

**Appendix E**  
**Technical Memo 5**  
**Indian Creek Reservoir**  
**Fishery Habitat Evaluation**

# TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

September, 2008

## TECHNICAL MEMORANDUM NO. 5

### INTRODUCTION

The following is a summary of issues for the management of the Indian Creek Reservoir (ICR) fishery. Based on concerns about water quality due to high levels of nutrients in the reservoir's water and sediment, the California Water Quality Control Board, Lahontan Region (RWQCB) developed a Total Maximum Daily Load (TMDL) for phosphorous. The purpose of the TMDL is to ensure the attainment of water quality standards and to protect beneficial uses of the reservoir. The two beneficial uses related to the ICR fishery are sportfishing and cold freshwater habitat. The TMDL and beneficial uses are described in detail in the technical staff report prepared by RWQCB (Unsicker and Schembri 2000).

The South Tahoe Public Utility District (STPUD) is developing a master plan for all of their Alpine County operations and facilities. As part of this master plan, a plan to reduce the eutrophication of ICR and protect beneficial uses will be developed and implemented. This technical memorandum describes the adequacy of the existing system's chemistry, hydrology, and operations with respect to coldwater fishery habitat suitability of ICR. In addition to describing parameters of the existing system, characteristics of fisheries habitat that protect beneficial uses to the extent feasible, given the nature of the site, are discussed.

### EXISTING CONDITIONS

#### Physical Parameters

Indian Creek Reservoir is a relatively small impoundment, from 110 surface acres at low pool to about 160 acres at maximum pool, with a volume at maximum pool of 3,160 acre-feet. It is also shallow, with a mean depth at maximum pool of 20 feet and a maximum depth of 56 feet. At low pool, about one-third of the reservoir is shallower than six feet and about 13 acres exceed 13 feet in depth.

#### Water Inflow

The reservoir was constructed in an ephemeral basin. STPUD has reportedly acquired 555 acre-feet of water rights from the West Fork of the Carson River and from Indian Creek, and also has winter flushing flow rights from Indian Creek when available, although this water cannot be stored. Yearly inflows from the West Fork of the Carson River and from Indian Creek were 1,057 acre-feet in 1997, 960 acre-feet in 1998, and 593 acre-feet in 1999 (Unsicker and Schembri 2000). However, most of this water was released because it entered the reservoir as flushing flows during the winter months, and the reservoir level dropped from 47.2 feet in elevation at the staff gage in November of 1996 to 43.6 feet in November of 1999.

#### Water Quality

ICR water temperature is near the upper limits for supporting a coldwater ecosystem. Surface water temperatures over 20°C were common during the summers of 1999 and 2000. ICR is also an extremely productive reservoir and is classified as eutrophic in the RWQCB staff report for the TMDL 1999 (Unsicker and Schembri 2000). Nutrient concentrations and algal biomass are relatively high.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

The reservoir stratifies in the summer. During stratification, the hypolimnion is often anoxic. Based on depth profiles collected by STPUD in 1999 and 2000, dissolved oxygen (DO) can also be depleted in lower portions of the reservoir when the profile is relatively isothermal.

### **Fish Community**

Based on reports of the June 1999 fish kill and California Department of Fish and Game (CDFG) gill net surveys (S. Lehr, CDFG, personal communication), the fish community of Indian Creek Reservoir consists primarily of rainbow trout (*Oncorhynchus mykiss*), Lahontan cutthroat trout (*Oncorhynchus clarki*), tui chub (*Gila bicolor*), and Tahoe sucker (*Catostomus tahoensis*). Although speckled dace (*Rhinichthys osculus*) were not observed in the 1999 fish kill or in gill net surveys, they are found in the area and are likely to be present (Jones and Stokes Associates 1978). The rainbow trout are stocked in the reservoir by Alpine County, with funding provided by STPUD, and the cutthroat are stocked by CDFG. Brown trout (*Salmo trutta*) are also stocked by Alpine County in low quantities. Brook trout (*Salvelinus fontinalis*) have been previously stocked and a few individuals may remain. Non-game species have probably entered the reservoir through inflows from Indian Creek or the West Fork Carson River. Following are descriptions of the most common species found in ICR.

