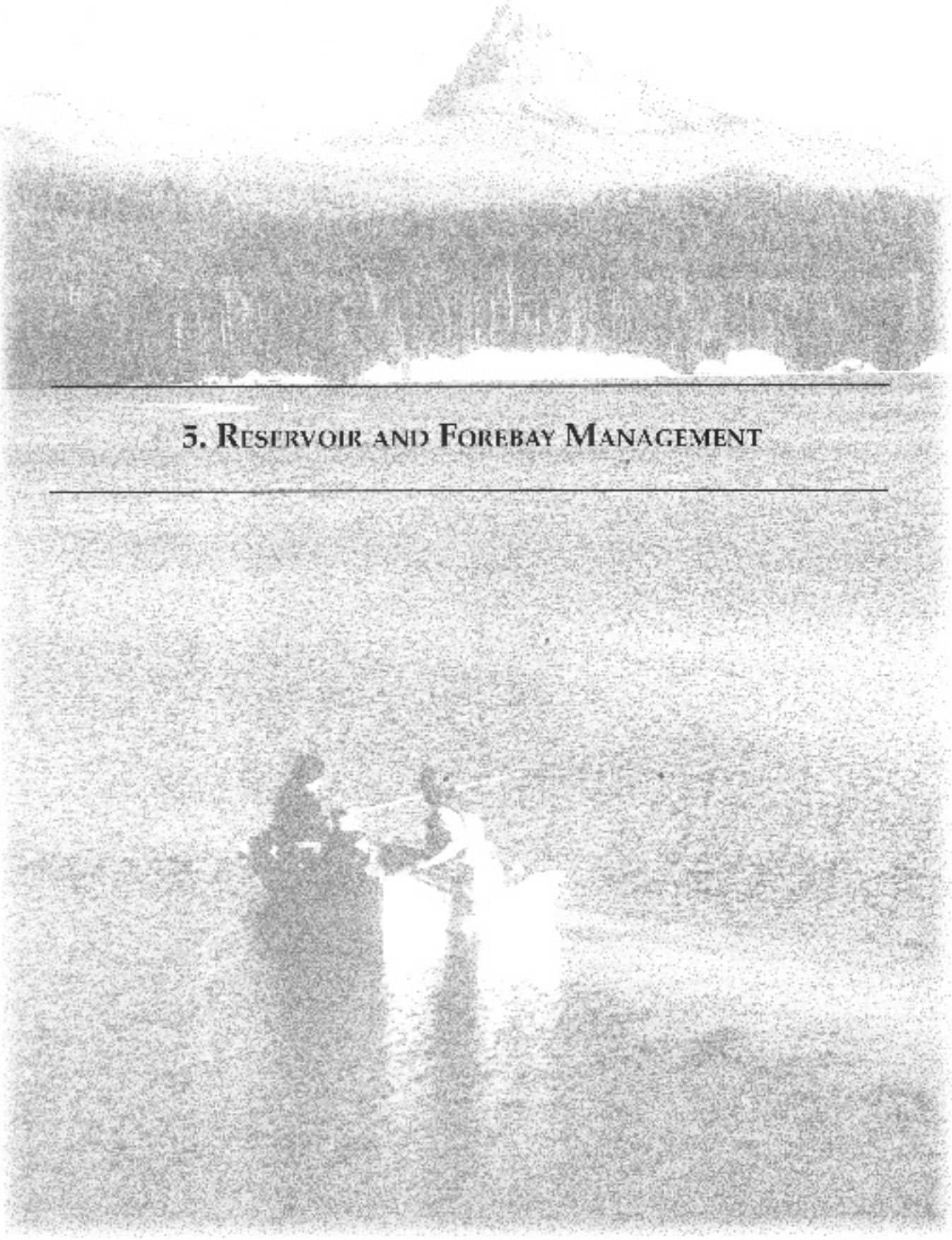

# 5. Reservoir and Forebay Management

# 5. RESERVOIR AND FOREBAY MANAGEMENT

The reservoir and forebay management portion of the watershed analysis deals with two issues. The first relates to the recreational fishery currently provided by project reservoirs and forebays. The analyses conducted for the purposes of evaluating current and potential trout production were limited in geographic scope to the project impoundments. The second issue focuses on stillwater amphibians (those that reproduce in ponds, lakes, stream pools, and wetlands). In addition to project reservoirs and forebays, the geographic scope of this topic also included other stillwater habitats in the hydroelectric project vicinity.

Management goals for these two issues were defined in the early phases of the watershed analysis.[1] For recreational fisheries, the general goal is to maintain and/or restore aquatic habitat in the reservoirs and forebays sufficient to support productive trout fisheries. An additional Oregon Department of Fish and Wildlife (ODFW) goal is to maintain a catch rate of 0.5 trout per angler-hour in Lemolo Lake (ODFW 1980); no catch-rate goals have been defined for the remaining impoundments (D. Loomis, pers. com. 1997). Recently, ODFW has considered modifying reservoir management goals to include production of trophy-sized (>41 cm or 16 inch) trout (D. Loomis, pers. com. 1997).

For stillwater amphibians, the management goal is to create an environment that supports healthy populations of these species. The analysis of current conditions focused on an evaluation of the role of reservoirs and forebays in providing habitat for stillwater amphibians. In order to develop and evaluate management options to achieve the management goal, the scientific team also assessed the availability of other stillwater habitats in the watershed and to evaluate whether creating additional habitat might be important for protection of stillwater amphibian populations at the watershed scale.

## 5.1 OVERVIEW OF RESULTS

### 5.1.1 Fisheries

The hydroelectric project's reservoirs and forebays have created a popular recreational fishery that did not exist prior to project construction. Trout populations in reservoirs have been self-sustaining since the cessation of stocking 20 to 25 years ago and forebay populations, while also not stocked, are likely sustained by recruitment of fish entrained at waterway intakes. To evaluate the potential for project impoundments to continue to provide self-sustaining fisheries that meet

[1] Constructed impoundments such as reservoirs and forebays are one of the five categories of Riparian Reserves addressed in the Northwest Forest Plan's Aquatic Conservation Strategy (USDA Forest Service and USDI Bureau of Land Management 1994, p. C-30). Therefore, management goals for Riparian Reserves apply to project reservoirs and forebays. The evaluation of the function of project impoundments as Riparian Reserves is discussed under the issue of aquatic and riparian habitat connectivity.

ODFW management goals, potential trout harvest and growth were modeled and compared with values observed under current project operations. Models used to predict potential trout harvest and growth were based on the current physical and environmental characteristics of project impoundments, while actual harvest and growth were estimated from creel survey and gillnetting data.

Results from the modeling analysis indicate that trout populations in reservoirs and forebays are healthy. Trout harvests in the larger impoundments meet or exceed model expectations based on harvest from other reservoirs. Trout harvest in the smaller impoundments, while less than predicted by the models, likely reflects the effects of low angling effort and/or loss of fish through entrainment rather than inherently poor production. The evidence further indicates that trout growth in project impoundments is not limited by food availability and that observed growth rates fall within or exceed the range expected under current temperature regimes.

### 5.1.2 Stillwater Amphibians

Although the construction of project reservoirs and forebays has increased the amount of stillwater habitat in the watershed, these habitats were judged to be largely unsuitable for stillwater amphibians. The objectives of the Northwest Forest Plan's Aquatic Conservation Strategy (USDA Forest Service and USDI Bureau of Land Management 1994, p. B-11) are probably not being met for stillwater amphibians in project impoundments. These conclusions were based on available information on current species distribution and habitat conditions in reservoirs and forebays. Six species of native stillwater amphibians are known to occur in the vicinity of the hydroelectric project, but observations of or evidence suggesting that reproduction by stillwater amphibians occurs in project reservoirs and forebays were limited to Stump Lake (for four species) and Clearwater No. 2 forebay (for one species). Moreover, it is not known whether the offspring produced in these areas survive until maturity.

Certain characteristics of the reservoirs and forebays probably reduce or eliminate their potential suitability as amphibian habitat. These characteristics include the presence of predaceous fish, a lack of habitat structural diversity, water level fluctuations, and entrainment into project waterways. In order to meet the management goal for stillwater amphibians in reservoirs and forebays, a different fisheries management approach, structural improvements to habitat (including isolating amphibian habitat from fish habitat), substantial operational changes to reduce or eliminate water level fluctuations, and/or screening to reduce or eliminate entrainment would be needed. Thus, management alternatives developed by the scientific team included creation of new stillwater amphibian habitat adjacent to or independent of the project reservoirs and forebays.

## 5.2 ANALYTICAL METHODS

Reservoir and forebay management issues required expertise from both the Aquatic and Terrestrial subgroups. The Aquatics Subgroup focused on the effects of current reservoir and forebay management on recreational fisheries while the Terrestrial Subgroup focused on how

project operations and habitat conditions affect stillwater amphibian populations. Each group identified and evaluated potential management options for meeting the defined watershed management goals. Specific methods used in these analyses are described below.

### 5.2.1 Fisheries

Resident trout in project reservoirs and forebays support a substantial sport fishery. Analyses were conducted to evaluate the current state of these fisheries and the potential effects of reservoir and forebay management on trout populations. Actual trout harvest and growth rates were compared to model results to determine if harvest and growth rates in North Umpqua River basin impoundments approach their estimated potential, and to identify potential factors limiting trout production. Where actual harvest and growth met or exceeded modeled potential, it was concluded that environmental conditions and project operations were not limiting to trout production. The analyses relied on two trout harvest models and one trout growth model, described below (see Attachment 5-1 for answers to specific questions on the harvest and growth models).

**Trout harvest models**

Predictions of trout harvest are inherently variable, and a wide range of results can be expected from modeling exercises (Downing et al. 1990, Scott 1996). For this reason, two models were used to evaluate trout harvest potential in project reservoirs and forebays. If the two models produced roughly similar results, reasonable confidence in their accuracy could be assumed. Both models are based on correlations between observed fish production and harvest and physical characteristics of water bodies.

The Morphoedaphic Index (MEI) model, first proposed by Ryder (1965) for use in lakes, predicts fish production or harvest (kg/ha/year) using physical variables related to primary productivity (total dissolved solids [TDS] and mean lake depth) as model input. MEI models have been used extensively in the United States and elsewhere; their predictive power has been increased by limiting the data sources used to develop the regression to certain types of water bodies and/or geographic regions. One such modification, used in this analysis, is the "reservoir sport fish harvest" model of Jenkins (1982), which is based on data from 294 reservoirs in the United States. The resulting equation is:

$$\log_{10} H = 0.925 + 0.563 \log_{10} MEI - 0.149 \log_{10} MEI^2$$

*where* H = sport fish harvest in kg/ha/yr
MEI = TDS (mg/L)/mean depth (m)

A potential limitation of the MEI model is that many of the water bodies from which the MEI regression equations are derived are much larger than North Umpqua project reservoirs and forebays. This may, consequently, limit the accuracy of predictions based on this model. While a

minimum size limit for water bodies is not specified in model documentation (Ryder 1974, Jenkins 1982), Ryder (1974) does suggest relaxing the original criteria contained in his (1965) model that the lake must be "large." The reservoir sport fish harvest equation which was used (Jenkins 1982) is based on a sample of reservoirs with a mean area of 48 $km^2$ (19 $mi^2$; range not given), while the mean area of North Umpqua River basin reservoirs and forebays is 0.4 $km^2$ (0.15 $mi^2$; range = 0.03 to 1.68 $km^2$ or 0.01 to 0.65 $mi^2$). The MEI model may underestimate fish harvest potential for small impoundments, because many small water bodies have entirely littoral-based (shallow water) food chains and thus may be more productive for trout than larger limnetic (deep water) systems.

Inputs to the MEI model were derived from data in PacifiCorp (1995). TDS were not measured directly in project reservoirs and forebays, but were calculated from measurements of conductivity using an equation provided in Downing et al. (1990). Conductivity data were taken from PacifiCorp (1995, Volume 22, Appendix 2.2-3). Seasonal variation in conductivity was limited; in Lemolo Lake, measurements of average summer-only conductivity showed a less than one percent increase over average annual conductivity. Input to the model was based on conductivity measured at the water surface, averaged over all sampling periods from 1992 to 1994. Volumes and surface areas of reservoirs and forebays were obtained from PacifiCorp (1995, Volume 2, Exhibit A). Mean depth was calculated by dividing total storage volume by area.

The second model used to predict harvest potential in project impoundments is the total phosphorus (TP) model of Plante and Downing (1993). Like the MEI models, it assumes that fish production is linked to primary productivity; however, instead of TDS and depth, phosphorus concentrations are the model input. The model is based on data from 10 lakes in various regions of the world, with a mean lake surface area of 10.7 $km^2$ (4.1 $mi^2$; range = 0.13–87.5 $km^2$ or 0.05–33.8 $mi^2$).

The equation is:

$$\log_{10} P = -0.47 + 0.95 \log_{10} TP$$

*where* P = salmonid production in kg/ha/yr
TP = total phosphorus concentration (micrograms/L)

One limitation in applying the TP model to North Umpqua River basin reservoirs and forebays is that it predicts production (not harvest), for which exactly comparable data are unavailable. We used the TP model predictions to estimate the maximum sustainable harvest that could be expected from project impoundments (see Attachment 5-1 for a discussion of the relationship between harvest and production). That the North Umpqua River system appears to be nitrogen-limited rather than phosphorus-limited (see Section 6, Water Quality) does not invalidate the model's applicability, since phosphorus-limitation is not a model requirement (Plante and Downing 1993).

Inputs to the TP model were derived from data in PacifiCorp (1995). While phosphorus concentrations were not measured in the water columns of project reservoirs and forebays during the relicensing studies, they were measured in bypass reaches below the dams and in project tailraces (PacifiCorp 1995, Volume 22, Appendix 2.2-1), where they are expected to be similar to concentrations in upstream storage locations. Input to the model was based on phosphorus concentrations at these surrogate sites averaged over all sampling periods from 1992 to 1994.

