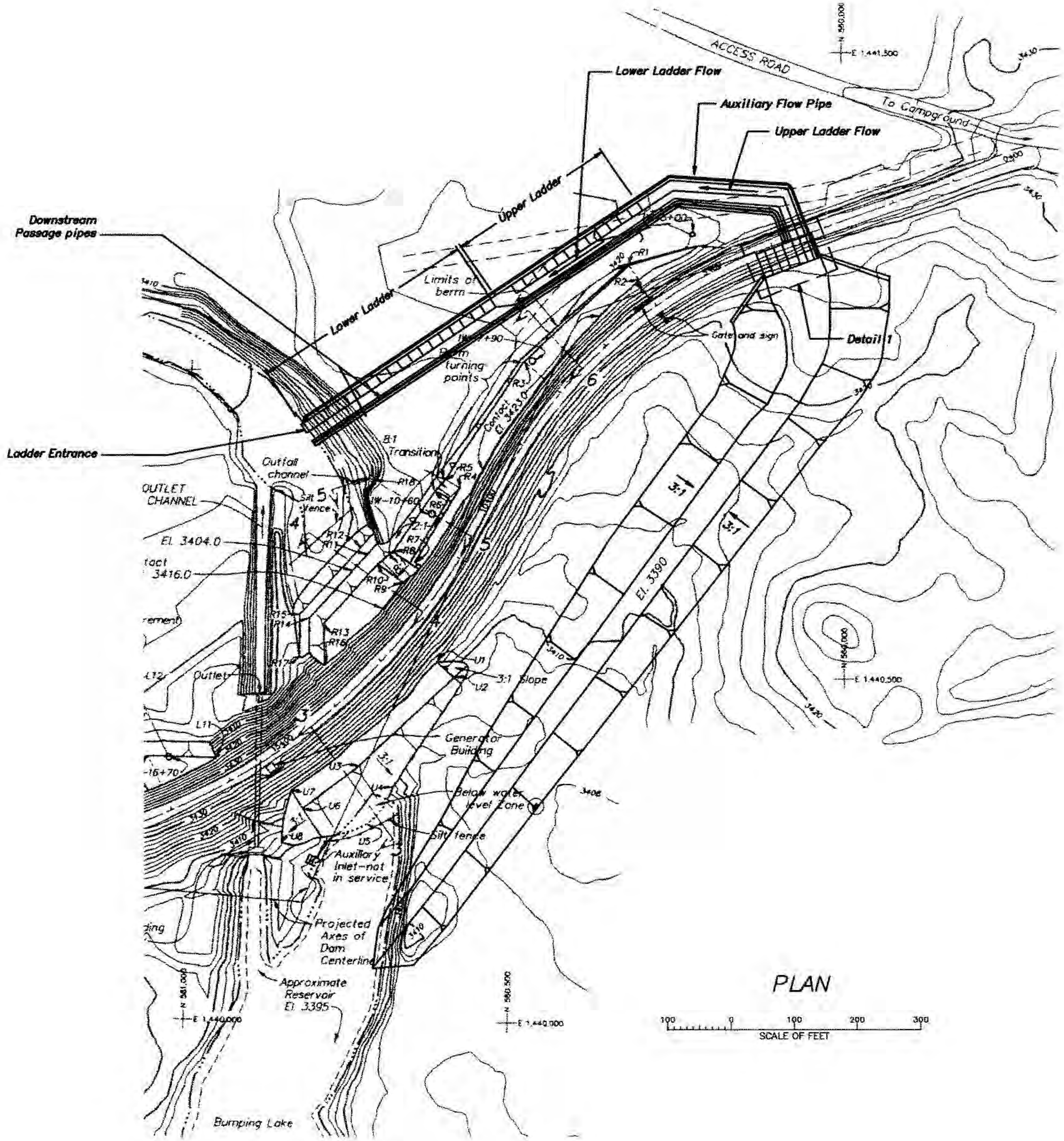
YAKIMA PROJECT – WASHINGTON

CLE ELUM DAM
DOWNSTREAM PASSAGE
NEW SPILLWAY

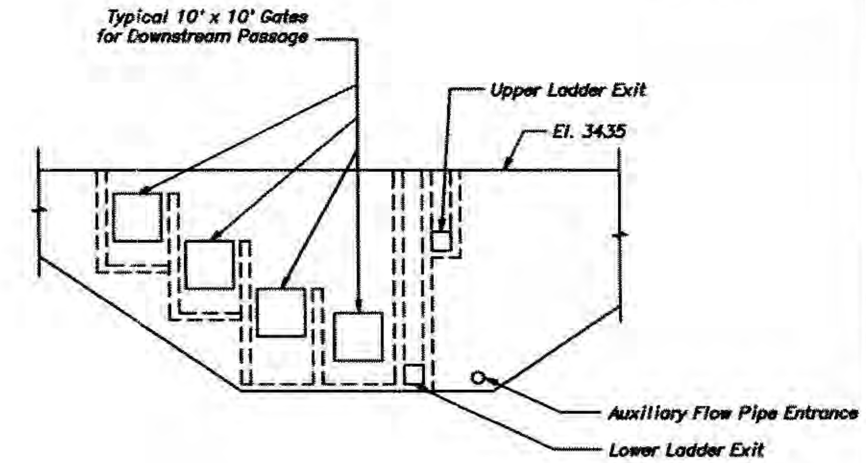
CADD SYSTEM AutoCAD Rel. 15.06 | CADD FILENAME Drawing17.dwg
BOISE, IDAHO | JULY 29, 2002