### Tui Chub

The tui chub is a widely distributed native species. It is found in a variety of habitats in California, Nevada, and Oregon. This species occurs in drainages on both sides of the Sierra Nevada, Lake Tahoe, and numerous reservoirs. While there are numerous subspecies, it generally reaches an average length of 230-280 mm. The tui chub eats invertebrates, vascular plants, algae, and occasionally fish. The composition of their diet depends on their habitat. As they increase in size, tui chub gradually prey on larger food items. Fish less than four inches in length eat little plant material, but as they increase in size, they feed more frequently on algae. Some subspecies are pelagic feeders and tend to prey more heavily on plankton, while others are associated with the substrate and feed primarily on aquatic invertebrates. It is not known which subspecies is found in ICR. In some areas, tui chub are an important food item for other species of fish, such as Lahontan cutthroat trout. In Pyramid Lake, for example, they make up most of the diet of adult cutthroat trout. Although they reproduce rapidly, their relatively small size makes them vulnerable to predation throughout their life. Tui chub may begin spawning as early as late April to as late as early August. Females mature at two to three years of age and are 200-250 mm long. Most males mature at two years when they are 200 mm long. Spawning generally occurs in the vicinity of heavy beds of vegetation in shallow water. After hatching, the young remain close to shore near heavy vegetative cover for most of the summer. In Lake Tahoe, some tui chubs are reported to spawn in or near the mouth of streams.

### Speckled Dace

The speckled dace is widely distributed throughout western North America. It has adapted to many different habitats and can be found in rivers, streams, lakes and ponds, though it is seldom found in water over about 1 m deep. Over 15 subspecies have been identified in Nevada. Speckled dace seldom live longer than about three years, and usually don't exceed 75-100 mm in length. They feed on benthic organisms, including aquatic insects, plant material and zooplankton. Juveniles feed more on plankton.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Spawning occurs over gravel substrate in lakes or streams. Dace spawn throughout the summer but peak activity occurs in June and July at water temperatures near 18°C.

### Tahoe Sucker

The Tahoe sucker is native to the Lahontan drainage of Nevada and northeastern California. It occurs in both large and small lakes and streams. The Tahoe sucker is a solitary, nocturnal forager that feeds on invertebrates, algae, and vascular plants. Midge larvae and pupae are the most common animal food eaten by suckers of all sizes. As they grow older, Tahoe suckers feed primarily on algae. This species is eaten by predaceous fish and birds. Although they are solitary feeders, fish of all age classes are reported to school for part of the day. Tahoe suckers spawn in spring in either lakes or streams. The timing is dependent on water temperature, which generally must reach at least 10°C. The majority of males are mature by age two. A few females are mature at age two, but most mature at three years of age. Spawning in lakes occurs over rocks and gravel bottoms at depths of 5 to 18 m. In streams, preferred spawning habitat is gravel riffles with a few large rocks. The young tend to stay in the weedy, shallow areas near shore in the lake or stream, however the adults occur in deeper water. During the day, areas with tall vegetation or shallow water are used, while at night, areas with sparse cover are used. At the beginning of winter, the fish tend to move offshore from warmer, shallow inshore water, which they inhabit during warm weather.

### Rainbow Trout

The original range of the rainbow trout is the Pacific coast of North America, mainly west of the Rocky Mountains. However, it has been introduced throughout the United States. The rainbow trout has adapted to a wide range of aquatic habitats and is found in large deep lakes, small farm ponds, large rivers, and small creeks with a flow of only a few cubic feet per second. Young rainbow trout feed on small benthic invertebrates, mainly insects and crustaceans. As they grow larger in size, rainbows may prey on small fish such as the tui chub. Wild rainbow trout spawn in spring, though fish raised in hatcheries have usually been selectively bred to spawn in the fall and winter.

### Lahontan Cutthroat Trout

The range of the Lahontan cutthroat trout includes the Truckee, Carson, and Walker Rivers, Donner Creek, and Pyramid, Walker, Donner, Independence, and Summit Lakes. The cutthroat occurs in a wide variety of cold waters, including large alkaline lakes (e.g., Pyramid Lake), small mountain lakes, major rivers, and small tributaries. In high elevation, cold water habitat, they can attain a length of 350 to 400 mm in about five years. They feed mainly on aquatic insects, although large individuals may prey entirely on fish. Fish greater than 300 mm in length prey on species such as the tui chub and the Tahoe sucker. This species spawns in spring, in similar habitat as rainbow trout. Females and males generally mature between two to four years of age.