**Trout growth model**

Trout growth in project impoundments was modeled using a bioenergetics approach (J. W. Hayes 1996). While the model was developed for riverine brown trout, it is also useful as a general index of salmonid growth potential. In its most explicit form, the model takes as input four types of data: invertebrate drift densities and energy values, water temperature data, daily foraging period data, and an estimate of the weight at which fish become reproductively mature. Reproductive costs, amounting to a fraction of the fish's available energy, are accounted for each year that the fish is heavier than the maturity weight. Model output consists of annual estimates of the weight of an average trout for a period of 12 years (note that this period may exceed the actual longevity of trout in some systems). To evaluate whether food supply limits trout growth in North Umpqua River basin impoundments, the model was programmed to provide maximum rations for trout swimming at optimal swimming speeds. When programmed in this manner, the model does not require invertebrate drift densities as input, and can be applied to lakes as well as rivers. If actual growth equals or exceeds modeled growth under the maximum rations assumption, it can be inferred that food is not limiting to trout growth.

Water temperatures were periodically monitored in project reservoirs and forebays (PacifiCorp 1995, Vol. 22, Appendix 2.2-3) and, thus, temperature data were available for two sites per impoundment, allowing for two independent estimates of trout growth for all impoundments except Lemolo Lake (one site) and Stump Lake (no sites). A set of 12 monthly mean temperatures for each site was constructed by using mean water column temperatures and interpolation. For shallow impoundments, temperatures were similar throughout the water column; therefore all temperature measurements for a particular sampling date were averaged. For deep, stratified reservoirs (Lemolo Lake, Toketee Lake), three scenarios reflecting different assumptions about how trout choose temperatures within the water column were modeled. The "optimum" scenario assumes that trout select positions in the water column that are as close as possible to 13°C (55°F), the optimal temperature for growth of brown trout (Elliot 1994) and brook trout (Donald et al. 1980). The "0 to 10 m" scenario assumes that trout experience temperatures that are a mean of those existing between 0 and 10 m (0 to 33 ft) depth, while the "0–20 m" scenario assumes that trout experience temperatures that are a mean of those existing between 0 and 20 m (0 to 66 ft) depth.

Foraging period is usually assumed to be roughly equal to the number of daylight hours. To allow for the possibility of night-feeding behavior, preliminary modeling tested both daylight and 24-hour foraging periods. Results showed no difference in growth for daylight and 24-hour foraging

periods; this can be explained by the cold water temperatures currently existing in the system. Temperatures of 19°C (66°F) or below limit trout digestion rates to one or two meals within a 24-hour period. Temperatures in project impoundments rarely reach 19°C (this temperature was reached on only a few occasions during 1992 to 1994, only in Lemolo Lake and the Fish Creek forebay, and only in the uppermost part of the water column); thus, for the vast majority of the time trout are physiologically limited to one or two meals per day and the addition of extra foraging time would not improve growth. Therefore, although the modeling results presented here are based on daylight foraging periods, they apply to fish that are night-feeding as well.

Size at maturity was determined from observations during relicensing studies (PacifiCorp 1995, Vol. 25, p. 3-68). Most brown trout observed during spawning surveys were 20 to 41 cm (8 to 16 inches) in length. For a 20-cm (8-inch) trout with a condition factor (ratio of length to weight) of 1.1 (which is representative of sampled fish in this size range), weight is 88 g (3.1 oz). Thus, 88 g was used as the weight at maturity for salmonids in the model runs.

The predictive results from the models were compared against actual field data. The type and source of this data are described below.

**Actual harvest**

Sport harvests (in kilograms per year) were estimated using a variety of data from 1992 creel surveys (PacifiCorp 1995, Vols. 25 and 26). Summer harvests (April 25 to October 31, 1992) were estimated by converting the numbers of fish harvested from each impoundment to biomass using the relative species composition of harvests, species-specific condition factors, and size-class structures. This constituted total harvest for Lemolo Lake, but other project reservoirs and forebays are open to year-round angling. Harvest during non-summer-periods was roughly estimated as a percentage of summer harvest based on qualitative observations of seasonal fishing pressure (R. Grost, pers. com. 1997). This assessment resulted in the following estimates of non-summer harvest percentages: Stump Lake = 0 percent; Fish Creek forebay = 0 percent; Clearwater Nos. 1 and 2 forebays = 20 percent; Soda Springs reservoir = 20 percent; Toketee Lake = 80 percent; Lemolo No. 2 forebay = 80 percent. Total annual harvest was then calculated as the sum of summer and non-summer harvests.

**Actual growth**

Age, length, and weight data were collected in the field by PacifiCorp (1995, Vol. 25, Section 5) using gillnetting and creel surveys, and were aged using scale analysis. Weight at maturity was estimated from field observations of length and condition factor.

**Entrainment**

Entrainment of >6 inch trout from project impoundments was characterized using data collected between 1991 and 1995 (PacifiCorp 1995, Volume 26; PacifiCorp 1996). The estimated number

of fish entrained annually from each impoundment into downstream waterways or penstocks was converted to biomass using condition factors and size-class structures. Because weights of entrained fish were not measured in the field, average condition factors of brown, brook, and rainbow trout sampled during reservoir creel surveys and gillnetting were used to estimate weights.

### 5.2.2 Stillwater Amphibians

The analysis of the effects of hydroelectric project facilities on stillwater amphibian populations integrated three approaches:

- application of professional judgement;
- review of relevant literature and relicensing study results; and
- engineering analysis of certain management options.

**Application of professional judgement**

The amphibian analysis relied heavily on the professional judgement of the members of the Terrestrial Subgroup because very little information was available regarding the status of stillwater amphibian populations in the North Umpqua River watershed and the population dynamics of stillwater amphibians in general. Amphibian species experts were brought into the watershed analysis to assist the Terrestrial Subgroup with defining the issue, identifying relevant analysis species, assessing project effects, and formulating potential management options. Species experts included the following individuals:

- Dr. Bruce Bury, National Biological Survey, Corvallis, Oregon
- Dr. Marc Hayes, Portland State University, Portland, Oregon
- Mr. Larry Jones, USFS, Pacific Northwest Research Station, Olympia, Washington.

**Review of literature and relicensing study results**

Scientific literature on the habitat requirements and life histories of stillwater amphibians was reviewed. Data gathered during PacifiCorp's relicensing studies (PacifiCorp 1995, Volumes 5, 33, and 34; summarized in M. P. Hayes 1996) provided the primary source of information regarding current conditions of stillwater amphibians in project impoundments and in the ponds and streams in the vicinity of the hydroelectric project. However, these relicensing studies focused primarily on establishing the presence of species at sites in the vicinity of the hydroelectric project; complete site-specific information regarding reproductive success, presence and abundance of each life stage (egg, tadpole, post-metamorph) for each species at each potential breeding site was not available. M. P. Hayes (1997) provided additional information on the presence of amphibians in the Diamond Lake area under historical and current conditions.

**Engineering analysis**

Potential management options for meeting the goal of creating an environment that supports healthy populations of stillwater amphibians were developed by the Terrestrial Subgroup. Structural engineers at Raytheon Corporation prepared schematic drawings and cost estimates for potential habitat enhancement design alternatives (see PacifiCorp 1997).

## 5.3 REFERENCE CONDITIONS

There were fewer lakes and ponds in the North Umpqua River watershed prior to the construction of hydroelectric project impoundments and the creation of smaller impoundments such as ponds developed for fire suppression purposes. Reservoirs and forebays, of course, did not exist under reference conditions. Diamond Lake was the largest water body in the watershed under historical conditions; several small lakes, ponds, wetlands, wet meadows, and pools and slow-moving side channels in streams were also present. These habitats, although not abundant in drainages with relatively steep topography such as the North Umpqua River basin, did occur in the watershed to some extent under reference conditions.

The character of many stillwater habitats in the watershed has been altered by human disturbances. Under reference conditions, most wetlands were likely associated with springs or streams, whereas currently, they are commonly associated with impoundments. Prior to the construction of Lemolo Lake, the inundated reach of the North Umpqua River was a low-gradient meandering stream, which probably provided a complex of stillwater habitats. The area where Toketee Lake and the Stinkhole currently occur was a relatively wide floodplain that probably supported a diversity of stillwater habitats. Stump Lake was a shallow wetland before it was developed into a project impoundment. In addition, many formerly shallow small wetland sites were developed in the 1950s and 1960s into ponds to be used as “pump chances” for fire suppression.

### 5.3.1 Fisheries

The distribution and abundance of native fish in the upper portion of the watershed prior to anthropogenic disturbance is not well known. Three species of salmonids may have been present in the upper watershed prior to human influence; rainbow and cutthroat trout probably occurred and it is possible that bull trout occurred as well. Of these, only rainbow trout currently exist in project reservoirs and forebays, although an observation from an experienced angler suggests that cutthroat trout may exist in Fish Creek and, thus, potentially in Fish Creek forebay (C. Burns, pers. com. 1997).

The eruption of Mt. Mazama approximately 7,500 years ago probably at least temporarily extirpated all fish in the upper basin; if so, barriers such as Toketee Falls (26 m [85 ft] in height) would have restricted recolonization from downstream areas. This suggests that native trout may have been restricted in distribution to downstream of Toketee Falls under reference conditions

and that resident trout currently existing upstream of Soda Springs dam may be descendants of hatchery fish stocked in the basin or remnants of formerly anadromous populations of steelhead and cutthroat trout.

### 5.3.2 Stillwater Amphibians

The distribution and abundance of stillwater amphibians in the watershed under reference conditions is largely unknown. Historical data on amphibians in the vicinity of Diamond Lake, summarized by M. Hayes (1997) indicates the presence in that area of northwestern salamander (1955), long-toed salamander (1932, 1949), western toad (1932, 1949), Pacific chorus (tree) frog (1932, 1949), and Cascades frog (various years between 1938 and 1953, and in 1982). Based on the habitat preferences of the stillwater amphibians that occur in the watershed, suitable habitat would have been provided by ponds, wetlands, wet meadows, and large streams with side channels and pools.

No native stillwater amphibian species are known to have been extirpated from the watershed, but M. Hayes (1997) provides anecdotal evidence that the abundance of these species in the vicinity of Diamond Lake has declined, possibly beginning in the late 1970s. Prior to the introduction of non-native fish and frog species to the watershed, native species of amphibians were free from predation by and competition with these species, particularly introduced sport fish. However, the introduction of predatory fish and the 1950s application of rotenone, a respiratory poison used to eradicate unwanted fish species, cannot be implicated as the sole or even primary causes of declines in the late 1970s, as the non-native fishes and the rotenone were introduced into the system long before the possible decline (M. Hayes 1995). Potential causes of decline suggested by M. Hayes (1997) include the effects of high lakewater pH caused by phytoplankton blooms, ultraviolet radiation (Blaustein et al. 1994), the synergistic effect of ultraviolet radiation and high pH (Long et al. 1995), and increased predation by fish as a result of a decline in invertebrate abundance.

As discussed above for fish, the eruption of Mt. Mazama approximately 7,500 years ago probably at least temporarily extirpated all amphibians in the upper basin. The long-term effects of this eruption on amphibian diversity, abundance, and distribution are unknown.

## 5.4 CURRENT CONDITIONS

### 5.4.1 Fisheries

The construction and subsequent management of project reservoirs and forebays have created lentic (stillwater) habitats that support a popular and productive trout fishery. Table 5-1 presents

Table 5-1. Fishery characteristics of project impoundments.

| Location | Species Composition[1] | | Maximum Fish Size[2] (g) | Angler Use[3] (hrs/ha/yr) | Catch Rate[3] (# fish > 6"/hr) | 1992 Angler Harvest[3] (kg) | Entrainment[4] (kg/yr) |
|---|---|---|---|---|---|---|---|
| Lemolo Lake[5] | brown trout | 78% | 860 | 158.5 | 0.47 | 2489.6 | 36.7 |
| | tui chub | 20% | | | | | |
| | rainbow trout | <1% | 720 | | | 4.1 | 0.1 |
| | kokanee | <1% | | | | | |
| | | | | | | *2493.7* | *36.8* |
| Toketee Lake | brown trout | 90% | 1250 | 268.9 | 0.52 | 1870.3 | 25.8 |
| | rainbow trout | 5% | 335 | | | 47.4 | 0.2 |
| | tui chub | 5% | | | | | |
| | | | | | | *1917.7* | *26.0* |
| Soda Springs reservoir | rainbow trout | 60% | 400 | 130.7 | 0.64 | 60.6 | 4.7 |
| | brown trout | 40% | 810 | | | 65.8 | 37.2 |
| | | | | | | *126.4* | *42.0* |
| Stump Lake | brook trout | 78% | 100 | 80.1 | 0.91 | 9.5 | 129.7 |
| | rainbow trout | 22% | 150 | | | 4.3 | 0.7 |
| | | | | | | *13.8* | *130.4* |
| Lemolo No. 2 forebay | brown trout | 87% | 2000 | 145.1 | 0.47 | 248.1 | n/a |
| | rainbow trout | 13% | 400 | | | 10.2 | |
| | | | | | | *258.3* | |
| Clearwater No. 1 forebay | brook trout | 98% | 300 | 99.4 | 0.89 | 67.4 | n/a |
| | rainbow trout | 2% | 193 | | | 2.3 | |
| | | | | | | *69.7* | |
| Clearwater No. 2 forebay | brook trout | 97% | 580 | 43.6 | 0.40 | 19.3 | n/a |
| | rainbow trout | 3% | 172 | | | 0.2 | |
| | | | | | | *19.5* | |
| Fish Creek forebay | rainbow trout | 100% | 260 | 8.1 | 0.27 | *1.4*[6] | n/a |

1 Species composition was obtained from the following sources:
Lemolo Lake: ODFW data 1975–1991 (PacifiCorp 1995)
Toketee Lake and Soda Springs reservoir: PacifiCorp (1995) gillnetting data
All others: PacifiCorp (1995) creel survey data

2 Maximum weights recorded in 1992 creel survey and gillnet studies (PacifiCorp, unpublished data). For rainbow trout in Clearwater Nos. 1 and 2 forebays, weight was estimated from length of the longest fish using a condition factor of 1.1.