Specification #

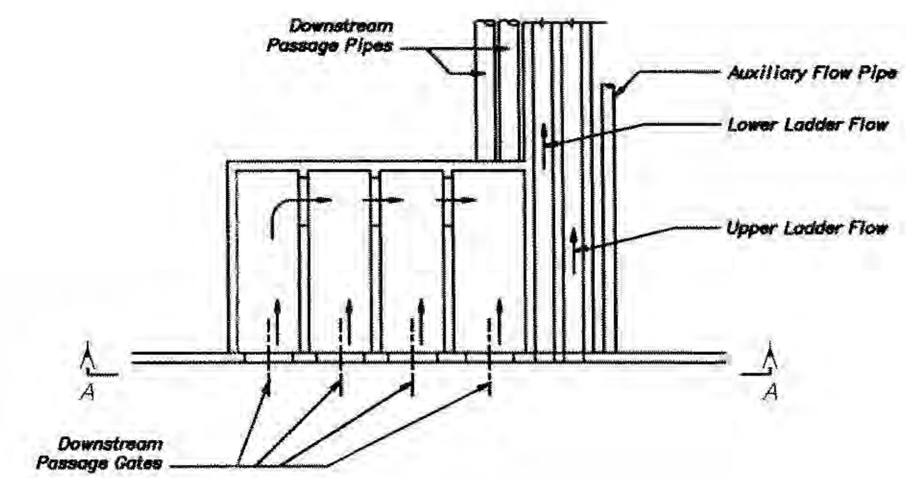
DRAWING 18



PLAN



SECTION A–A



DETAIL 1
PLAN

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BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON

BUMPING LAKE DAM

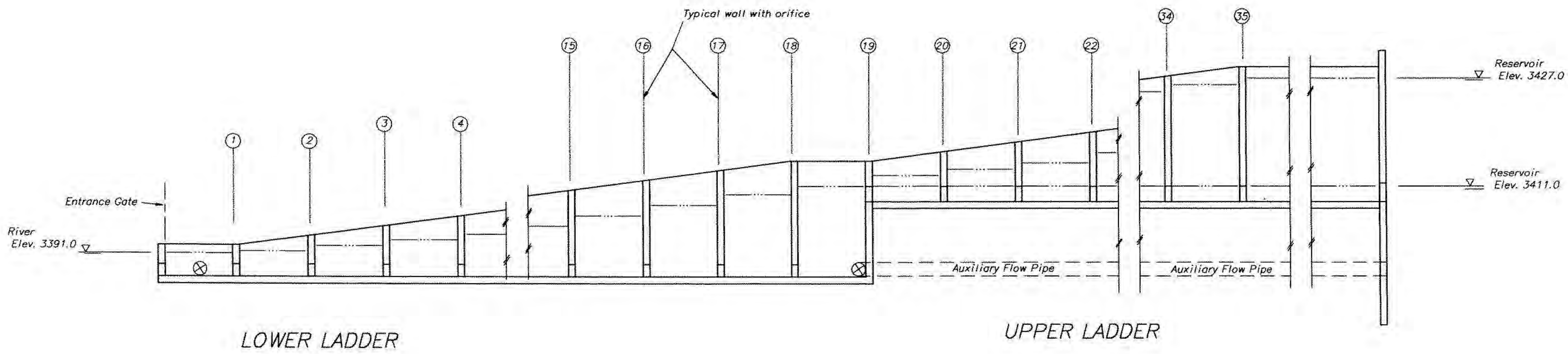
UPSTREAM AND DOWNSTREAM PASSAGE
FISH LADDER AND NEW SPILLWAY

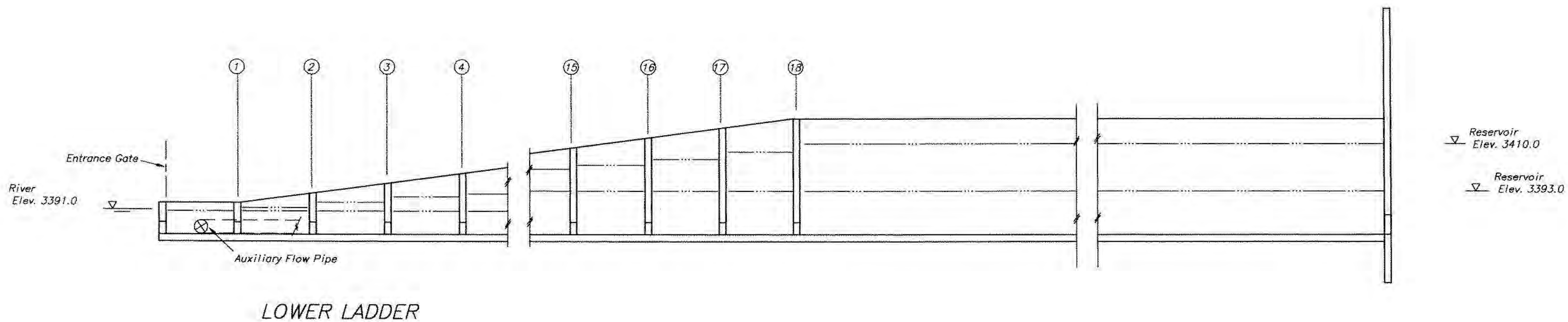
CADD SYSTEM AutoCAD Rel. 15.05 | CADD FILENAME Drawing18.dwg
BOISE, IDAHO | SEPTEMBER 3, 2002

DRAWING 18

Specification #

DRAWING 19





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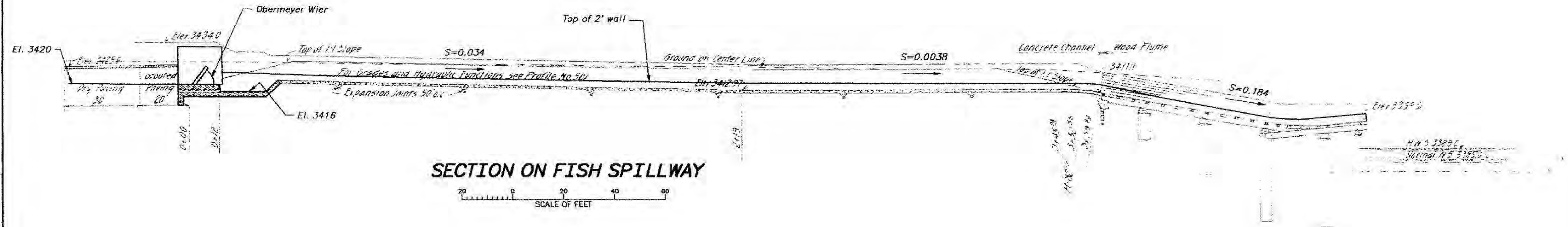
WASHINGTON