### Data on Fish Populations in ICR

No data are available to assess population size of the various fish species present in ICR. However, CDFG collected some fish in gill net sets in 1985, 1993, 1995 and 1997 (Table 1: data are preliminary

## **TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION**

---

and subject to revision). While these data are not representative of relative abundance due to variability in capture probability among species, they nonetheless show that both tui chub and Tahoe sucker are important components of the fish community. They also suggest that year-to-year variability in the size of non-game fish populations may be high, and that relative abundance of non-game fish may be changing over time, perhaps in response to changes in reservoir conditions.

**TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT  
EVALUATION**

---

**Table 1  
CDFG Gill Net Catch, 1985-1977<sup>1</sup>**

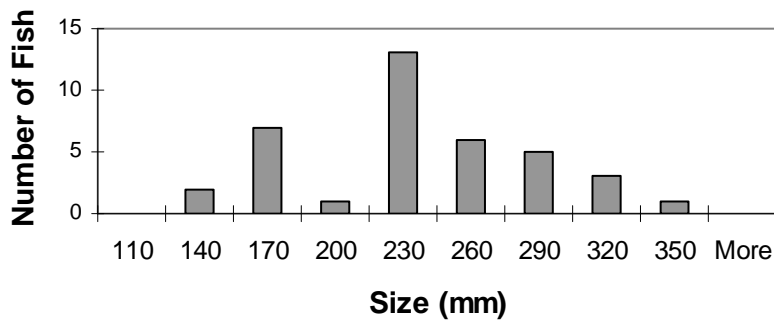
Year	Rainbow Trout	Tui Chub	Tahoe Sucker	Brook Trout	Lahontan Cutthroat
1985	3	254			1
1993	16		2		
1994	99		1	2	
1997	1	1	123		

Note:

<sup>1</sup> Data are preliminary and subject to revision. Data from S. Lehr, CDFG.

Analysis of the length-frequency distribution of Tahoe suckers captured in 1997 indicates that several year-classes of Tahoe suckers are present in ICR (Figure 1). A qualitative review of fish killed in June 1999 by CDFG indicated that several age classes of all of the non-game fish were represented. This suggests that non-game fish are either entering the reservoir each spring during high inflows, or are successfully spawning in the reservoir. Because of the relatively high density of non-game fish suggested by both the gill net sets and fish kills, it is likely that non-game fish are successfully spawning.

**Figure 1.** Length-frequency of Tahoe suckers in the 1997 CDFG gill net catch. Data are preliminary and subject to revision. (Data from S. Lehr, CDFG.)



# TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

## Fishery Management

Recreational use of ICR, measured at the Indian Creek Campground by the Bureau of Land Management (BLM), was 30,927 visits in the 2000 season, yielding over \$26,000 in revenue from campsites (T. Knight, BLM, personal communication). The most common reason for visiting the campground was freshwater fishing (12,414), followed by camping (6,153), hiking (5,128), picnicking (4,102), rafting (3,077), bicycling (2,051), and wildlife viewing (1,026). Although the survey did not differentiate between fishing in ICR and other local streams, it is likely that most of these visitors spent some time fishing ICR.

Salmonids are the primary target of fishing at ICR. Because no spawning habitat is available for trout, the fishery is sustained by regular stocking. The majority of the fish stocked are rainbow trout, planted by Alpine County. The source of rainbow trout is the American Trout and Salmon Farm in Susanville, California. These fish are hybridized; ancestral stock includes Eagle Lake rainbow, a wild strain adapted to high alkalinity, and steelhead. Unlike wild fish, the hybridized trout spawns in the late fall through winter (from October through February). This farm has been tested through U.C. Davis for several diseases (including whirling disease, *Ceratomyxa*, and bacterial kidney disease) for the past 17 years and has had no positive tests (D. MacFarland, American Trout and Salmon, personal communication). Cutthroat trout are occasionally stocked in ICR by CDFG. These fish are broodstock from the Heenan Lake stock maintained by CDFG. Annual stockings of cutthroat are usually less than 100 fish.

Rainbow trout are by far the most common fish planted. About 5,000 total pounds of catchable-size (100-300 mm) and trophy-size (2-6 kg) rainbow trout are stocked each year, about half of each. Some fingerling (125-150 mm) rainbows are also stocked at lower rates. To increase survival, stocking occurs in the spring before water temperature rises (usually before June 1), and in the fall after water temperature drops (late September or October).