3 Based on 1992 creel survey data (PacifiCorp 1995), see Section 5.2.1 for derivation.

4 Entrainment of > 6 inch trout based on 1991–1995 data (PacifiCorp 1995, 1996) (see Section 5.2.1 for derivation).

5 Recent information indicates that the actual species composition in Lemolo Lake is approximately 80 percent tui chub and 20 percent brown trout (D. Loomis, pers. com.)

6 Although the number of trout harvested in 1992 (8) from Fish Creek forebay was reported (PacifiCorp 1995), size class structures were not; therefore, biomass calculations could not be made in the same manner as for other project forebays. This estimate is based on the size class structures of rainbow trout harvested in other project forebays.

n/a = data not available

characteristics of the fisheries currently existing in reservoirs and forebays. Three species of trout (brown, rainbow, and brook) reside in various combinations in project reservoirs and forebays, and there is a relatively small population of kokanee salmon in Lemolo Lake. Tui chub are found in large numbers in Toketee and Lemolo Lake and in smaller numbers in Toketee Lake.

Of the trout species currently present in project impoundments, only rainbow and cutthroat are potentially native. If so, their genetic integrity is likely to have been compromised by the formerly widespread and frequent introductions of hatchery rainbow and cutthroat trout and other potentially hybridizing trout species that occurred for many years in the basin. Documented rainbow trout introductions to the North Umpqua River system occurred as early as 1910; these consisted of stocks of Klamath Basin origin that were raised in the Diamond Creek Hatchery (D. Loomis, pers. com. 1997). Stocking of hatchery rainbow trout (using out-of-basin stocks) occurred in Toketee Lake from 1958 through 1976 (ODFW 1984) and in Lemolo Lake from 1955 through 1972 (ODFW 1980). The impact of hatchery rainbow trout introductions on native cutthroat trout in the basin is also of concern, as fish exhibiting characteristics consistent with hybridization between the two species have been reported in both the Clearwater and Fish Creek drainages (C. Burns, pers. com. 1997).

Angling use, or angling pressure (expressed as angler hours per hectare per year), varies among project impoundments (see Table 5-1). Rankings from highest to lowest angling use are: Toketee Lake, Lemolo Lake, Lemolo No. 2 forebay, Soda Springs reservoir, Clearwater No. 1 forebay, Stump Lake, Clearwater No. 2 forebay, and Fish Creek forebay. In the Clearwater River system (including Stump Lake and the Clearwater Nos. 1 and 2 forebays), brook trout are the most frequently caught fish, and in Soda Springs reservoir the catch is made up of equal parts rainbow and brown trout. Catch from Fish Creek forebay consists of rainbow trout only. Fish from these impoundments constitute only a small portion of the total catch from all project reservoirs and forebays. Brown trout are by far the most frequently caught fish in Toketee Lake, Lemolo Lake, and the Lemolo No. 2 forebay. Catch rates in Lemolo Lake (Table 5-1) meet the ODFW goal of 0.5 trout per angler-hour (ODFW 1980).

The configuration of the hydroelectric project facilities results in the entrainment of fish at waterway intakes in all reservoirs and forebays. The effects of entrainment vary among impoundments. In Lemolo Lake, Toketee Lake, Soda Springs reservoir, and Stump Lake, fish populations are depleted by entrainment. In project forebays, fish populations are increased by entrainment from upstream sources (reservoirs and stream diversions), but at the same time are depleted by entrainment at the downstream end of the forebay (into penstocks which lead to powerhouses).

Reservoir fish populations are sustained by both natural reproduction and by immigration of fish from upstream areas. Although stocking took place in Lemolo Lake through 1972 and in Toketee Lake through 1976, the fish populations in these impoundments are now self-sustaining. Spawning surveys in 1992 and 1993 in reaches of the mainstem North Umpqua River upstream of Soda Springs reservoir and Toketee Lake, and in the mainstem and other streams draining into

Lemolo Lake, found numerous redds constructed by brown trout that presumably migrate upstream from the reservoirs to spawn (PacifiCorp 1995, Vol 25, Section 5). In addition, the 1993 survey observed kokanee redds in the Spring River upstream of Lemolo Lake, confirming that these fish also reproduce naturally. Brook trout have been observed spawning upstream of Stump Lake, and rainbow trout have been observed spawning upstream of Soda Springs reservoir (R. Grost, pers. com. 1997). The continued presence of these species in the absence of stocking indicates they are reproducing naturally.

Since the cessation of stocking in the 1970s, forebay fish populations have for the most part been sustained by fish that enter the forebays after becoming entrained at waterway intakes. Evidence suggests there is only limited spawning occurring in canals upstream of forebays (R. Grost, pers. com. 1997) or in creeks that empty into the forebays. For example, most fish in the Lemolo No. 2 forebay likely originate in the North Umpqua River, recruited via entrainment at the Lemolo No. 2 diversion near the tailrace of the Lemolo No. 1 powerhouse. Some possibility exists that natural reproduction occurs in Fallen Mountain Creek, which would contribute to the Lemolo No. 2 forebay population (C. Burns, pers. com.).

### 5.4.2 Stillwater Amphibians

Native stillwater amphibians known to occur in the vicinity of the hydroelectric project include northwestern salamander, rough-skinned newt, western toad, Cascades frog, red-legged frog, and Pacific chorus frog (PacifiCorp 1995). See PacifiCorp (1995, Volume 5) and M. Hayes (1996) for a summary of distribution information in the hydroelectric project vicinity and PacifiCorp (1995, Volumes 33 and 34) for more detailed information. Long-toed salamanders have been observed in Horse and Teal lakes, located near Diamond Lake (M. Hayes 1997), but this species has not been documented at sites affected by or in close proximity to the hydroelectric project.

Although six species of stillwater amphibians are known to occur in the vicinity of the hydroelectric project, observations of these species in project reservoirs and forebays during relicensing studies were very limited. Eggs of the northwestern salamander were found in a pond next to Toketee Lake; larval or post-metamorphic stages were observed in the Clearwater Nos. 1 and 2 waterways, suggesting that Stump Lake may be a reproductive site (M. Hayes 1996). Rough-skinned newts were not observed in any project impoundments. Western toad eggs and tadpoles were observed at Stump Lake and although one post-metamorphic individual was observed at Toketee Lake, no eggs or tadpoles were observed at this location. Pacific chorus frog eggs and post-metamorphs were observed at Stump Lake and the Clearwater No. 2 forebay; only post-metamorphs were observed at Toketee Lake and the adjacent Stinkhole. Red-legged frogs may have been captured from project impoundments during fish entrainment studies (see M. Hayes 1996), but identification of captured species was not verified. Only three post-metamorphic red-legged frogs were positively identified during relicensing studies (M. Garrett, pers. com. 1997). Cascades frogs were common throughout the project vicinity, but reproduction was confirmed only at Stump Lake, where eggs, tadpoles, and post-metamorphs were observed. In summary, observations demonstrating or suggesting reproduction by stillwater amphibians in

project reservoirs and forebays were limited to Stump Lake (for northwestern salamander, western toad, Pacific chorus frog, and Cascades frog) and Clearwater No. 2 forebay (for Pacific chorus frog only). However, it is not known whether the offspring produced in these areas survive until maturity.

## 5.5 ECOLOGICAL IMPACTS

### 5.5.1 Fisheries

Results of analyses of trout harvest and growth indicate that reservoir and forebay populations are healthy. Trout harvests in the larger impoundments meet or exceed model expectations based on harvest from other reservoirs. Trout harvest in the smaller impoundments, while less than predicted by the models, likely reflects the effects of low angling use and entrainment rather than inherently poor production. Modeling indicates that trout growth is not limited by food supply, at least for the age range of fish caught by anglers and taken in the gill net surveys. Water temperature appears to be the overriding variable controlling trout growth in project reservoirs and forebays, and growth rates approach their theoretical maximums under current temperature regimes. Thus, the analyses indicate that trout growth does not appear to be limited by current reservoir and forebay management. The management objective as defined for the watershed analysis is therefore currently being met. Detailed results and analysis of the comparison between actual and modeled trout harvest and growth are presented below.

**Trout harvest in project reservoirs and forebays**

Modeled trout harvest based on the MEI and TP models were compared with actual 1992 harvest and are displayed in Figure 5-1. In general, points above the line indicate that harvest is less than expected, possibly indicating that limiting factors may be operating on the population or that potential harvest is not being realized due to low fishing pressure. Points below the line indicate that actual harvest exceeds model predictions and that the fishery is either unusually productive or may be overexploited. Because the TP model predicts total production and the MEI model predicts harvest potential, the TP prediction should be greater than that of the MEI. This is the case for all impoundments except for Soda Springs reservoir, Lemolo No. 2 forebay, and Stump Lake. This may indicate that the TDS estimates for these impoundments include a high proportion of biologically inert dissolved solids, which would cause the MEI model to overestimate harvest. Biologically inert dissolved solids are those not used metabolically by the stream biota, but no studies have been done to determine if high concentrations of such solids exist in North Umpqua impoundments.

For the larger reservoirs, harvest is on par with expectations derived from nationwide (MEI model) and worldwide (TP model) assessments of fish harvest in reservoirs and lakes. Actual harvest exceeded modeled harvest in Toketee Lake and Lemolo No. 2 forebay. For Lemolo Lake, actual harvest exceeded the MEI model estimate by 400 kg/yr, but was 700 kg/yr less than the TP model estimate; this indicates that harvest in Lemolo Lake is likely in the average range.

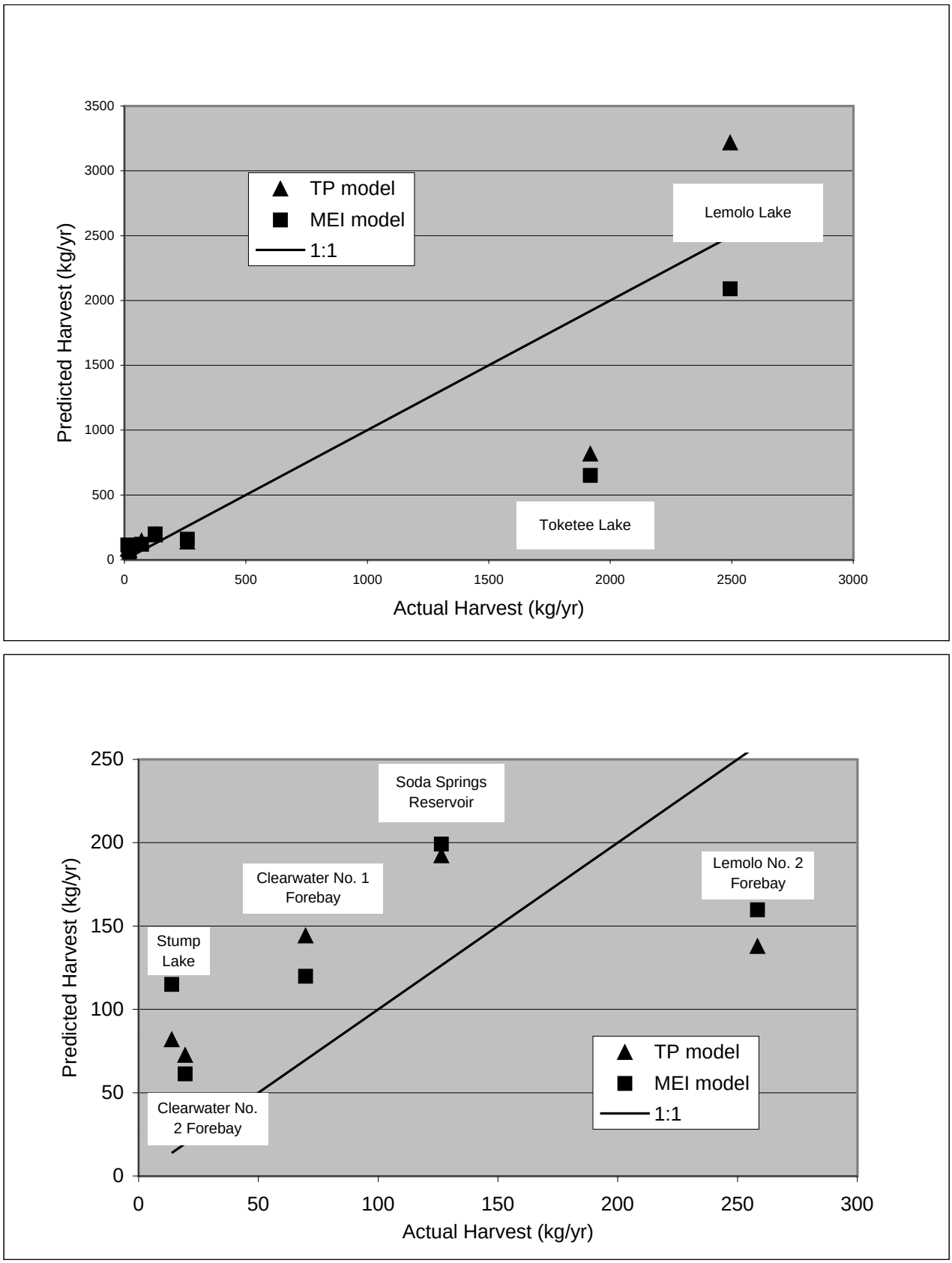


**Figure 5-1. Comparisons of MEI and TP model Predictions with actual trout harvest in the North Umpqua River basin reservoirs and forebays.**

In contrast with harvest in the larger impoundments, harvest in the smaller impoundments (Soda Springs reservoir, Clearwater Nos. 1 and 2 forebays, and Stump Lake) is smaller than that predicted by the models. Potential causes of the disparity include:

- smaller impoundments are not as heavily fished;
- entrainment of > 6 inch fish into downstream waterways may be substantial enough to reduce harvest;
- cold water temperatures in all but Soda Springs reservoir reduces the growth of trout and therefore the number attaining minimum legal harvest length;
- the models used may not be appropriate for very small water bodies;
- fish production may be suppressed by other project-related or non-project related factors; and/or
- estimates of non-summer harvest man not have been representative for Soda Springs reservoir and Clearwater Nos. 1 and 2 forebays.