BUMPING LAKE DAM
UPSTREAM PASSAGE
FISH LADDER PROFILES

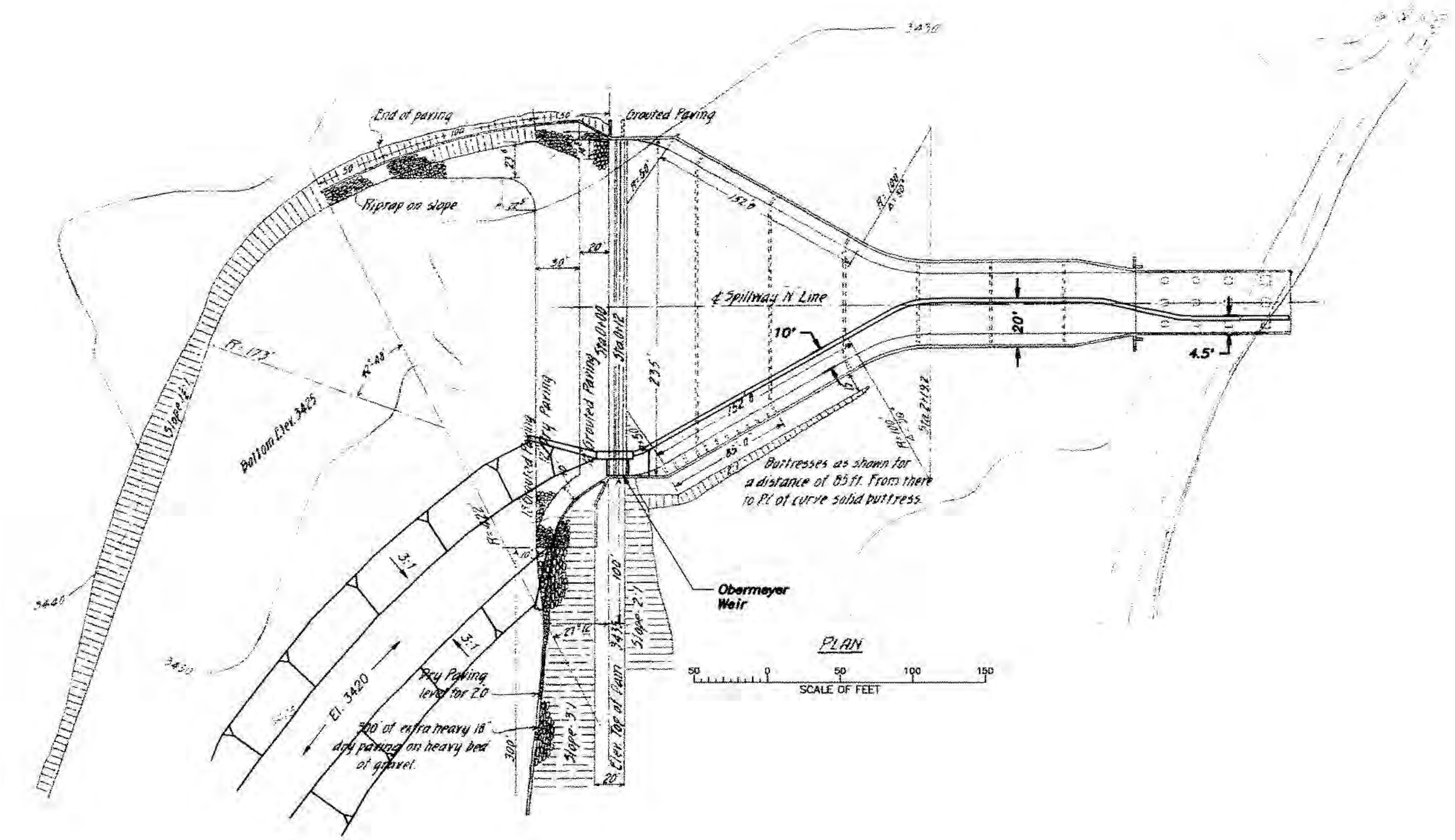
CADD SYSTEM AutoCAD Rel. 15.06
BOISE, IDAHO
CADD FILENAME Drawing17.dwg
NOV. 2002

DRAWING 20



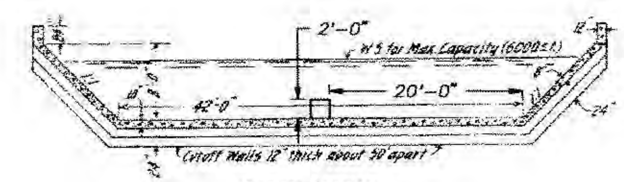
SECTION ON FISH SPILLWAY

SCALE OF FEET



PLAN

SCALE OF FEET



TYPICAL SECTION
Sta. 2+192 to Sta. 3+20

SCALE OF FEET

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BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON

BUMPING LAKE DAM
DOWNSTREAM PASSAGE
NEW GATE ON SPILLWAY
PLAN AND SECTIONS

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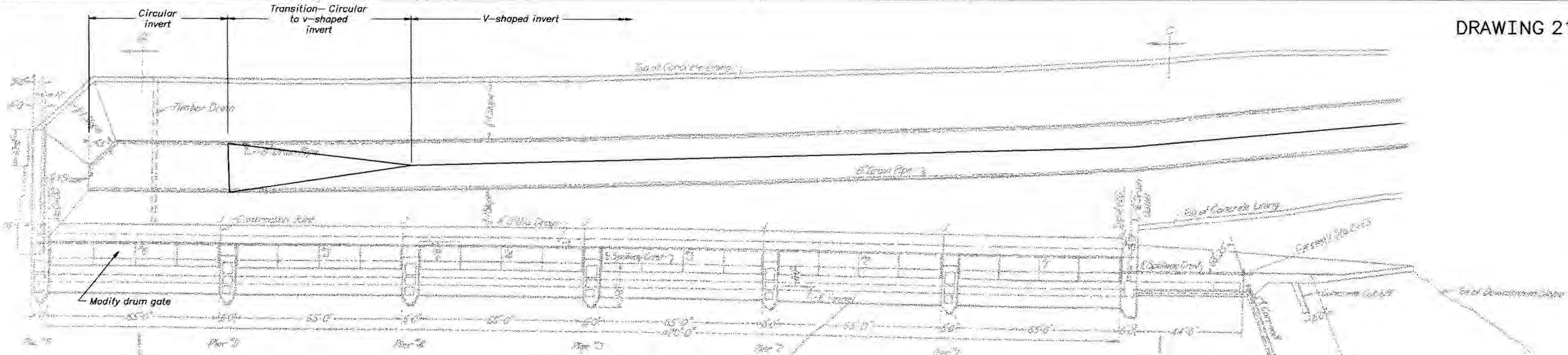
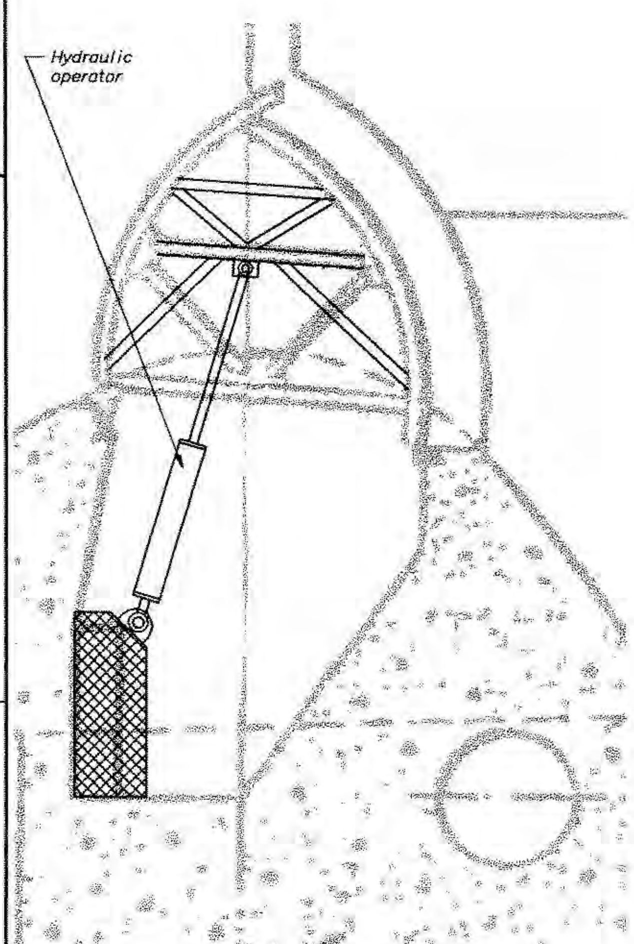
BOISE, IDAHO | NOVEMBER 13, 2002 | DRAWING 20