Fishing is regulated by California State regulations. The season is open all year-round. Five fish of any size can be kept. All standard forms of capture are allowed, including bait. Boats are allowed and used extensively for fishing. Fishing also takes place from shore and from float tubes.

Two general forms of stocked fisheries are recognized. Put-and-take refers to a stocked fishery in which stocked fish are expected to be captured relatively quickly, before significant growth occurs. Put-and-take fisheries are common in situations where use is extremely high, or environmental conditions limit the long-term survival of fish. Put-and-grow management assumes that fish will survive for a period after stocking and will grow. Usually fish are stocked at a younger age and smaller size than in put-and-take fisheries.

Current conditions at ICR are intermediate between these two management types. Like most put-and-take fisheries, stocked fish are generally of a larger size, primarily due to the concern that survival of smaller fish would be low. However, like put-and-grow fisheries, stocked fish appear to survive for long periods. Though no data are available to assess growth and survival, substantial anecdotal evidence indicates that fish survive and grow for fairly long periods. All anglers interviewed for this analysis (9)

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

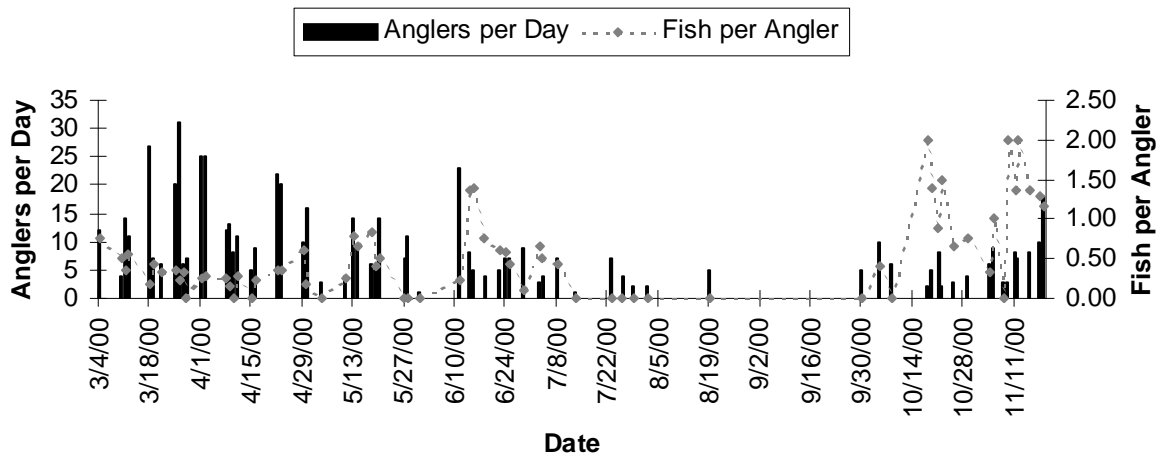
noted that fish were generally in excellent condition, representing good growth rates. Also, fish are captured at all times of the year, and fishing is often especially good in the early spring, representing fish that have survived over the winter.

Alpine County collects creel data at ICR. Most surveys are done on the weekends. The number of anglers checked and the number of fish in possession are recorded. For this analysis, data were available for the period March through November 2000. Creel surveys were conducted on 68 days during that period; 615 anglers with 287 fish in possession were surveyed. Almost all were rainbow trout; only one was a brown trout. The average daily possession was 0.52 fish per angler.

The number of anglers surveyed and the average daily possession varied significantly over the course of the season (Figure 2). Angler use and possession of fish were both low in the summer. In the spring, angler use is very high but the number of fish in possession was low, suggesting low catch rates. Angler use was much lower in the fall, although catch rates appeared to be higher. Variability in use and catch rates were probably influenced by two primary factors:

- § High water temperature. Catch rates dropped significantly at the end of June and remained low through the end of September. This was at least partly due to high water temperature, which reduced angling success. Few anglers were surveyed from the end of June through to the end of September. In fact, angling use of ICR is so low in the middle of the summer that the number of creel surveys is reduced. Based on the number of fish in possession, catch rates appeared to increase significantly in the late fall, which is probably at least partly due to lower water temperature.
- § Stocking. The timing of stocking also likely has significant influence over angling use related to fish stocking, which tends to occur in the fall when water temperature drops.