Of these potential causes, the first three are likely to be the most important. There is evidence that the smaller impoundments receive less fishing pressure relative to the larger impoundments (Table 5-1); for example, after correcting for area differences, Stump Lake receives only one-third of the angler use that Lemolo Lake receives. Although catch rates are relatively high in the smaller impoundments, the catch is characterized by small fish (the largest caught are usually <30 cm [11.7 inches] and <300g [10.5 oz]), which may explain the lower use by anglers. In addition, entrainment is substantial in at least two of the smaller impoundments (see *Entrainment*, below) and likely contributes to the reduced harvest relative to model predictions. Finally, cold water temperatures may be limiting trout growth (see *Trout Growth in Project Reservoirs and Forebays*, below). Since natural mortality occurs continuously, the slower the growth rate, the fewer the trout that will reach legal minimum harvestable size.

**Trout growth in project reservoirs and forebays**

Two important conclusions emerged from the trout growth modeling analysis. First, there is no evidence that trout growth in any project impoundment is limited by food availability. Second, there is great potential for fish to vary in size because of spatial variation in thermal conditions. The basis for these conclusions is discussed below.

Figure 5-2 summarizes actual and modeled trout growth in project impoundments. Y-axis scales differ between graphs. Curves in each graph represent different temperature sampling sites for which growth was modeled, or different assumptions about how trout choose temperatures within the water column. For Lemolo and Toketee lakes, the "optimum" scenario assumes that trout select positions in the water column as close as possible to 13°C, the optimal temperature for growth of brown trout (Elliot 1994) and brook trout (Donald et al. 1980). The "0-10 m" scenario assumes that trout experience temperatures that are a mean of those between 0 and 10 m depth, while the "0-20 m" scenario assumes that trout experience temperatures that are a mean of those

between 0 and 20 m depth. For Clearwater No. 2 forebay, actual growth is not presented because of likely errors in the mean sizes presented in PacifiCorp (1995).

The effects of differing temperature regimes on growth are apparent. The Clearwater system impoundments have the lowest temperatures and the lowest potential growth rates, while Lemolo and Toketee lakes have the highest temperatures and the highest potential growth rates.

For the large impoundments (Lemolo Lake, Toketee Lake, and Soda Springs reservoir), observed trout growth falls within the range predicted given maximum rations (Figure 5-2), suggesting that food is not limiting growth in these impoundments. Predictions vary within a particular reservoir because different areas have different temperature regimes, and because of the different ways in which mean water column temperatures have been calculated.

For the smaller impoundments (Lemolo No. 2 forebay, Clearwater Nos. 1 and 2 forebays), observed fish growth was faster than modeled fish growth. Possible explanations include:

- large fish from upstream reaches are entering the impoundments;
- scale analysis may have underestimated fish age, leading to overestimates of actual growth; and/or
- some trout may be feeding on fish prey rather than invertebrate prey, which would cause the model to underestimate their growth.

The third possibility was evaluated for Lemolo No. 2 forebay using modeling. Once trout reached 200 mm (approximately 8 inches) (the size at which most trout can become piscivorous), a new, higher value for prey energy density was used consistent with a switch from invertebrate to fish prey. Under this scenario, the modeled trout growth curves were much closer to the actual values, indicating that Lemolo No. 2 forebay trout (which are predominantly brown trout) may achieve their high growth rates via piscivory.

**Entrainment**

Entrainment of >6 inch trout was evaluated for four impoundments (Table 5-1). Although entrainment takes place at many locations within the system, this analysis focused on the fish removed from the impoundments via the downstream waterways or penstocks. When compared with annual harvest, annual entrainment from the larger reservoirs (Lemolo and Toketee lakes) was insubstantial, amounting to only 1.5 and 1.4 percent, respectively, of the harvested biomass. (Note that PacifiCorp's [1995] estimate that the number of > 6 inch trout entrained from Lemolo Lake—4 percent of the harvest—was based on numbers of fish, not biomass.) In contrast to Lemolo and Toketee lakes, annual entrainment was substantial relative to the small harvest of fish from Soda Springs reservoir and Stump Lake (33 and 945 percent, respectively, of the harvested biomass).

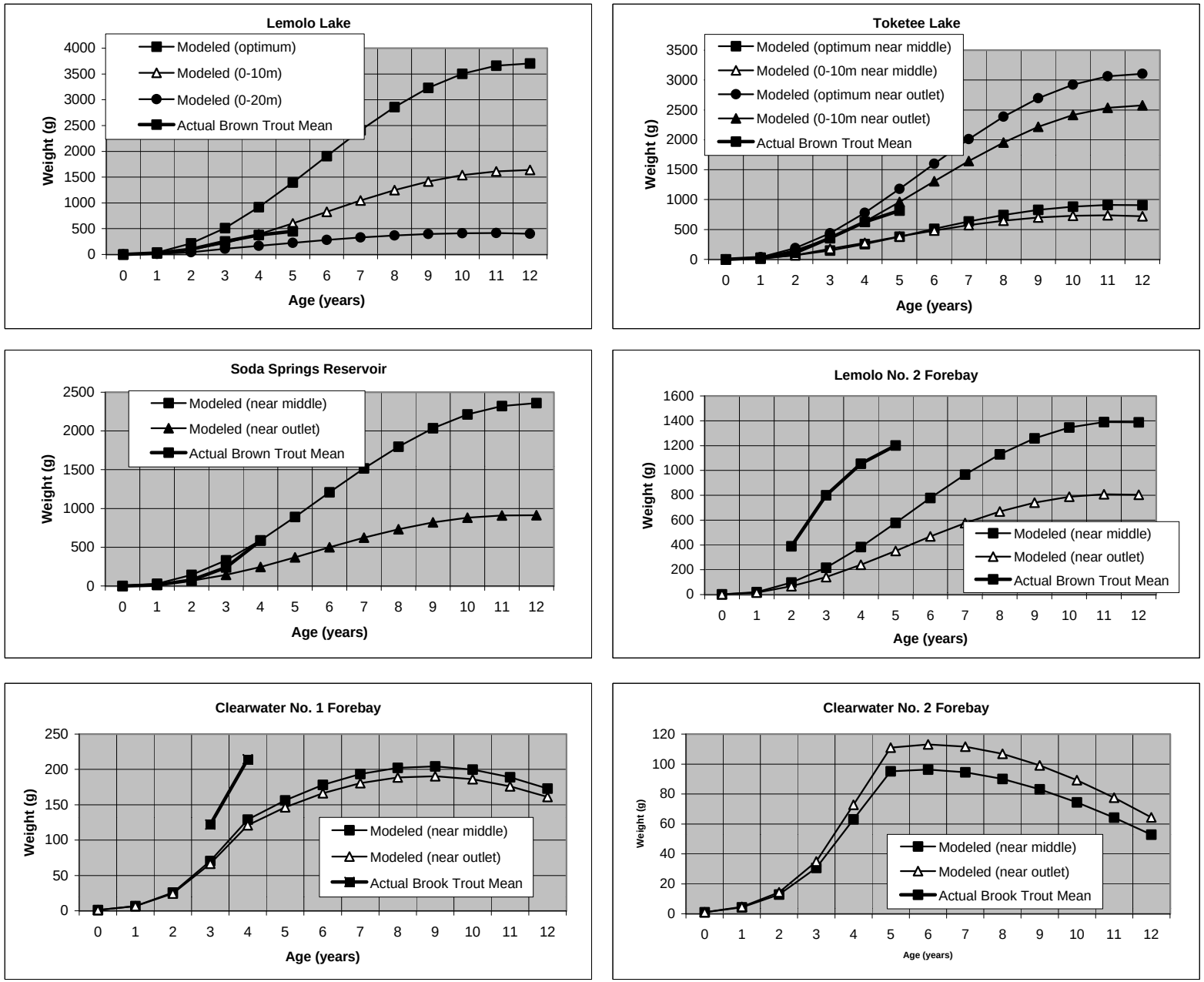


Figure 5-2. Comparisons of modeled trout growth rates

The fact that >6 inch trout that are being removed by entrainment from Soda Springs reservoir and Stump Lake make up a relatively large percentage of harvested biomass may help explain the results of the trout harvest modeling analysis described previously. Based on modeling, harvest at Soda Springs reservoir and Stump Lake were judged to be less than expected from similar water bodies. If the biomass of entrained >6 inch trout is added to the harvest, the resulting estimate more closely matches the modeled harvest. For example, harvest at Soda Springs reservoir was only 126 kg (277 lb), but if entrainment were included, the number increases to 168 kg (370 lb) which more closely approaches model predictions of 192 kg (423 lb; TP model) and 199 kg (438 lb; MEI model).

Although entrainment has not been quantified for the Clearwater Nos. 1 and 2 forebays, they may experience relatively high levels of entrainment similar to those of Soda Springs reservoir and Stump Lake because of their similarly small size. Such entrainment might explain why harvests at the Clearwater Nos. 1 and 2 forebays are less than predicted by the models.

Entrainment that occurs upstream of impoundments, in addition to that occurring directly from them, may negatively affect impoundment fisheries. This may be the case for Soda Springs reservoir, where the Slide Creek diversion may remove substantial numbers of fish that would have contributed to the Soda Springs reservoir fishery. The Slide Creek diversion dam is estimated to entrain over 2,500 brown trout annually (PacifiCorp 1995, Vol. 26), many of which are >6 inches in length.

### 5.5.2 Stillwater Amphibians

There are several characteristics of reservoirs and forebays that could account for the scarcity of stillwater amphibians, particularly eggs and tadpoles, in these impoundments. Most significant of these may be the presence of predaceous fish, a lack of habitat structural diversity, water level fluctuations, and entrainment. Each of these factors is described separately below, and their possible effects on populations of stillwater amphibians in the watershed are then discussed.

#### Predation

Introduced fish species currently occur throughout the watershed and are abundant in reservoirs, forebays, natural and developed ponds, wetlands, and streams. These species include brown trout, brook trout, kokanee, tui chub, bluegill, and brown bullhead. In addition, hatchery-produced rainbow trout are commonly stocked in the numerous ponds created for the purposes of fire suppression (USDA Forest Service and USDI Bureau of Land Management 1995). The egg and larval stages of most native amphibians are palatable to trout and predation during these stages reduces the survival rate of juvenile stages to metamorphosis. Northwestern salamander and western toad tadpoles are believed to discourage predation by their toxicity (M. Hayes 1996), but stomach sample analysis of rainbow trout in Diamond Lake has shown that they will eat larval northwestern salamanders, at least when their food supply is limited (M. Hayes 1997).

The bullfrog, a non-native species known to be a predator on many native amphibians, has been observed in the lower North Umpqua River watershed (for example, in the Little River drainage; USDA Forest Service and USDI Bureau of Land Management 1995), but its presence in the vicinity of the hydroelectric project has not been documented. Habitat conditions in the vicinity of the hydroelectric project are generally not suitable for bullfrogs (M. Hayes, pers. com. 1997). Three bullfrogs may have been captured at the Clearwater No. 1 diversion in the fish entrainment nets during relicensing studies, but the identification of the captured species was not verified (see M. Hayes 1996) and is questionable. Other observations of bullfrogs in the immediate hydroelectric project vicinity are limited to sites along the transmission line corridor.

**Habitat structural diversity**

Hydroelectric project impoundments lack the habitat structural diversity on which the co-existence of amphibians and predatory fish may depend. A variety of water depths can partition habitat between fish and amphibians, such that amphibians use shallow shelves while fish are restricted to deeper areas. Also, substrate such as emergent or floating vegetation and large woody debris can provide cover to amphibians and attachment sites for their egg masses. Richter and Azous (1995) reported that a positive relationship between amphibians species richness and aquatic bed habitat (wetlands dominated by plants that grow on or below the surface of the water (Cowardin et al. 1979)). Habitat structural features are frequently lacking in project forebays and are uncommon in project reservoirs.

**Water level fluctuations**

Water level fluctuations in forebays and reservoirs may prevent the establishment of aquatic vegetation and disturb or dewater amphibian egg masses. Richter and Azous (1995) found that amphibian species richness in wetlands in Washington state declined with increasing water level fluctuations, flow velocity, and watershed urbanization; in contrast, species richness was not correlated with other factors such as fish and bullfrog predators, vegetation class diversity, wetland size, water persistence, and distance to other suitable sites. Both current and proposed fluctuations in the North Umpqua Hydroelectric Project impoundments are greater than the degree of fluctuation that was determined in Richter and Azous' (1995) study to reduce amphibian species richness.

**Entrainment**

Data collected from the fish entrainment studies (PacifiCorp 1995, Volume 26) indicate that amphibian egg, larval, and post-metamorphic stages are entrained from reservoirs and/or diversions of the mainstem streams into project waterways. Amphibians that are entrained at diversion points are shunted into waterways. Entrained egg masses are most likely disturbed prior to entrainment, and would likely be broken apart and destroyed in the waterways. Post-metamorphic individuals entrained into project waterways likely drown due to the velocity of the

water and lack of structures that allow small animals to escape. Post-metamorphs can also enter open canals directly from terrestrial habitats; the rate of such entry is unknown.

Individuals that survive the journey through project waterways are deposited into a forebay, where the chance of survival and successful reproduction is low, for the reasons described above. Amphibians may also be entrained from the forebays into waterways that lead to powerhouses; the rate of such entrainment, if it occurs, is unknown. Any amphibians entrained from forebays would not be expected to survive.