Specification #

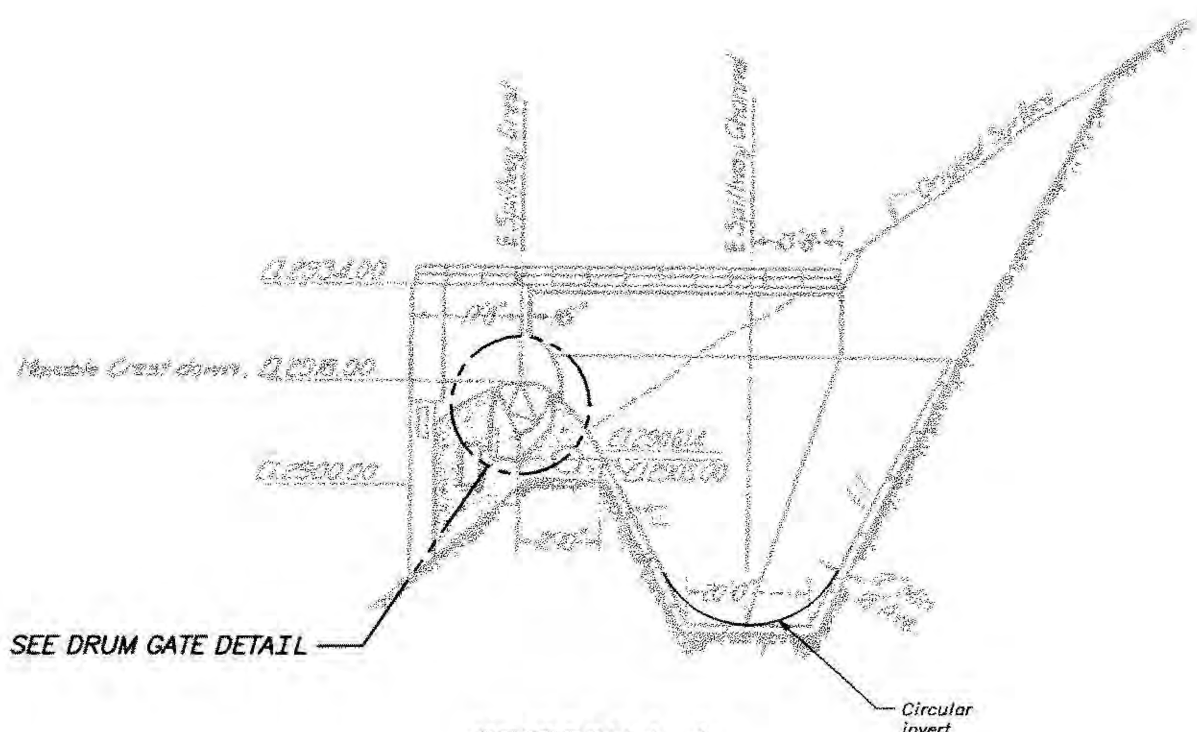
DRAWING 21



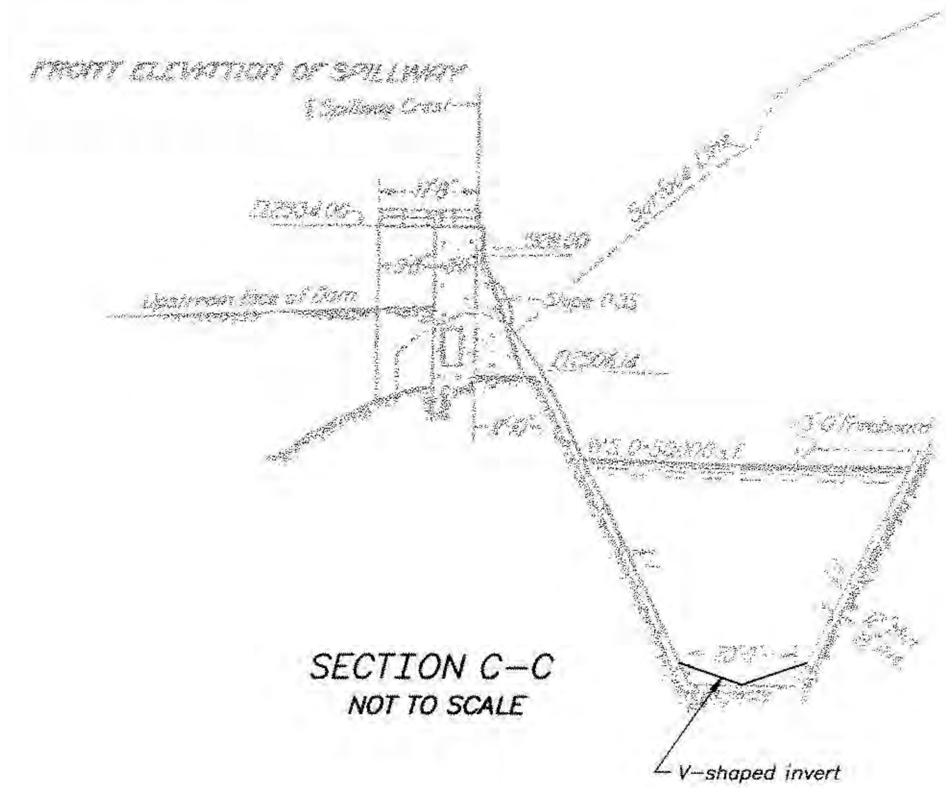
PLAN – SPILLWAY
NOT TO SCALE



DRUM GATE DETAIL
NOT TO SCALE



SECTION A–A
NOT TO SCALE



SECTION C–C
NOT TO SCALE

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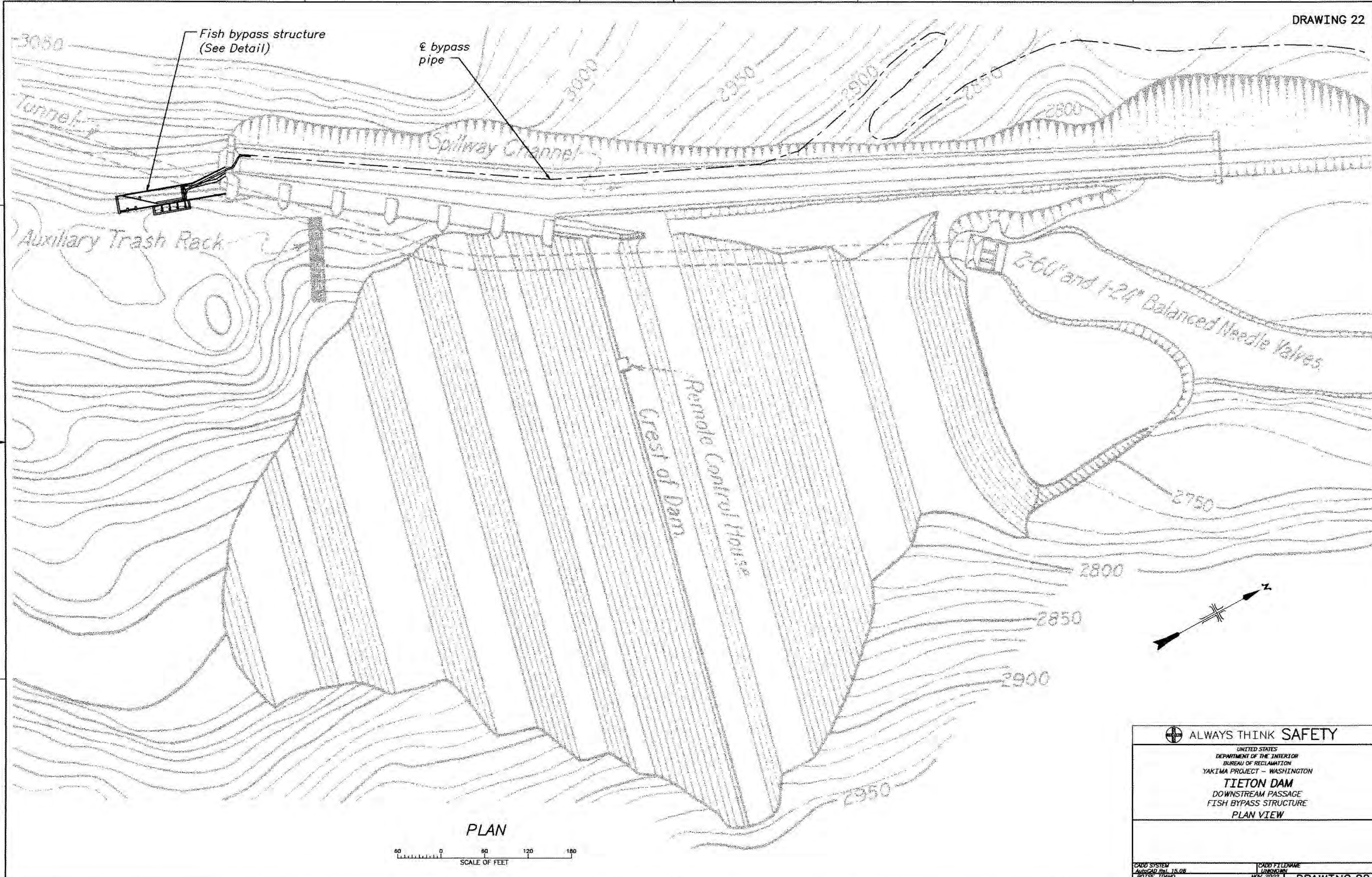
YAKIMA PROJECT – WASHINGTON

TIETON DAM
DOWNSTREAM PASSAGE
MODIFY EXISTING SPILLWAY GATE

CADD SYSTEM AutoCAD Rel. 15.06 BOISE, IDAHO | CADD FILENAME Drawing19.dwg NOV.2002 | DRAWING 21