**Figure 2.** ICR anglers per day and fish in possession for the 2000 season, from Alpine County creel surveys.



# TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

## COLDWATER FISH ECOLOGY AND HABITAT

Adult trout require cold water less than about 23°C. They also require relatively high levels of dissolved oxygen compared to other fish. Based on laboratory studies, adult trout production may be impaired at DO concentrations of less than 7.0 mg/l (EPA 1993). Trout are also more sensitive to toxic agents, such as ammonia, than other fishes. Generally, younger trout are more sensitive to all of these parameters. The following discussion will therefore primarily address the habitat requirements of trout, as they are the most likely to be limited by conditions in the reservoir.

To assess the habitat requirements and ecology of the coldwater ecosystem in ICR, limnological data were collected for several regional reservoirs with similar characteristics to ICR (Table 2). These reservoirs were selected because they all support productive fisheries and they have similar characteristics to ICR. Data for Marlette Lake, Spooner Lake and Knott Creek Reservoir are from Sater (1994). Data for Heenan and Red Lakes are from Greene (1990). A short description of each of these reservoirs follows.

### Marlette Lake

Marlette Lake is located in the Carson Range on the east shore of Lake Tahoe. The reservoir was constructed in 1873; the dam was raised in 1960. It drains into Marlette Creek and eventually to Lake Tahoe, and is a water supply for Carson City and Virginia City. Marlette lies within Lake Tahoe Nevada State Park and supports a broodstock cutthroat trout population for the Nevada Department of Wildlife. There are no known significant anthropomorphic watershed disturbances and the lake is closed to fishing and swimming. Data for this reservoir were collected from 1991 to 1993.

### Spoooner Lake

Spoooner Lake is also in the Carson Range, a few miles south of Marlette Lake. It was constructed prior to 1927 to provide irrigation water. It supports a trout fishery open to catch and release fishing. Spoooner Lake also lies within Lake Tahoe Nevada State Park and there are no known significant watershed disturbances. Data for this reservoir were collected from 1991 to 1993.

### Knott Creek Reservoir

Knott Creek Reservoir is located in the Pine Forest Mountains of Humboldt County, near Denio. It was originally constructed in 1910, and the dam was last modified in 1989. The Nevada Department of Wildlife manages the reservoir as a trophy trout fishery, which is very popular. The watershed is small and is grazed extensively (J. French, NDOW, personal communication). Data for this reservoir were collected from 1991 to 1993.

### Heenan Lake

Heenan Lake is a reservoir constructed in 1929. It is located about 4.4 km southwest of Monitor Pass in Alpine County. Since the 1940's, the CDFG has maintained a population of Lahontan cutthroat trout in the reservoir, the broodstock for all reintroduction programs for this fish in the state (B. Sommer, CDFG, personal communication). There have been many reports of the lake's unusually high productivity

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

(Greene 1990). A master's thesis published in 1990 compared Heenan Lake to Red Lake and Lower Blue Lake to determine if physical, chemical or biological factors could be isolated which explained the high productivity in Heenan (Greene 1990).

In the following analysis, data for Heenan Lake are from this study. Field data were collected in 1985, when water diversions from the reservoir were managed significantly differently from today. Greene (1990) notes that the lake was drained for agricultural purposes beginning in August, resulting in mixing of the water column. It was drained to a depth of 4 m by October.

Since that time, CDFG has purchased water rights for the reservoir and now owns half the water right, with a minimum deeded pool of 500 acre-feet (B. Sommer, CDFG, personal communication). The data presented here are therefore not representative of current conditions. The levels of eutrophication and productivity were likely higher in 1985. However, the data from 1985 do represent conditions that had supported a trout fishery for about 40 years.

### Red Lake

Red Lake is located 1.4 km northeast of Carson Pass in Alpine County. This reservoir was constructed in 1924. It is currently managed primarily for a recreational fishery. Both brook trout and cutthroat trout are stocked. The entire watershed is a CDFG wildlife management area and there are no known significant anthropomorphic disturbances.