**Effects on populations**

Although the construction of the hydroelectric project impoundments increased the amount of stillwater habitat in the watershed, these impoundments are not generally considered by the Terrestrial Subgroup to provide suitable habitat for stillwater amphibians. At best, the reservoirs provide some habitat for some species, but in general they add very little to the available habitat in the watershed. At worst, the reservoirs and forebays created by the hydroelectric project may act as "population sinks" for amphibians—sites to which amphibians disperse and breed, but where their offspring cannot survive, due to the factors described above.

As a consequence of the limited information available on amphibian populations in the watershed, the Terrestrial Subgroup relied on professional judgement, in combination with available data, to assess the habitat suitability and ecological role of the various water bodies in the vicinity of the hydroelectric project. Based on the information available, the collective judgement of the group regarding the habitat suitability of various stillwater sites is as follows:

- all forebays: poor suitability (probable population sinks)
- Stump Lake: good suitability (possible population source for some species; habitat structural diversity may be good but the presence of trout may limit suitability for some species)
- Lemolo Lake: poor suitability (probable population sink)
- wetlands at the upstream margins of Lemolo Lake: good suitability (possible population source)
- Toketee Lake, Stinkhole, and associated wetlands: poor to medium suitability (possibly a population sink, but structural habitat diversity in some areas may allow co-existence of amphibians and predaceous fish)
- Ranawapiti Pond: good suitability (possible population source for some species; habitat structural diversity may be good but predaceous fish may limit suitability for some species).

The long-term population trends for stillwater amphibians in the watershed cannot be predicted based on the available data. To assess whether stillwater amphibian populations are likely to be viable in the watershed over the long term, a "metapopulation" or "source-sink" analysis examining the role of project impoundments on amphibian populations would be required. Information needed for this analysis would include: (1) population numbers of each species at each life history stage at each site (based on field surveys conducted at several times during the

reproductive cycle); (2) estimates of reproductive, survival, and dispersal rates of species at each life history stage; and (3) information on the patterns of dispersal by each species in the watershed.

The Terrestrial Subgroup concluded that, in general, the habitat value of project reservoirs and forebays for stillwater amphibians is probably very limited and that these impoundments may have negative impacts on the population dynamics of these species in the watershed. Thus, habitat enhancement measures independent of project impoundments, in addition to those associated with the impoundments, should be considered in order to meet the management goal of creating an environment in the watershed as a whole that supports healthy populations of stillwater amphibians.

## 5.6 MANAGEMENT OPTIONS

### 5.6.1 Fisheries

Studies indicate that reservoir and forebay fisheries currently meet ODFW's management objectives and are, for the most part, in good condition. Nonetheless, a number of management options have been proposed (PacifiCorp 1995) or have emerged during the watershed analysis process. These options might improve habitat for aquatic organisms or improve the fishery. The management options relate to the alteration of existing facilities or their operations, or changes in management programs administered by the ODFW, except for the options for the proposed Lemolo No. 1 forebay. The following options were evaluated for reservoirs (Soda Springs reservoir, Toketee Lake, Lemolo Lake, Stump Lake) and forebays (Fish Creek, Clearwater Nos. 1 and 2, Lemolo No. 2, and the proposed Lemolo No. 1) to assess the potential to maintain or enhance existing fisheries:

- Modification of timing and magnitude of water level fluctuations (both seasonal and daily in Lemolo Lake; daily in the other water bodies);
- Excavation or partial dredging of some reservoirs and forebays;
- Addition of large woody debris, stumps, and brush piles;
- Screening at reservoir and forebay outlets to retain fish in the reservoir or forebay;
- Screening at waterway intakes to keep fish out of forebays (i.e., retain them in river reaches);
- Modification of sport harvest regulations (e.g., slot limits on fish length); and
- Stocking hatchery fish

**Description of management options**

**Changing the timing and rate of water level fluctuations** (drawdown and refill) could reduce the impact of fluctuations on the littoral zone of water bodies and, in some cases, reduce the exposure of fish to entrainment. In general, increased stability of the water level could increase the quality of habitat for fish and other aquatic organisms and could decrease the exposure of organisms to entrainment. Relatively stable water levels can facilitate the establishment of aquatic

macrophytes in the littoral zone. Alternatively, unrestricted fluctuations would permit maximizing hydroelectric generation.

**Excavation/dredging** and adding habitat structure were considered for all water bodies, but they were evaluated primarily for water bodies where PacifiCorp proposed such measures in the relicensing application (PacifiCorp 1995): Soda Springs reservoir, Lemolo No. 2 forebay, and Clearwater Nos. 1 and 2 forebays; addition of habitat structure only was proposed in Fish Creek forebay. Excavation could likely be designed and implemented in a biologically sound manner to recover some deeper-water channels in the impoundment while retaining some adjacent shallower littoral habitat. Excavation is likely to have short-term impacts but may benefit fisheries in the long term.

**Addition of structural components** such as large logs, stumps, and brush piles to reservoirs and forebays could increase the amount of cover for fish, possibly allowing them more holding and feeding positions away from the outlet structures and thus reducing exposure to entrainment. PacifiCorp (1995) proposed adding large wood to improve structural diversity following excavation and to reduce entrainment. The Aquatic Subgroup estimated that these structures might have "medium" benefits to the fisheries through decreased entrainment, increased productivity, and increased angler success, but felt there was a "low" likelihood of this success due to biological uncertainties with this option.

**Screens** to exclude fish can be designed in many different ways for different sizes of fish, and placed in various locations. They are not always effective and can cause fish mortality or operational problems due to site-specific conditions and blockage by ice and debris. Screens designed to exclude small fish are generally much larger, more expensive, and more subject to blockage than those designed to exclude larger (> 6 inches long) fish. For example, conceptual cost estimates for fish screens designed to exclude trout fry at most forebay and reservoir sites ranged from about $400,000 to $7,000,000 per site, plus $20,000 to $170,000 per year for maintenance (PacifiCorp 1995, Vol. 26). Screening options evaluated by the Aquatic Subgroup involved screens designed to retain larger trout (> 6 inches long) only, not smaller fish. In addition to fish sizes targeted, the effect of fish screens on a fishery varies with the location of the screen and routing of the screened fish (Table 5-2).

Table 5-2. Summary of potential effects of screens for larger fish, by fish routing system and location.

| Routing System | Screen Location | |
|---|---|---|
| | At a Stream Intake to a Waterway Leading to a Forebay | At the Outlet of a Reservoir or Forebay |
| Screen stops larger fish from passing | • excludes larger fish from waterway<br>• keeps larger fish in river<br>• possible benefit to fishery in river and/or downstream reservoirs<br>• reduces or stops recruitment of larger fish to forebay fishery (may reduce number and/or size of fish in forebay) | • retains larger fish in reservoir or forebay<br>• may cause reduced growth due to crowding (especially brook trout in cold water)<br>• benefits uncertain in most cases |
| Screen routes larger fish into river reach downstream of dam | Same as above, but improved downstream connectivity of fish movement | • no benefit to water body<br>• possible benefit to downstream water bodies (rivers, reservoirs, and/or forebays) |

**Changing harvest regulations** would require official proposal by ODFW, a public review process, and approval by the Fish and Wildlife Commission, and may then be changed during biennial reviews. This approach would directly alter fish populations if anglers comply with the new regulations (for example, releasing adult-sized fish) or are willing to harvest more and smaller fish (for example, to reduce brook trout numbers).

**Stocking hatchery trout** of catchable size for put-and-take fisheries is also in the purview of ODFW. Fisheries in all of the hydroelectric project reservoirs and forebays are currently the product of natural fish production; no stocking has occurred since the mid-1970s. Stocking would constitute a fundamental change in management from the existing naturally produced fish populations. Routine stocking of hatchery fish has the potential to introduce diseases and parasites and is expensive compared to natural production.

**Evaluation of management options**

There is substantial uncertainty related to fishery management and the anticipated results of management and operational changes. For example, increases in angler effort and harvest could deplete natural recruitment in a particular water body and precipitate an unforeseen need for changes in regulation or stocking. Similarly, excavation of a forebay might deplete the fish population in the short term until entrainment or stocking resupply the water body. To evaluate the results of major management and operational changes, a monitoring and reporting plan would be prudent. Fishery monitoring may include creel surveys (to describe effort and catch rates), age and growth analysis of fish, measures of relative species composition (e.g. tui chubs and brown trout in Lemolo Lake), or studies of the efficiency and mortality associated with fish screens.

As a first step in assessing management options, the Aquatic Subgroup applied professional judgment to rate all project reservoirs and forebays in terms of their current fishery value, their potential future value (given the full suite of management options that could be applied), and the likelihood that changes in management could actually achieve the potential increased value (Table

5-3). One purpose of this table is to permit consideration of a water body's current and potential values to North Umpqua fisheries in comparison with other water bodies when evaluating management alternatives. All nine water bodies were ranked relative to each other using a Low (L), Medium (M), High (H), or Very High (VH) ranking, with finer levels designated by a "–" or "+" (e.g., L–, L, L+, M–, M, etc.).

In Table 5-3, the "current value" of the fishery was ranked in terms of catch rate, size and species of fish being caught, and current levels of use (which are related to accessibility and public awareness of the fishery's existence). The current value is defined as the value in 1995 and is meant to represent the value of the fishery given typical recent operations under the existing license conditions. The "potential future value" of each fishery was determined by considering the fishery that might be expected to result from an optimal suite of enhancement measures implemented at some time in the future. For the purposes of this exercise, potential future values assume that measures would be implemented in the late 1990s, and that the potential fishery value would be achieved and stable by the year 2010. The "likelihood of success" (the likelihood of achieving the potential future value) is an expression of the uncertainty that a suite of enhancements would actually produce the envisioned benefits. The management actions considered optimal for each water body were prioritized as Tier 1, 2, 3, etc., with Tier 1 being both the most important and most likely action to produce a benefit. A more detailed evaluation of management options at each impoundment is provided in Section 5.6.3. The following three examples illustrate how to interpret the information in Table 5-3.

- The Lemolo Lake fishery is currently rated very high (VH). It is considered to be the most valuable fishery of all the North Umpqua Hydroelectric Project water bodies, because it supports the greatest amount of angler effort, a catch rate meeting ODFW's objective, and a valuable alternative to the hatchery trout fishery at Diamond Lake. It has the potential to be improved to VH+, but even if the optimal suite of enhancements are carried out, there is only a medium (M) chance it will improve from VH to VH+.

Table 5-3. Current (1995) and potential future (2010) values of reservoir and forebay fisheries [a].

| Water Body | Current Value | Potential Future Value | Likelihood of Success | Comments, Measures Most Likely to Benefit Fishery [b] |
|---|---|---|---|---|
| Lemolo Lake | VH | VH + | M | • Most popular and valuable of all project fisheries.<br>• Goal would be to increase size of trout (would be ODFW management change to "trophy fishery").<br>• Tier 1: increase minimum pool elevation (reduce drawdown magnitude), reduce drawdown rate, restrict harvest (e.g. slot limit to protect some larger fish)<br>• Tier 2: screen reservoir outlet or stock hatchery trout |
| Toketee Lake | H | H | H | • Second most popular project fishery.<br>• Current and proposed operations appear adequate to sustain at high value.<br>• Not much opportunity for improvement (possible moderate benefit to stocking catchable trout, if catch rate decreases as a result of increased angling pressure). |
| Lemolo No. 2 Forebay | H | H | H- | • Most productive water body, with fastest growth rate of trout.<br>• Tier 1: excavate to restore deep-water channel through shallow arm, minimize water level fluctuations<br>• Tier 2: screen forebay outlet as proposed in PacifiCorp (1995)<br>• Tier 3: stock with hatchery fish |
| Soda Springs reservoir (assumes that no anadromous fish are present—if anadromous fish passage is implemented, fishery may be closed or restricted to maximize the success of fish restoration efforts) | M+ | M – | H | Manage to increase hydroelectric generation.<br>• Tier 1: excavation to restore storage capacity and increase water level fluctuations as proposed by PacifiCorp (1995)—will decrease the value of the fishery. |
| | M+ | H - | M | Manage to improve fishery.<br>• Tier 1: decrease water level fluctuations, excavate only enough to retain existing reservoir depths.<br>• Tier 2: screen reservoir outlet, dredge to restore storage capacity (as proposed), add LWD to supply cover. |
| Clearwater No. 1 and 2 Forebays | M | M + | L | • Lowest priority fisheries of all project water bodies; fish growth limited by cold water.<br>• Currently dominated by brook trout, which are not desirable fish (per ODFW 1997 regulations).<br>• Tier 1: intensive stocking of catchable trout (only way to substantially improve fishery)<br>• The Aquatic Subgroup felt that for these forebays, it may be appropriate to manage for aggressive hydropower generation instead of limited fishery benefits (emphasize hydropower over fishery benefits, concentrate fishery efforts in other places); possibly modify Mowich Creek confluence to protect potentially native rainbow trout |
| Stump Lake | L | L | H | No action.<br>• Low priority fishery<br>• Fish growth limited by cold water<br>• Currently dominated by brook trout, which are not a desirable species (per ODFW 1997 regulations)<br>• Current and proposed operations already have stable water levels and high-quality structural habitat |
| | L | H | H | Manage to maximize fishery potential.<br>• Intensive stocking is the only way to substantially improve the fishery<br>• Has higher potential future value than Clearwater forebays, because it is easily seen and accessed from Hwy 138. |

| Water Body | Current Value | Potential Future Value | Likelihood of Success | Comments, Measures Most Likely to Benefit Fishery [b] |
|---|---|---|---|---|
| Fish Creek Forebay (several options are presented because of the management importance of potentially native rainbow trout which dominate this water body) | L | M + | M | Manage to optimize harvest with naturally produced trout.<br>• Tier 1: decrease water level fluctuations<br>• Tier 2: add LWD to supply cover, screen forebay outlet<br>• Tier 3: publicize fishery (the current low value is related to a lack of use) |
| | L | L- | H | Manage to protect potentially native rainbow trout (ODFW preferred alternative).<br>• Tier 1: no action, retain low level of angling effort<br>• Tier 2: screen Fish Creek waterway intake to keep potentially native rainbow trout out of forebay; permits emphasis on hydropower generation |
| | L | M+ | H | Manage for harvest and rainbow trout protection.<br>Tier 1: screen Fish Creek waterway intake, stock hatchery fish in forebay<br>Tier 2: reduce water level fluctuations<br>Tier 3: screen forebay outlet |
| Lemolo No. 1 Forebay (proposed for construction) | — | H – | H | Construct forebay.<br>• Tier 1: build forebay as proposed in PacifiCorp (1995), allow recruitment of brown trout from Lemolo Lake (possible benefits to screening forebay outlet and stocking hatchery fish, but these are unknown until the forebay is constructed) |

a. Assuming implementation of all measures most likely to benefit the fishery.
b. Tier 1, 2, etc., indicate the relative merit of each suite of options. Where no tiers are listed, no options were identified to substantially improve the fishery.