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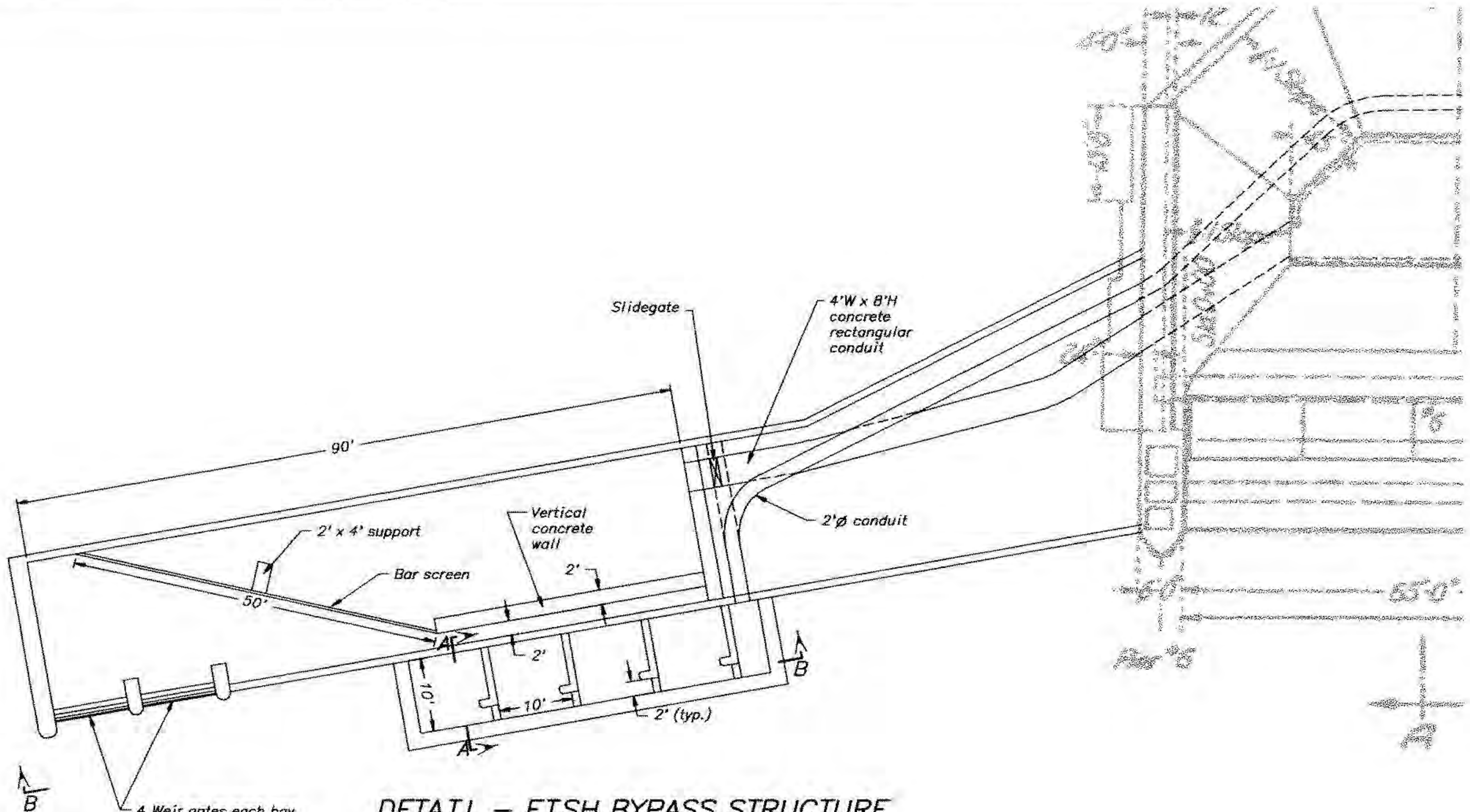
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON

TIETON DAM

DOWNSTREAM PASSAGE
FISH BYPASS STRUCTURE
PLAN VIEW

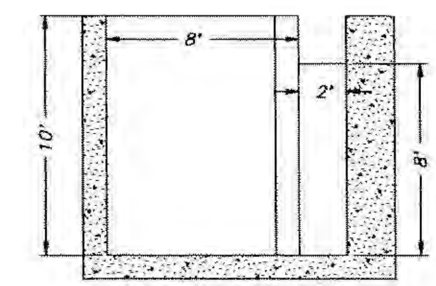
CADD SYSTEM AutoCAD Rel. 15.06
BOISE, IDAHO
CADD FILENAME UNKNOWN
NOV. 2002

DRAWING 23



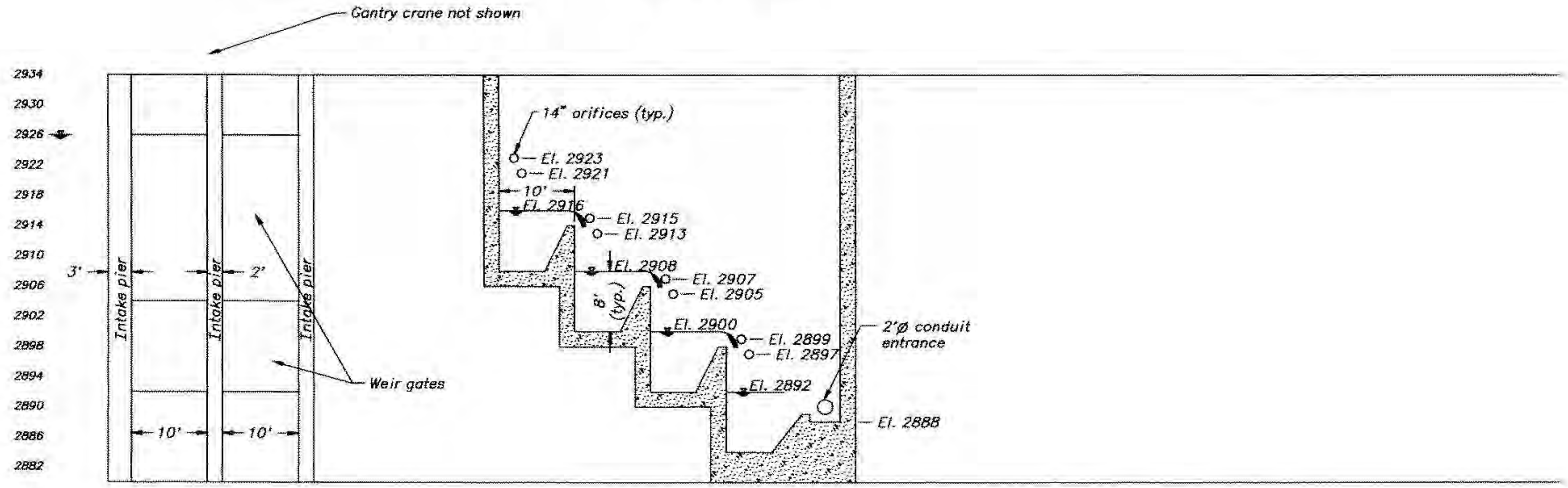
DETAIL – FISH BYPASS STRUCTURE

SCALE OF FEET



SECTION A–A

SCALE OF FEET



SECTION B–B

SCALE OF FEET

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DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON

TIETON DAM
DOWNSTREAM PASSAGE
FISH BYPASS STRUCTURE
DETAIL AND SECTIONS

CADD SYSTEM AutoCAD Rel. 15.06 | CADD FILENAME Drawing21.dwg
BOISE, IDAHO | NOV. 2002

APPENDIX E

(REPRINT OF)

"KEECHELUS DAM FISH PASSAGE AND SAFETY OF DAMS RECONSTRUCTION"

SEPTEMBER 2002

[by R. Dennis Hudson,
Fish Passage Coordinator
Liaison & Coordination Group
Pacific Northwest Regional Office
U.S. Bureau of Reclamation
Boise, Idaho]

TABLE OF CONTENTS

1. PURPOSE

The Bureau of Reclamation (Reclamation) began an assessment of fish passage potential at Yakima Project storage dams in April 2002. Initial efforts were directed towards evaluation of potential fish passage features at Keechelus Dam and the relationship of those features to the on-going Safety of Dams (SOD) reconstruction activities. The studies to-date support Reclamation's earlier decision to move ahead with the SOD reconstruction while continuing the investigation of the feasibility of providing future fish passage features at Keechelus and the other Yakima Project storage dams. The purpose of this paper is to summarize the studies that have been done to-date relating to the Keechelus Dam fish passage and SOD reconstruction issues.

2. BACKGROUND

During review of the Keechelus Safety of Dams Draft Environmental Impact Statement (DEIS), a large number of comments were received that dealt with the issue of fish passage at Keechelus Dam. Many commenters requested Reclamation include alternatives in the EIS that would provide fish passage at Keechelus Dam as part of the SOD project. Other commenters simply requested that Reclamation add fish passage at the dam as part of any alternative that did not otherwise provide for it. Another set of comments dealt with the issue of increased cost for retrofitting the dam with fish passage after any modifications are made as part of the SOD process. Finally, several commenters indicated that there was biological information available that indicated that fish passage would have substantial biological benefits and should be included on those grounds.

All of the fish passage comments were addressed in "Attachment A, Fish Passage Issues" to the Final Environmental Impact Statement (FEIS). Attachment A discussed authority for fish passage, design constraints, cost considerations, and biological information. After carefully considering the comments received and the information developed for Attachment A, Reclamation decided to proceed with the SOD work without providing fish passage features at the same time. The following statement appeared in the *Record of Decision* (ROD) *for Keechelus Dam Modification* that the Regional Director signed on January 18, 2002:

> *The decision is to proceed with the preferred alternative to modify Keechelus Dam along the existing alignment to correct identified safety deficiencies as documented in the FEIS.*
>
> *In addition, Reclamation will seek funding under existing authorities to conduct a feasibility study for fish passage at all of the storage dams which are part of the Yakima Project. The feasibility study was not discussed in the FEIS, but is a result of further discussion with the State of Washington, National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS). As a result of those discussions, Reclamation is now prepared to conduct such a feasibility study, in cooperation with others and subject to appropriation of funds.*

Further discussion and negotiations with the fisheries agencies subsequent to the ROD culminated in two documents that summarize the fish passage issues related to Keechelus SOD reconstruction and impose certain requirements on Reclamation in order to proceed with the SOD work. These are summarized below.

2.1 Hydraulic Project Approval

The first document is the *Hydraulic Project Approval* (HPA) *for Safety of Dams Reconstruction of Keechelus Dam* issued by the Washington Department of Fish and Wildlife (WDFW) on April 17, 2002. The HPA requires Reclamation to conduct a project-wide assessment of fish passage at all Yakima Project reservoirs with Keechelus Dam to be the first facility to be considered (provision #56). Provision #57 of the HPA requires Reclamation to:

1. Determine whether the proposed design and construction of the SOD project will adversely affect the feasibility, cost, or effectiveness of fish passage facilities at the dam.

2. Modify the SOD work if necessary to ensure that SOD reconstruction actions will not cause significant additional costs for retrofitting fish passage facilities nor require future modification of the portions of the dam being reconstructed as part of the SOD work.

2.1 Mitigation Agreement

The second document is the *Mitigation Agreement* (Agreement) *between the USDI Bureau of Reclamation and Washington Department of Fish and Wildlife regarding Keechelus Dam Construction Issues Including Fish Passage* signed on April 8, 2002. The Agreement covers the same issues as the HPA. In Paragraph II-8, Reclamation agrees to ensure that SOD reconstruction-related actions at Keechelus Dam will not result in significant additional costs for retrofitting fish passage facilities at the Dam nor require future significant modification of the portions of the dam being reconstructed as part of the SOD work.

3. JUNE 2001 APPRAISAL DESIGN STUDY

In June 2001, prior to the FEIS, Reclamation's PN Region Design Group prepared an *Appraisal Design Study for Keechelus Dam Fish Passage*. This appraisal design study examined potential methods for upstream and downstream fish passage at Keechelus Dam. The report summarized known information about the existing facilities, operations, and hydrology and described options to be considered to provide fish passage. The information in the report was confined to engineering issues related to habitat accessibility. Other factors that limit productivity and carrying capacity of Keechelus Lake and the headwater tributaries to the lake were not addressed.