Like Heenan Lake, the data used in this analysis for Red Lake were collected in 1985, when the reservoir was managed differently. In 1985, Greene (1990) noted that the lake was drained for agricultural purposes beginning in August, and was nearly dry in September. Today all the water rights in the watershed are owned by CDFG and there is a 1,100 acre-foot minimum pool for fish (B. Sommer, CDFG, personal communication). Thus, the 1985 data likely reflect more productive and eutrophic conditions than present, though a viable trout fishery existed at that time.

### **ICR Coldwater Habitat**

Selected physical, water and trophic characteristics for each of these reservoirs were summarized (Table 2). A discussion of fish habitat parameters pertinent to the TMDL follows.

### Temperature

Of all the reservoirs, the highest summer water temperature (21°C) measured was in ICR, Heenan and Spooner Lakes. Although this temperature may be lethal to trout acclimated to lower temperatures, their upper temperature limit is around 24°C when they are acclimated to relatively high temperatures (Baker et al. 1993). The presence of a fairly strong trout population in Spooner Lake suggests that trout populations may persist in relatively high water temperature. Trout populations also occur in the Walker River in temperature measured at 24°C (S. Parmenter, CDFG, personal communication).

However, high summer water temperature is indicative of a marginal coldwater habitat. Temperature conditions in ICR are clearly borderline for a coldwater fishery. The ICR environment is such that

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

unusual climatic conditions, such as prolonged drought or persistent high air temperatures coupled with low wind, may result in lethal conditions for trout.

Another factor to be considered in assessing temperature is that trout are mobile and will seek refugia from temperature extremes (Spence et al. 1996). In lakes and reservoirs, thermal refugia are often found in the summer below the thermocline, in inflowing water, or in spring seeps. None of these refugia are found in ICR. The hypolimnion is generally unavailable due to low DO concentration, and the site constraints do not allow for large inflows of surface or groundwater.

Although temperature is likely limiting to trout at some times in ICR, high temperatures probably increase productivity of the trout population. Standing crop (biomass per area) and growth rates of fish in coldwater lakes tend to be considerably less than those of fish in warm water lakes (Moyle and Cech 1982).

The high water temperature in ICR is due to several environmental factors. It is located in a relatively dry and warm region, on the edge of the Great Basin (many of the reservoirs analyzed have similar conditions due to their geographic setting). The siting of the reservoir in an ephemeral tributary allows for little interaction with local groundwater, reducing the potential for cold water inflows. Little or no cold surface water enters the reservoir in the summer. Finally, the morphometry of the reservoir, characterized by low mean depth, increases the concentration of solar radiation and also contributes to high water temperature.

It is interesting to note that native trout in the central and southern Sierra or western Great Basin were generally confined to high elevation, oligotrophic lakes fed by snowmelt throughout the summer, or to very large lakes such as Pyramid. They did not persist in environments similar to that of ICR. Regardless of beneficial use designation, ICR is a marginal coldwater habitat due to inherent environmental factors. Though capable of high fishery productivity, it is subject to periodic limiting habitat conditions. This description fits most of the reservoirs compared in this analysis. All support highly productive fisheries and, with the possible exception of Marlette Lake, all have been subject to periodic fish kills.

**Table 2**  
**Selected Physical, Water and Trophic Characteristics of Regional Reservoirs**

	Marlette Lake	Spooner Lake	Knott Cr. Reservoir	Heenan Lake	Red Lake	Indian Creek Reservoir
<b>Physical Characteristics</b>						
elevation, m (ft)	2384 (7823)	2127 (6980)	1966 (6453)	2194 (7200)	2438 (8000)	1706 (5600)
surface area, h (acres) <sup>1</sup>	142 (352)	--	39 (96)	52 (129)	34 (85)	45 (110)
maximum depth, m (ft) <sup>1</sup>	13.4 (44)	6.7 (22)	5.5 (18)	10.7 (35)	10.7 (35)	12.2 (40)

**TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT  
EVALUATION**

**Table 2  
Selected Physical, Water and Trophic Characteristics of Regional Reservoirs**

	<b>Marlette Lake</b>	<b>Spooner Lake</b>	<b>Knott Cr. Reservoir</b>	<b>Heenan Lake</b>	<b>Red Lake</b>	<b>Indian Creek Reservoir</b>
mean depth, m (ft) <sup>1</sup>	10.4 (34)	6.4 (21)	3.0 (10)	7.1 (23.3)	5.0 (16.5)	4.2 (13.7)
volume (af) <sup>1</sup>	11,000	--	1,000	3,000	1,410	1,515
drainage area (acres) <sup>2</sup>	1,920	768	--	2,688	1,280	5,304
ratio of drainage area to surface area	5.5	--	--	20.8	15.0	48.2
year-round inflow in most years?	yes	yes	no	yes	yes	no
est. annual water yield to reservoir (af) <sup>3</sup>	--	--	--	--	--	1,500
ratio of annual water yield to volume	--	--	--	--	--	0.99
<b>Water Characteristics</b>						
summer stratification?	yes	yes	no	yes	yes	yes
winter stratification?	yes	yes	no	--	--	no
summer surface water temp., range °C <sup>4</sup>	12.4-17.5	16.5-21.0	14.0-18.4	12.0-21.0	11.5-20.5	12.0-21.0
hypolimnion regularly anoxic, summer	yes	yes	no	yes	yes	yes
hypolimnion regularly anoxic, winter	yes	yes	no	--	--	no
summer surface DO conc., range (mg/l) <sup>4</sup>	6.0-9.0	6.2-9.0	5.0-10.6	3.0-9.5	7.0-9.2	5.19-9.1
surface TP conc., range (mg/l) <sup>5</sup>	0.01-0.025	0.013-0.026	0.06-0.23	0.01-0.14	0-0.077	0.04-0.09
maximum hypolimnion TP conc., (mg/l) <sup>5</sup>	0.059	--	--	--	--	0.640
<b>Trophic Characteristics</b>						
secchi disk depth, range (m)	3.0-4.2	2.75-3.5	2.33-3.55	1.07-2.65	1.12-3.31	0.67-2.13
chlorophyll a concentration, range (ug/l)	1.2-8.9	0.2-2.6	0.6-14.0	0-70.0	0-35.0	10.0-41.0
carlson trophic index, range	39-52	15-40	26-57	--	--	--
carlson trophic index, mean	42	28	37	--	--	--
trophic state	meso-trophic	meso- oligotrophic	meso-trophic	--	--	eutrophic
occurrence of blue-green algae	common, dominant	occasional	dominant	common, dominant	common, dominant	common
occurrence of nitrogen-fixation	high	low	moderate	--	--	--
nutrient limitation	N, N-P	N, N-P	uncertain	--	--	P

**TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION**

---

**Table 2  
Selected Physical, Water and Trophic Characteristics of Regional Reservoirs**

	Marlette Lake	Spooner Lake	Knott Cr. Reservoir	Heenan Lake	Red Lake	Indian Creek Reservoir
--	---------------	--------------	---------------------	-------------	----------	------------------------

NOTES:

- <sup>1</sup> Calculated at the current operating pool elevation for Indian Creek Reservoir, as used in the TMDL. For other reservoirs, calculated at the maximum pool, where available.
- <sup>2</sup> For Indian Creek Reservoir, the drainage area includes the estimated contributing area for the water right diverted from the West Fork Carson River, as calculated by Kennedy/Jenks Consultants (2001).
- <sup>3</sup> Calculated by applying estimated rainfall to watershed area, minus evapotranspiration. Yield to the reservoir may be either surface or subsurface. May overestimate yield to the reservoir if a significant amount of precipitation goes to deep groundwater that bypasses the reservoir.
- <sup>4</sup> May through September.
- <sup>5</sup> These are ranges of instantaneous measurements for all of the reservoirs, generally collected during the summer months. Separate samples were collected from the epilimnion and the hypolimnion in Indian Creek Reservoir and Marlette Lake studies.

Dissolved Oxygen (DO)

During the summer the hypolimnion is regularly anoxic in ICR. Oxygen depletion also appears to take place in the lower part of the reservoir when the water column is nearly isothermal. Though low levels of oxygen may have adverse affects on aquatic habitat (Unsicker and Schembri 2000), neither of these conditions are particularly unusual in regional reservoirs supporting productive fisheries (Table 2). Marlette Lake, for example, regularly has an anoxic hypolimnion in the summer, as well as oxygen depletion in bottom waters during mixing (Sater 1994). On August 27, 1992 DO was below 3 mg/l at a depth of 10 m even though the reservoir was isothermal and no hypolimnion was observed. All the reservoirs studied, with the exception of Knott Creek, are oxygen-depleted in some location in the water column at some times of the year. Both Marlette and Spooner Lake inversely stratify in the winter and have anoxic hypolimnionia.