- The Toketee Lake fishery is currently rated high (H); its potential value is also high (that is, there is not much room for improvement, and no expectation of decline), and there is a high likelihood of remaining at this value.

- Lemolo No. 2 forebay has a high value, but it may decline in the future as a result of increased angling pressure (it appears to be getting more popular in recent years), even if the optimal suite of enhancements are implemented.

**Evaluation of specific sites**

Management options for each water body are discussed in the following order: (1) fluctuations of water level; (2) excavation and/or addition of structure; (3) harvest regulations; (4) screens at outlets and waterway inlets; (5) stocking of hatchery fish; and (6) any others. Alternative sets of options are rated according to their magnitude and likelihood of success.

***Lemolo Lake***

The value of the Lemolo Lake fishery is currently very high. The potential for improvement, to a very high + value, would involve changing the management goals for the fishery and increasing the number of trophy-sized brown trout caught by anglers. The management alternatives were evaluated largely in terms of whether they contribute to the creation of such a trophy trout fishery. Increasing the numbers of larger trout in the reservoir may have additional benefits to the fishery: tui chubs are currently present in large numbers, and although they do not appear to be reducing the brown trout population in Lemolo Lake (as they have rainbow trout in Diamond Lake), the potential exists for competitive interactions between the species. The existence of larger brown trout may increase predation on tui chubs.

Lemolo Lake is currently drawn down as much as 15 m (50 ft) from full summer pool during fall and winter months, for power generation and to allow for seasonal water storage. There are no restrictions on fluctuation rates, and they can be up to several feet per day. Seasonal storage and release results in moderate (generally <1 to 5.7 cms [610–200 cfs]) spring decreases and fall increases in flow downstream of Soda Springs powerhouse, which may be beneficial to anadromous fish (especially fall-spawning species like chinook and coho salmon). However, the minimum pool size is 20 hectares (50 acres) compared to full pool size of 160 hectares (400 acres), and it is concentrated near the outlet, exposing fish to higher levels of entrainment. PacifiCorp (1995) proposed to reduce the magnitude of fluctuations to no more than 7.5 m (25 ft) below full pool and to reduce the rate of drawdown to no more than 15 cm (0.5 ft) per day to increase overwintering habitat for trout and decrease exposure to entrainment. PacifiCorp voluntarily implemented this proposal in 1994, and monitored the effects on fish entrainment for three winters (1994, 1995, and 1996). A report on the results of this study will be available in the spring of 1998.

Other fluctuation scenarios discussed by the Aquatic Subgroup were (1) to further reduce the magnitude of drawdown to no more than 3 m (10 ft) (as proposed by ODFW in 1995), which would improve the opportunity for macrophytes to grow along the littoral zone or (2) to refrain from any fluctuation at all (i.e., to manage Lemolo like a natural lake). The “natural lake” scenario could be with a full pool, maintaining the reservoir at its summer size throughout the year; or, at a lower pool, to operate it more like a river (for example,., maintain a stable pool size of 20 hectares [50 acres]), which could have a dramatic effect on the fish community and water quality. This “low-pool” scenario would essentially eliminate the existing thermal stratification (reducing the amount of warm water present); likely reduce the number of fish in the reservoir, including reducing or possibly eliminating tui chubs; and possibly reduce growth rates of trout by reducing water temperatures and the abundance of fish prey. The “full-pool” scenario would retain the existing summer thermal regimes and fish community, but might increase tui chub production disproportionately to trout production in areas of permanent littoral habitat. A modification would be to stabilize the pool at a water level that would minimize the amount of shallow (<1 m [3 ft] deep) habitat preferred by tui chubs.

Excavation and addition of structures were not judged by the Aquatic Subgroup to have fishery benefits for Lemolo Lake, and no excavation or structure placement were proposed by PacifiCorp (1995).

The primary goal of modifying harvest regulations in Lemolo Lake would be to increase the number of trophy size trout (> 41 cm, or 16 inches), changing it to a "trophy fishery". A slot limit restricts the harvest of adult fish (for Lemolo Lake, 30 to 41 cm, or 12 to 16 inches would be appropriate), which would allow some fish to grow to larger sizes. One drawback of a slot limit is that anglers may significantly increase their harvest of fish 28 cm (11 inches) or smaller, in particular keeping 11-inch fish that might have been released under former regulations in the hope of catching even larger fish. Under this scenario, few fish would be recruited into the restricted size range, defeating the purpose of the slot limit. If this occurred, it would happen primarily in the first few years after implementation of a slot limit, before large numbers of trout > 41 cm (16 inches) could become available for harvest. A possible solution this problem, if it occurred, would be to provide large numbers of catchable (20 to 28 cm, or 8 to 11 inch) hatchery fish in the early years of the program to meet angler demand, which might allow more fish to grow into the restricted size class. Another potential benefit to increasing the number of large trout in Lemolo Lake might be more efficient predation on larger tui chubs: ideally, brown trout predation would keep the tui chub population in check.

The primary goal of screening the outlet of Lemolo Lake would be to retain larger catchable fish (> 20 cm, or 8 inches) in the reservoir. Because the Lemolo No. 2 intake diverts water from the North Umpqua River in addition to water from the Lemolo No. 1 powerhouse, it is not likely that screening fish at the Lemolo Lake outlet would adversely affect recruitment of fish into Lemolo No. 2 forebay, although the reduction in small fish from the Lemolo No. 1 waterway might reduce the very high growth rates observed in Lemolo No. 2 forebay, by reducing the food supply of the larger trout residing there. If a Lemolo No. 1 forebay is built, the fishery that might develop there could be adversely affected by screening of the Lemolo Lake outlet.

Potential ecological benefits or costs of screening would depend on the size of fish for which the screens are designed and the placement and operation of the screens. In terms of screen efficiency, two options were discussed by the Aquatic Subgroup: screening for all sizes of trout, and screening for trout larger than 15 cm (6 inches) long. Three options for screening location and operation were discussed: (1) screening at the lake outlet; (2) screening in the waterway (downstream of the outlet), with the salvaged fish hauled back to the reservoir; and (3) screening in the waterway and diverting screened fish to the river downstream of Lemolo dam (Table 5-4).

Table 5-4. Potential benefits and concerns related to screening fish at the Lemolo Lake outlet.

| Management Option | Screening of Fish of All Sizes | Screening of Fish > 6 inches in Length |
|---|---|---|
| 1, 2 | • may increase fish in Lemolo Lake<br>• little expected effect on recruitment in Lemolo No. 2 forebay<br>• may reduce growth rate of trout in Lemolo No. 2 forebay<br>• may adversely affect a potential future Lemolo No. 1 forebay fishery | • may increase fish in Lemolo Lake<br>• little expected effect on recruitment of fish to Lemolo No. 2 forebay<br>• no expected effect on growth rate of trout in Lemolo No. 2 forebay<br>• little expected effect on a potential future Lemolo No. 1 forebay fishery |
| 3 | Same as above, except not expected to improve fishery in Lemolo Lake. | Same as above, except not expected to improve fishery in Lemolo Lake. |

Stocking legal-sized brown and/or rainbow trout and/or juvenile kokanee might benefit the Lemolo Lake fishery. Natural reproduction is likely high now, due to high-quality spawning habitat upstream of Lemolo Lake, so stocking fry would probably not benefit the fishery. Potential benefits of stocking include higher catch rates and higher angler effort, both of which could have a negative impact on natural production.

The temperature stratification of Lemolo Lake could be altered by changing the withdrawal depth of the outlet. A shallower outlet would tend to reduce the temperature and/or depth of the epilimnion (surface waters), possibly reducing the habitat suitability for tui chubs in the reservoir, and possibly increasing habitat suitability for trout. The impacts on water temperatures and eutrophication in the Lemolo Nos. 1 and 2 bypass reaches would need to be explored for this option.

***Toketee Lake***

Toketee Lake is the second most valuable fishery in the project area, and the current and proposed habitat conditions are quite good. Fluctuations in water level are small, habitat structural diversity is high, and spawning habitat is abundant upstream of the lake. Further reductions in water level fluctuation would not be expected to produce much benefit to fish populations. Excavation is planned in a small portion near the spillway, but this would not have a substantial effect on the fishery. Addition of structure would not be beneficial. Stocking small fish would not be beneficial, since natural reproduction is believed to be high already, but stocking catchable-size trout might have a potential benefit if increases in angling pressure cause the catch rate to decline in the future. The effect of screening the outlet to retain fish in the lake is unknown (it could be somewhat beneficial, but it could be detrimental, since most entrained fish were small and retaining them could increase competition and reduce growth rates. Overall, the Aquatic Subgroup did not find any alternatives to substantially improve the fishery at Toketee Lake (Table 5-5).

Table 5-5. Rating of management alternatives for Toketee Lake, compared to the 1995 value of H.

| Alternative # | Proposed Actions | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action<br>H | H<br>1 | H<br>H<br>1 | |
| 2 | PacifiCorp (1995) proposal:<br>• reduce daily water level fluctuations<br>• dredge near spillway | H<br>(marginally better than Alt 1) | H | would be similar to run-of-the-river |
| 3 | 1st Tier:<br>stocking catchable size trout if harvest rates decrease due to increased angling pressure | H | M+ | |

***Soda Springs reservoir***

If anadromous fish passage is provided at Soda Springs dam, the reservoir and operations will probably be managed primarily for anadromous fish and not for a resident fish fishery. Consequently, the working assumption for developing most of management alternatives for a resident fishery was that anadromous fish passage would not be implemented at Soda Springs dam (although the alternatives analysis does include an anadromous fish management option).

Soda Springs reservoir is currently a productive fishery, but it is not heavily used because it is small and access to it is poor compared to Lemolo and Toketee lakes. Fluctuations in water level are currently moderate, with a maximum of 0.9 m (3 ft) per day. More aggressive fluctuations of a maximum of 5 m (16 ft) per day have been proposed by PacifiCorp (1995), which would probably lead to increased entrainment, degraded aesthetics and access, and decreased productivity of the reservoir. In contrast, stable water levels would be somewhat more beneficial than the current condition, although entrainment would still occur and littoral habitat would be limited by the steep canyon walls and riverbanks.

Excavation to retain the existing reservoir depths (that is, to prevent continued filling of the reservoir with sediment) was judged by the Aquatic Subgroup to be beneficial, and excavation to restore the storage capacity as proposed was considered somewhat detrimental to fish habitat and populations in the short term because of reduced shallow habitats and increased turbidity during excavation. One potential benefit of excavation is that the gravel/cobble portion of the excavated material could be transported downstream of Soda Springs dam to augment the bedload supply.

Addition of large wood has been proposed by PacifiCorp (1995), and it might benefit the fishery, although Soda Springs is already structurally complex. Harvest restrictions were not judged to have benefits, since harvest is low already. However, if anadromous fish are introduced, angling in Soda Springs reservoir may be restricted (for example, to brown trout only) or closed to avoid the harvest of juvenile and adult anadromous fish.

Screening at the outlet to retain fish in the reservoir would have a low benefit to the reservoir fishery, and screening to pass fish downstream of the dam would have no benefit to the reservoir fishery and might have deleterious effects on downstream salmonids by supplementing the brown trout population. Stocking hatchery fish was considered to have a small benefit because access for angling is limited.

The proposed alternatives are listed in Table 5-6.

Table 5-6. Rating of management alternatives for Soda Springs reservoir, compared to the 1995 value of M+.

| Alternative # | Description of Alternative | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action<br>• 8-ft maximum water elevation change<br>• 3-ft maximum water elevation change in August | H- | M+ | reservoir sedimentation may gradually diminish habitat quality |
| 2 | PacifiCorp (1995) proposal:<br>• dredging<br>• 16-ft daily maximum water level fluctuations<br>• addition of LWD | M- | H | |
| 3 | Enhance resident fishery<br>1st Tier:<br>• maintain constant water level<br>• dredging allowed only to maintain current reservoir depths<br>2nd Tier:<br>• addition of LWD<br>• install screen at outlet<br>(could include excavation to restore storage) | H- | M | |
| 4 | Manage for anadromous fish instead of resident fish—angling may be restricted or closed<br>1st Tier<br>• maintain constant water level, or allow minor fluctuation (< 5 ft)<br>• install screen with bypass at outlet<br>• construct fish ladder<br>• minor excavation to prevent filling of reservoir with sediment | M<br><br>(none if fishery is closed) | H | |

***Lemolo No. 2 forebay***

Lemolo No. 2 forebay is a productive habitat with a high-quality fishery and the highest growth rate of trout in the system. It is a popular fishing site with good access. Increased popularity in recent years and possibly into the future may lead to reduced catch rates and/or reduced size of fish caught. Stabilization of water level fluctuations is considered to be of low benefit to the fishery. Excavation has been proposed by PacifiCorp (1995) and would have a neutral to negative impact on the fishery (although a slight benefit is also possible if it is done in a biologically sound manner). Placement of wood structure has also been proposed by PacifiCorp and would have the benefits and uncertainties listed in the introductory section.