3.1 Upstream passage concepts considered:

1. Trap and haul
2. Roughened channel fish ladder to right abutment with pumped ladder flow
3. Fish ladder to left abutment with pumped ladder flow

3.2 Downstream passage concepts considered:

4. Fish collection barge with a fish conveyance pipe
5. Fish collection barge with trap and haul
6. Stationary surface collector with a fish lock
7. Multiple level intake gates with multiple bypass pipes
8. Multiple level intake gates with Eicher screen
9. Multiple level intakes with bottom flow energy dissipation wells
10. Multiple level intakes with top flow energy dissipation wells

Costs for the upstream options ranged from $7.5 million to $13 million. Costs for downstream options ranged from $3.5 million to $30 million.

4. CURRENT STUDIES

4.1 Project-wide assessment

Reclamation has launched a preliminary assessment of fish passage at all of the storage dams of the Yakima Project and is seeking funding for detailed feasibility studies that may lead to implementation of fish passage features at the dams. Reclamation is proceeding with the preliminary assessment in phases as directed by the HPA. The HPA requires completion of Phase I of the assessment by January 2003 and Phase II by January 2004. The HPA also requires that interim passage (in collaboration with WDFW) be provided at selected sites within a year of completing Phase II of the study.

A core team of biologists and engineers from Reclamation, NMFS, USFWS, U.S. Forest Service (USFS), WDFW, irrigation interests, local governments, and others was organized in April 2002. Yakama Nation staff were invited to be part of this team but have not participated up to this point. The core team and sub-groups have met on several occasions to work through biological, engineering, and operational issues associated with fish passage at the storage dams.

4.2 Keechelus Dam

As required by the HPA, initial study efforts have been directed towards Keechelus to determine if the design and construction of the SOD project will adversely affect the feasibility, cost, or efficacy of fish passage facilities at the dam.

The concepts developed for the June 2001 *Appraisal Design Study for Keechelus Dam Fish Passage* mentioned above were thoroughly reviewed and discussed in the core team meeting in May. Several of the concepts were then dropped from further consideration due to technical problems and based on experience at existing similar facilities. These concepts either would not have functioned as intended or would have been detrimental to fish.

Some concepts cannot be built until the SOD work is complete. Other concepts were modified to eliminate conduits through the dam embankment to satisfy dam safety concerns. The concepts were also modified to eliminate conduits through foundation material in the maximum section of the dam.

This ensures that future construction of fish passage facilities will not require alterations to the major portions of the dam being reconstructed as part of the SOD work. The modified options were reviewed in the June core team meeting.

4.2.1 Upstream Passage — Modified versions of Concepts 1 and 3 for upstream passage were retained for future analysis to determine the best method of passing fish upstream into the reservoir. Each option still has unanswered engineering and biological questions that will require more in-depth discussion and analysis. Option 2 involved fish exiting the roughened channel fish ladder into Meadow Creek. Option 2 was dropped due to anticipated confusion to fish. Option 2 could still work if fish were not transferred into Meadow Creek, but it would offer no advantage over Option 3.

4.2.2 Downstream passage — Concepts 4, 7, 9, and 10 were dropped due to technical concerns. Concept 5 was retained for further analysis. A scaled-down version of concept 6 will be studied further and concept 8 will be considered further if bypass issues can be resolved. Two additional concepts for downstream passage were reviewed and discussed in the July core team meeting. Both concepts would include addition of gates to the spillway to permit surface releases of water. The idea would be to allow juvenile fish to pass through the spillway area in the spring when the reservoir pool is at maximum elevation. These concepts, in common with those previously mentioned, require further engineering and biological study.

4.2.3 Biological and habitat conditions — The core team is gathering existing data and evaluating physical and biological components of the Keechelus watershed ecosystem.

Physical components that will be addressed include:

1. Water quality
2. Habitat accessibility
3. Habitat structure
4. Channel condition and dynamics
5. Instream flow/hydrology
6. Watershed condition

Biological components include:

1. Predation
2. Competition
3. Pathogens/parasites
4. Mutualism

This information will help the team to estimate the likelihood of success of fish passage at the dam. The tradeoffs between passage parameters and expected biological gains[1] for different options will help the team formulate plans and establish priorities for continued study. Target species and migration periods have been identified, and other information is being assembled. Analysis of the biological data, formulation of more detailed passage options, and comparison with similar plans for the other project reservoirs will continue in Phase I and Phase II of the study.

1 Estimated biological gains would include increased populations of steelhead, coho, and chinook; potential for reintroduction of sockeye; reconnection of isolated populations of bull trout; restoration of life history and genetic diversity of salmonids; etc.

5. SUMMARY AND STATUS

Providing fish passage at Keechelus Dam and the other storage dams in the Yakima Project will be a complex and challenging undertaking. Some of the challenges at Keechelus that must be addressed by engineers and biologists include:

1. Seasonal reservoir pool fluctuations of 85 feet in elevation
2. Harsh winter conditions that may influence the length of time that passage can be reasonably provided
3. Adult and juvenile migration periods that do not coincide with appropriate pool elevations or reservoir release patterns
4. Uncertainties associated with existing fish presence downstream of the dam and likelihood of fish using the passage facilities and successfully spawning and rearing in the lake and upstream tributaries
5. Potentially high costs with uncertain biological benefits
6. The difficulty of providing opportunities for volitional movement of fish, considering the realities of site limitations and operational parameters
7. Several different target species that require passage at different time periods

These questions, and many others, suggest that a cautious, measured approach be taken before investing millions of taxpayer dollars in facilities that may or may not achieve the intended purposes. The Phase I and Phase II Assessment will compare conditions at the different reservoirs and suggest implementation of interim pilot passage projects at the most promising sites. This will provide opportunities to test passage concepts and evaluate fish movement, spawning, and rearing success. Final fish passage designs will evolve from what is learned in the pilot projects.

The on-going SOD work will not impact the feasibility of building fish passage facilities in the future. As noted above, there are many unanswered questions regarding biological issues, engineering parameters and possible operational changes that must be resolved before proceeding with implementation of permanent fish passage facilities at the site.

Since a workable plan has not yet been identified, installation of any portion of a passage facility during the SOD reconstruction would be premature. The ultimate decision may be to install fish passage facilities; however, it could just as well be to develop an alternative to passage that would provide equivalent salmonid productivity and ecological function. In any event, the final decision does not depend on the SOD work nor would it be influenced in either a positive or negative direction by the SOD work.