Screening at the outlet structure to retain larger fish (> 6 inches long) in the forebay as proposed by PacifiCorp (1995) could increase numbers of fish but could also increase competition for food and space, which could cause growth rates to decline. Screening at the waterway intake on the North Umpqua River would reduce or stop recruitment of fish to the forebay and probably would be detrimental to the forebay fishery. There is a fish screen at the Lemolo No. 2 waterway intake, but it has been out of service for decades, due to problems with algae and concerns about maintaining the forebay fishery.

Stocking is not considered beneficial at this forebay unless catch rates decline to the point that stocking catchable trout would help sustain them. However, the large brown trout in the Lemolo No. 2 forebay are capable of consuming even catchable-sized hatchery trout. Overall, no alternatives were found to improve this already high-quality fishery (Table 5-7).

***Clearwater No. 1 and No. 2 forebays***

The forebays in the Clearwater system have the lowest priority for resident fishery values because they are dominated by non-native brook trout. Fish production is likely limited by cold water temperatures rather than by operational or management conditions. Brook trout are not a high priority management species for ODFW; they are not native and typically out-compete native species where they exist sympatrically. Consequently, ODFW's management for brook trout includes unrestricted harvest (no limit on numbers or size) in streams and rivers. There are small numbers of rainbow trout in the Clearwater system, however, and these may be of native stock. Consequently, management options for these water bodies that reduce the number of brook trout but protect rainbow trout were favored by the Aquatic Subgroup.

Table 5-7. Rating of management alternatives for Lemolo No. 2 forebay, compared to the 1995 value of H.

| Alternative # | Description of Alternative | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action | H | M | M likelihood of success is due to the uncertainties regarding increased fishing pressure |
| 2 | PacifiCorp (1995) proposal:<br>• increase daily water level fluctuations (max 4-ft, 3.2-ft in August; average fluctuation will increase)<br>• dredging<br>• install screen at outlet for fish >6 inches long<br>• placement of LWD | H | M - | |
| 3 | Enhance resident fishery.<br>1st Tier<br>• beneficial dredging using biological design<br>• maintain constant water level<br>2nd Tier<br>• screen outlet of forebay<br>3rd Tier<br>• stock catchable trout | H | H - | |

Fluctuations in water level were considered beneficial for reducing the number of brook trout in these forebays. Excavation and addition of wood structure, as proposed by PacifiCorp (1995), could possibly have the intended result of maintaining or increasing numbers of trout, but of an undesirable species.

Screening at the forebay outlets would have the detrimental effect of retaining brook trout in forebays, probably stunting growth rates of trout. Screening at the waterway intakes, however, would reduce movement of brook trout and rainbow trout from Stump Lake and the Clearwater River to the forebays. This could increase the growth rate of brook trout in the forebays by reducing competition. It would benefit rainbow trout by keeping them in the river, although very few rainbow trout occur in this portion of the Clearwater River). Also, screening the intake to Clearwater No. 1 waterway, if it kept fish in Stump Lake, could cause stunting of brook trout in Stump Lake, and it might reduce habitat suitability for amphibians in the lake.

ODFW's 1997 harvest regulations allow the harvest of large numbers of small brook trout. Stocking catchable rainbow trout would provide a fishery for larger trout, which might prey on small brook trout, further reducing competition. Stocking could provide a fishery even if screens at waterway intakes precluded recruitment of wild trout. A routine stocking program might, however, require fish screens at the forebay outlet to prevent loss of hatchery trout from the forebays.

Overall, in the light of the ODFW management objectives regarding brook trout and the medium value of the present fisheries, the Aquatic Subgroup felt that the Clearwater forebays represented the best opportunity to emphasize hydropower over fishery value (that is, to limit efforts to improve a medium-value fishery with low potential for improvement, and instead to focus fishery enhancement efforts on higher priority issues at other, higher priority sites). This would result in relatively low-value fisheries at both Clearwater forebays (Table 5-8).

Table 5-8. Ratings of management alternatives for Clearwater No. 1 and No. 2 forebays, compared to the 1995 value of M.

| Alternative | Description of Alternative | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action | M ? | H ? | |
| 2 | PacifiCorp (1995) proposal:<br>• excavation<br>• wood placement<br>• daily fluctuation | M + | L | actions would benefit brook trout, an ODFW low-value species |
| 3 | Emphasize hydropower over fisheries<br>• excavation<br>• unrestricted fluctuation | L? | M ? | recognizes the much higher value of most other sites |
| 4 | Alternative 3, plus rainbow trout protection | L? | M ? | prevent brook trout in the Clearwater River from entering Mowich Creek |
| 5 | Intensive stocking of catchable trout | M + | M ? | would circumvent cold water growth limitation, may require outlet screen |

***Stump Lake***

Like the Clearwater forebays, Stump Lake is dominated by brook trout, and the fish in it have slow growth rates due to cold water temperatures. It has a lower current fishery value than the Clearwater forebays because the trout in it are smaller, but higher potential value because of its high visibility and easy access from Hwy 138. Fluctuations in water level are not an issue, as essentially none occur and none are proposed. Excavation is not proposed or considered beneficial, and wood structure is already plentiful.

Screening at the outlet would not be beneficial, since brook trout would tend to become stunted in the lake (if screens retained them there) or in the Clearwater No. 1 bypass reach (if fish were passed below Stump Lake). This waterway intake has the highest rate of entrainment (10,000 trout per year), possibly indicating that brook trout in habitats upstream may exceed their carrying capacity.

Harvest regulation would not be beneficial, except to encourage the harvest of large numbers of small fish, which the 1997 ODFW regulations already accomplish.

Stocking was considered the only management alternative with a chance of increasing the value of the fishery. Intensive, routine stocking of catchable trout could provide a put-and-take hatchery trout fishery easily accessed from the highway. However, this level of intensive stocking was not judged by the Aquatic Subgroup to be worthwhile. Overall, the “no action” alternative was considered preferable at this site, coupled with efforts devoted to higher priority sites (Table 5-9).

Table 5-9. Rating of management alternatives for Stump Lake, compared to the 1995 value of L.

| Alternative # | Action | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action | L | H | preferred—focus on higher-priority sites |
| 2 | PacifiCorp (1995) proposal | L | H | |
| 3 | Intensive routine stocking of catchable trout | H | H | not preferred |

***Fish Creek forebay***

The Fish Creek forebay currently has a low value fishery, because it has low catch rates, it is remote, and small numbers of fish are entrained (recruited) into it from Fish Creek. It differs from all other forebays in that the rainbow trout dominating it are more likely to be native fish, and of higher management priority. Alternatives for minimizing impacts on native trout at this forebay were based on two possible approaches: (1) retain the current fish recruitment from Fish Creek but minimize the harvest of trout; or (2) halt entrainment of trout into this waterway and manage the forebay for hydropower generation or as a put-and-take fishery.

Fluctuations in water level are substantial at this forebay under current and proposed (PacifiCorp 1995) conditions. Maintaining a stable water level would provide a medium level of benefit to the fish community, but it would greatly reduce hydropower generation.

No excavation is proposed at this forebay, because it not be expected to benefit fish habitat. Addition of wood structure is proposed and would have the potential benefits and uncertainty associated with this type of habitat enhancement that have been discussed earlier. Harvest regulation was not perceived to be beneficial at this site.

Screens at the forebay outlet would retain fish in the forebay, potentially improve the fishery, and decrease turbine mortality. Screens at the waterway intake would keep trout in Fish Creek, preventing them from entering the forebay, probably causing the eventual elimination of the forebay fishery, unless catchable hatchery fish were routinely stocked to maintain it. Stocking was not recommended in the absence of waterway intake screens, since unrestricted movement of hatchery rainbow trout from the forebay to the stream would jeopardize any native rainbow trout that may remain in Fish Creek and whatever steelhead may be restored to Fish Creek.

One alternative discussed by the Aquatic Subgroup was to protect potentially native rainbow trout in Fish Creek by means of a fish screen at the waterway intake and use the Fish Creek forebay to emphasize hydropower production rather than establishing a hatchery-based fishery (Table 5-10). This option was based in part on a concern that, if instream flows are increased in Fish Creek such that diversion of water into Fish Creek forebay ceased for part of the summer, the warm water temperatures could kill all trout in the forebay (if water diversions are curtailed for more than a couple of days during the summer, the forebay becomes too hot to support trout).

Table 5-10. Rating of management alternatives for Fish Creek forebay, compared to the 1995 value of L.

| Alternative # | Description of Alternative | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action | L | H | |
| 2 | PacifiCorp (1995) proposal:<br>• add LWD to forebay<br>• maximum water level fluctuation = 6 feet, maximum in August = 2.7 feet | M - | M | |
| 3 | Enhance resident fishery<br>• add LWD to forebay<br>• screen penstock<br>• publicize fishery<br>• decrease water level fluctuations | M + | M | would increase harvest of potentially native trout |
| 4 | Manage for native trout production (protect trout in Fish Creek by screening waterway intakes) | | | |
| 4A | Maximize hydroelectric power generation | L - | H | preferred, recognizes limited value of hatchery-based fishery |
| 4B | Supplemented forebay fishery<br>• stocking<br>• maintain constant water level<br>• screen penstock | M + | H | expensive; resources might be better used at other sites |
| 4C | Manage for amphibians and remove fish<br>• maintain constant water level | 0 | H | |

***Lemolo No. 1 forebay***

A forebay on the Lemolo No. 1 development does not currently exist, but has been proposed by PacifiCorp (1995) as a 5-hectare (12-acre) pond between Lemolo Lake and Lemolo No. 1 powerhouse. The fishery value of the forebay is difficult to predict, but it will likely be high quality if fish are allowed to recruit from Lemolo Lake into the forebay. Because this forebay would be accessible from a paved road and near the resort area of Lemolo Lake, it would likely experience substantial angling pressure.

If the forebay is built, fluctuations in water level are expected to be small and would not be expected to affect fish habitat detrimentally. Excavation aside from construction is not planned and would not benefit the fishery. Addition of wood structures is not planned, but might improve habitat conditions and reduce entrainment. Harvest regulation may be beneficial, but its value would depend on the characteristics of the fishery, which are not yet known. Screening at the forebay outlet could be beneficial by retaining larger trout in the forebay, but may result in overcrowded conditions and reduced growth rates. Screening upstream in the Lemolo No. 1 waterway (at the Lemolo Lake outlet) could be either detrimental to forebay fisheries if all fish are screened, or neutral if only larger fish are screened. Stocking catchable hatchery fish may have benefits if Lemolo Lake is screened, or if harvest exceeds recruitment of wild catchable fish. Overall, the preferred approach is to construct the forebay as proposed (Table 5-11) and postpone

additional management actions until the forebay fishery characteristics develop and can be evaluated.

Table 5-11. Rating of management alternatives for the proposed Lemolo No. 1 forebay.

| Alternative # | Description of Alternatives | Potential Future Value | Likelihood of Success | Comments |
|---|---|---|---|---|
| 1 | No action<br>0 | 0 | | |
| 2 | PacifiCorp (1995) proposal:<br>• construct 12-acre forebay similar to Lemolo No. 2<br>• no screens<br>• no daily water level fluctuations<br>• mitigate for spillway (high benefit to mainstem water quality) | H | H+ | • assume biologically friendly contour<br>• colder water temperature will preclude the very high growth rates observed in the Lemolo No. 2 forebay |
| 3 | Alternative 2, plus additional enhancements:<br>• screen intake<br>• stocking | H+ | M– | benefits of enhancement uncertain |

### 5.6.2 Stillwater Amphibians

The Terrestrial Subgroup developed and evaluated six management options for addressing stillwater amphibians (Table 5-12).

Table 5-12. Comparison of management options for stillwater amphibians.

| Management Option | Comparative Rank | Ability to Meet Management Goal (out of 100) |
|---|---|---|
| Single-Action Options | | |
| 1. No Action | 6 | 10 |
| 2. Management of project impoundments for stable water levels | 2 | 90 |
| 3. Creation of stillwater amphibian habitat independent of project impoundments | 5 | 30 |
| 4. Improvement of habitat conditions in or adjacent to project impoundments | 4 | 50 |
| Combination Options | | |
| 5. Management of project impoundments for stable water levels and improvement of habitat conditions in or adjacent to project impoundments *(combination of Options 2 and 4)* | 1 | 100 |
| 6. Creation of stillwater amphibian habitat independent of project impoundments and improvement of habitat conditions in or adjacent to project impoundments *(combination of Options 3 and 4)* | 3 | 80 |

Each of these management options in described and evaluated below. Of course, the options described below reflect the preliminary ideas of the Terrestrial Subgroup, and are not comprehensive. Additional types of habitat enhancement or variations on the types described below could be developed and evaluated.

**Management Option 1: No action**

Under this alternative, no specific action would be taken to improve habitat conditions for stillwater amphibians. The future abundance and distribution of these species might remain relatively similar to those under current conditions (although the current population trend is not known), but if bullfrogs or non-native predatory fish continue to invade the area, stillwater amphibian populations may decline. Future changes in the abundance and distribution of currently occurring fish species and in hydroelectric operations could also influence the abundance and distribution of stillwater amphibians. Although certain sites in the watershed may continue to support stillwater amphibian populations, this management option would probably not meet the management goal of creating an environment in the watershed as a whole that supports healthy populations of stillwater amphibians, primarily because the introduction of predaceous fish to most stillwater habitats in the watershed has reduced habitat suitability, and the structural complexity to allow co-existence of fish and amphibians is lacking in most stillwater sites. There would be no monitoring under this option.

**Management Option 2: Management of project impoundments for stable water levels**

Managing the hydroelectric project to minimize water level fluctuations would mean that the water levels in most reservoirs and forebays would not be adjusted to improve power generation; instead, they would fluctuate primarily in response to stream flows. Under this scenario, daily water level fluctuations for power production would be limited and seasonal water level changes in the reservoirs would be minimized. Precipitation, snowmelt, and geological influences would be the primary determinants of water levels.

This option would improve habitat conditions for stillwater amphibians and other native lentic species because the disturbance of daily and seasonal water level fluctuations would be greatly reduced. The impoundments would experience hydrological regimes that are much more similar to the conditions to which native species in the watershed are adapted. For these reasons, this option is judged to be second only to Option 5 in its desirability, and there is a high confidence that the management goals for stillwater amphibians would be met if it were implemented. If this option were implemented, dredging of project forebays would probably not be necessary, which would add to the desirability of this option, because the sedimentation of project impoundments might help to establish shallow zones where aquatic plants could become established and where amphibians could be free from predation by fish. Because of the relatively high confidence that management goals for stillwater amphibians would be met under this option, monitoring would be limited.

**Management Option 3: Creation of stillwater amphibian habitat independent of project impoundments**

New stillwater habitat would be created at several sites in the watershed under this option. The goal of such actions would be to provide habitat where stillwater amphibians can successfully reproduce that would be located within dispersal distance from other suitable breeding sites, to allow for movement and genetic exchange among sub-populations. Criteria for creation of such habitats are that sites be free from salmonid and bullfrog predators and that they contain the habitat structure (such as emergent vegetation) required for cover, reproduction, and maintenance of a food supply. To protect against establishment of bullfrog or introduced fish populations, constructed habitats must be able to be drained periodically. (Bullfrog tadpoles have longer developmental periods than native stillwater amphibians [Nussbaum et al. 1993], so draining ponds at certain times of the year could eliminate bullfrogs without harming native amphibians.) The potential effects of draining ponds on aquatic vegetation and invertebrates should also be considered prior to taking such an action. Conceptual designs and costs for two types of artificial habitat structures were developed by structural engineers at Raytheon Corporation (see PacifiCorp 1997) and are described below.

***Diking of small drainages to create ponds***

Pool and/or wetland habitat could be created by diking an existing intermittent stream in a small drainage to create a pond or a series of step-pools covering about 0.1 to 0.4 hectare (0.25 to 1 acre). Creating this type of stillwater habitat would require clearing existing vegetation, grubbing stumps, grading, excavation, and dike construction. The dike would be sufficient in height to retain a desired surface area of water given the site-specific slope, and would be made of rip-rap with a sand and gravel filter or filter fabric to retain fine materials in the natural swale or channel (see diagrams in PacifiCorp 1997). Using natural materials is often preferred by restoration scientists to using artificial geotextiles, because when artificial materials eventually degrade they add human-made refuse to the environment. The water depth in the impoundment would be one to two feet and could be manipulated. A potential site where this type of design might be appropriate was identified by the Terrestrial Subgroup on a tributary to Warm Springs Creek, which is a tributary to the North Umpqua River in the upper basin. Cost estimates based on the assumptions noted in PacifiCorp (1997) indicate that one impoundment could be built for approximately $56,000 (see PacifiCorp 1997, Appendix A, Table 5-1 for a detailed break-down of costs).

***Construction of artificial ponds***

Artificial ponds could be created that mimic natural ponds or wetlands. A shallow pond would be built in a location where water would either naturally accumulate or could be routed to the pond via an inlet structure. The water would be retained using a surrounding embankment. Inlet and outlet structures would be built slightly above the pond bottom and would allow manipulation of water levels in the impoundments. The pond could be colonized by or planted with wetland-associated plants, such as cattails, to improve habitat conditions for stillwater amphibians and to support a diverse wetland community of plants and invertebrates. It would be lined with a

relatively impermeable bottom layer to retain water and support emergent vegetation. Potential artificial lining materials include a flexible membrane made of plastic, rubber, or similar material. Options for natural lining materials, which would not introduce artificial substances into the environment when they degrade, include bentonite or other high-swelling clay material. Red clay soil that may serve as an appropriate bottom layer is available from the Fish Creek Desert (located between Fish Creek and Clearwater River); this material was used in the construction of project forebays. Creating the artificial pond would require clearing existing vegetation, grubbing stumps, grading, excavation, and construction of the embankment and liner. Potential locations for creating this type of habitat would need to be determined via aerial photo or GIS analysis in combination with field surveys. Also, hydrologic and hydraulic analyses would be required prior to construction to determine site-specific natural flow capacity, flood elevation, and groundwater characteristics (PacifiCorp 1997). Cost estimates based on the assumptions noted in PacifiCorp (1997) indicate that one artificial pond could be built for approximately $120,000 (see PacifiCorp 1997, Appendix A, Table 5-2 for a detailed break-down of costs). A potential alternative design would be to construct a pond without a liner, such that the pond would retain water over a hydroperiod of 6 to 8 months. In wet years, it might support substantial amphibian production, while in dry years, it may support none. Such a design might cost less and would not have to be drained to remove introduced predators.

If the two types of artificial habitat structures described above are considered for implementation, the choice between them should depend on site-specific factors such as topography, availability of construction materials, and accessibility for construction equipment (PacifiCorp 1997). These factors would affect both the costs and the likelihood of success of the project. The costs, constructability, risk of damage, and aesthetics of these two design alternatives were summarized by PacifiCorp (1997, Table 5-2). The diked drainage option was judged by PacifiCorp (1997) to be less expensive; easier to construct; less likely to be damaged by high flows, sedimentation, and animals; and more aesthetically pleasing (in terms of blending into the surrounding environment) than the constructed pond option. However, dikes could be damaged and course and fine sediments could accumulate during high-flow events. Also, this design alternative would involve the use of heavy machinery in riparian areas, with the associated potential problems of soil compaction and petroleum pollution.

The Terrestrial Subgroup arrived at a few generalizations regarding the ecological value of constructing artificial ponds or wetlands. Constructing several artificial impoundments would be more beneficial than a single one because it would provide greater habitat abundance, diversity, and connectivity. Also, constructing one or more of these impoundments at higher elevations in the project vicinity (such as the potential site near Warm Springs Creek) and one or more at lower elevations would provide a geographic range of sites that might be used by a greater variety of species than if sites were limited to a single area or elevation. While most stillwater amphibians in the project vicinity occur at elevations throughout the elevational range of the project facilities, northern red-legged frogs tend to occur only up to about 1,160 m (3,800 ft) (Jennings and Hayes 1994) and Cascades frogs above 800 m (2,600 ft) (Stebbins 1985; however, Jennings and Hayes note that they can be found at elevations near sea level). Constructing stillwater habitat at higher

elevation sites might not benefit red-legged frogs, while sites near the elevation of Soda Springs dam might not benefit Cascades frogs. For the purposes of this evaluation, it was assumed that artificial habitat would be constructed at a total of four sites—two at higher elevations and two at lower elevations.

Option 3 was not considered to be a particularly good alternative for meeting the management goals for stillwater amphibians, for several reasons. Although it would improve conditions at certain sites, it is unknown whether creating four such sites would be beneficial to the amphibian populations in the watershed. Also, design and construction of artificial pond or wetland habitat is a relatively new and experimental field, so the likelihood of success is unknown. If this option is selected, a monitoring and adaptive management plan including criteria for success would need to be developed so that the success of the projects are evaluated and actions can be taken to improve the likelihood of success if goals are not being met.

**Management Option 4: Improvement of habitat conditions in or adjacent to project impoundments**

Under this management option, project impoundments would be modified to improve habitat conditions for stillwater amphibians. The types of improvements that would increase the habitat suitability for amphibians include: (1) initial removal and ongoing exclusion and/or removal of trout; (2) introduction of suitable habitat structure; (3) screening of intake structures to prevent entrainment of amphibians into project waterways; and/or (4) significant alteration of project operations to minimize water level fluctuations. Several ideas for improving project impoundments were developed by the Terrestrial Subgroup and are described below.

***Wetland enhancement on Fallen Mountain Creek at the Lemolo No. 2 forebay***
Fallen Mountain Creek is diverted into the Lemolo No. 2 forebay and forms a small, structurally diverse wetland where the stream meets the forebay. Cascades frogs and Pacific tree frogs have been observed in the wetland and immediately upstream (M. Garrett and C. McShane, pers. obs.), but whether any amphibians successfully reproduce there is unknown. Currently, fish in the forebay have access to the wetland, most likely limiting the suitability of the site for amphibians. However, construction of some type of barrier between the forebay and the wetland could make the wetland more suitable for stillwater amphibians by excluding fish predators and/or reducing or eliminating the effects of water level fluctuations on the wetland.

***Creation of stillwater habitat at the proposed Lemolo No. 1 forebay***
In the North Umpqua Hydroelectric Project relicensing application (PacifiCorp 1995), the construction of the Lemolo No. 1 forebay was proposed to improve management flexibility for power generation. If this forebay is constructed, there may be an opportunity to design an associated pond or wetland that is hydrologically linked to the forebay. It may be possible to install a valve at the intersection of the forebay and the artificial pond or wetland that would block the movement of fish from the forebay into the pond or wetland, and would allow water to pass

from the forebay when water levels in the forebay are high, but prevent water from moving out of the constructed pond or wetland into the forebay when water levels are low.

***Habitat enhancement at Toketee Lake and/or Stump Lake***
It may be possible to create structures at Toketee and/or Stump lakes that partition habitat between deep and shallow water habitats and thus separate the habitats, to some degree, of predaceous fish and stillwater amphibians. Habitat improvements of this type, if feasible, would provide shallow water habitat and habitat structure for amphibians and would lessen water level fluctuations in shallow areas. A structure such as a "tide gate" could isolate shallow water areas and prevent or reduce water level fluctuations in the isolated areas. Structural enhancements such as aquatic vegetation and large woody debris would improve conditions for amphibians. It is probably not feasible to completely remove predaceous fish from areas of Toketee or Stump lakes that would be designated for stillwater habitat enhancement, to restrict their re-colonization from deepwater areas, and to prevent people from intentionally introducing them into the system—therefore, the goal of this design alternative would be to create the habitat conditions that favor amphibians in certain areas, even in the presence of predaceous fish. At Toketee Lake, areas that have been identified for potential enhancement of shallow water habitats include backwater areas along the northeast shore and an associated pond that currently supports northwestern salamanders.

The engineering designs and costs of the design alternatives described above for this management option have not been evaluated. As described above for Management Option 3, it would be preferable to implement several of these types of improvements, including both high elevation sites (such as the Lemolo No. 1 forebay) and low elevation sites (such as where Fallen Mountain Creek empties into Lemolo No. 2 forebay), in order to maximize potential benefits to amphibian populations in the watershed. For the purposes of this evaluation, it was assumed that artificial habitat would be constructed at a total of four sites. Management Option 4 was judged by the Terrestrial Subgroup to represent an intermediately desirable option, with moderate likelihood of meeting the management goals for terrestrial amphibians. As in Option 3, this option would involve experimental methods for improving habitats, but it may have a higher likelihood of success because it involves modifying existing habitats that may currently be at least partially suitable for amphibians, rather than creating habitats "from scratch". If this option is selected, a monitoring and adaptive management plan including criteria for success would need to be developed so that the success of the projects are evaluated and actions can be taken to improve the likelihood of success if goals are not being met.

**Management Option 5: Management of project impoundments for stable water levels and improvement of habitat conditions in or adjacent to project impoundments (combination of Options 2 and 4)**

This management option would combine the elements described above for Options 2 and 4. Water level fluctuations in project impoundments would be greatly reduced and structures would be added at four sites to improve shallow water habitat for stillwater amphibians and reduce the

vulnerability of amphibians to predation by fish. This option was judged by the Terrestrial Subgroup to be the best option, with an excellent chance of successfully meeting management goals for stillwater amphibians. Because of the confidence that the Terrestrial Subgroup has in its likelihood of success, monitoring under this option could be more limited than what would be appropriate under Options 3 and 4.

**Management Option 6: Creation of stillwater amphibian habitat independent of project impoundments and improvement of habitat conditions in or adjacent to project impoundments (combination of Options 3 and 4)**

This management option would combine the elements described above for Options 3 and 4. Stillwater habitats would be both improved in project impoundments and constructed off-site, for a total of eight sites. This option was judged by the Terrestrial Subgroup to have a relatively high chance of success of meeting management goals for stillwater amphibians. As in Option 5, monitoring under this option could be more limited than what would be appropriate under Options 3 and 4.

**Cost-benefit summary of management options**

Based on the currently available information, it is the judgement of the Terrestrial Subgroup that Option 1 (the no action option) would not be likely to meet the management goal for stillwater amphibians. In increasing order of likelihood of meeting the goal are Options 3, 4, 6, and 2, while Option 5 is considered to be the ideal option. It is not possible to fully evaluate the relative costs of the options described above, because the costs for most of the options have not been estimated.

**Other considerations**

Prior to development of site-specific plans for any of the action options, further consideration should be given to:

- the best spatial configuration of stillwater habitat enhancements in the basin, taking into account the potential population sources for colonization, likely dispersal distances between stillwater sites, and any physical or ecological barriers that would inhibit movement of stillwater amphibians across the landscape;

- the likely water temperatures and productivity levels that would exist in enhanced or created habitats, and how these factors would influence which species may live and successfully reproduce in them (for example, Cascades frogs would be more successful in relatively warm water sites; see Tyler et al. [1998] for a discussion of the influences of lake productivity on northwestern salamander populations);

- the potential impacts of habitat improvements on water temperatures and eutrophication in the watershed; and

- the successes and failures of similar projects that have been undertaken, especially those within the region.

## 5.7 OVERLAPPING ISSUES

Reservoirs and forebays are included as Riparian Reserves under the Northwest Forest Plan's Aquatic Conservation Strategy (USDA Forest Service and USDI Bureau of Land Management 1994). The evaluation of the function of project impoundments as Riparian Reserves is discussed under the issue of aquatic and riparian habitat connectivity (Section 3). Because of the direct hydrological connection between project impoundments and streams, management of reservoirs and forebays is interconnected with issues of water quality (Section 6) and instream flows (Section 4); in particular, ramping of reservoirs and forebays affects ramping in downstream reaches. Stillwater amphibians are also affected by terrestrial habitat connectivity (Section 8) and stream channel geomorphology (Section 2).