As noted earlier, laboratory research has shown that concentrations of DO of less than 7 mg/l affect productivity of trout. However, DO concentrations in natural environments are variable both spatially and temporally and dissolved oxygen has a major direct effect on fish distribution (Moyle and Cech 1982). As with water temperature, trout avoid areas of low dissolved oxygen concentration and seek oxygen refugia. In ICR, like many of the other reservoirs in this analysis, trout are likely in the epilimnion throughout most of the summer.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Physiological demand for oxygen is also variable temporally. During the winter, low water temperature may result in very low physiological demands for oxygen in trout. For example, DO below the ice in Kirman Lake was measured at less than 2 mg/l in the winter of 1999, yet trout survival was excellent (Steve Parmenter, CDFG, personal communication). Conversely, high water temperature results in higher physiological demands for oxygen.

Available oxygen appears to be limiting to trout populations during some portion of the year in other regional reservoirs. For example, Marlette Lake, which tends to mix relatively early in the year, was isothermal on 27 August 1992 with a water temperature of about 17.5° C. and a DO concentration of 6 mg/l or less (Sater 1994). On 13 July 1985, Hennan Lake was stratified at a depth of about 4 feet. Below this depth, DO concentration was less than 2 mg/l (Greene 1990). At some time during the summer, DO concentrations were below 7 mg/l in all available habitat in each of the reservoirs in this analysis. Thus, although some low DO concentrations may be mitigated by the physiological demands of trout, particularly during the winter, it appears that many productive trout fisheries in this area are likely limited to some extent by low DO concentrations during the summer.

ICR is probably the most limited by DO and temperature of all reservoirs studied. Refugia from low oxygen in ICR are likely to be very high in temperature compared to other reservoirs. These conditions are at least partly due to the inherent limiting environmental conditions in ICR: low surface inflow, low mean depth, reservoir siting, and climatic region.

### Productivity

With the exception of Knott Creek Reservoir, ICR and Heenan Lakes had the highest levels of total phosphorous (TP), significantly higher than Spooner or Marlette Lakes (Table 2). The cause of high TP concentrations in Knott Creek is not known, although there is heavy grazing nearby which could be causing erosion and high external loading (J. French, NDOW, personal communication). Because Knott Creek Reservoir does not stratify, internal loading is not likely to be a significant source of TP (Sater 1994). In 1985, Hennan Lake may have had even higher TP concentrations in the epilimnion than current levels in ICR. Hypolimnion TP concentrations in Heenan Lake were not sampled.

Unsicker and Schembri (2000) concluded that high TP concentrations in ICR are likely due to internal loading from sediments rich in phosphorous from past effluent discharge. This conclusion appears to be partly validated by data obtained from other area reservoirs. Although internal loading of phosphorous is an important process in both Marlette and Spooner Lakes (Sater 1994), neither have TP concentrations approaching those of ICR. Yet TP concentrations in Heenan Lake were also unusually high in 1985. This may have been partly due to the irrigation and grazing practices at the time, but is probably also reflective of inherent environmental conditions in east side reservoirs.

The RWQCB also concluded that TP is the nutrient likely to limit productivity in ICR (Unsicker and Schembri 2000). Though it is possible that ICR differs in this respect from other area reservoirs, studies have shown that Marlette Lake and Spooner Lake are more likely to be nitrogen limited or nitrogen-phosphorous co-limited (Sater 1994).

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Whatever role TP plays in limiting production in ICR, productivity is high in relation to other area reservoirs. Chlorophyll a concentrations and Carlson Trophic Index (used in Table 2) are higher in ICR than in all other reservoirs for which data were available, except for Heenan Lake in 1985 (Table 2). There are many factors that could contribute to high productivity: the shallow depth of the reservoir, which allows rapid and continuous cycling of nutrients from sediment into the water column; high water temperature; nutrient concentration due to low inflows in the summer; and extensive fish stocking, which may load significant amounts of nutrients from external sources. It also appears clear that loading of phosphorous from years of effluent storage plays a major role in current productivity. The interaction of all these potential causes of high productivity is complex and makes determination of the importance of any single factor difficult.

The link between impacts on water quality due to eutrophication and resulting impacts on the coldwater fishery are similarly complex. Many conditions perceived to be symptomatic of eutrophication and therefore detrimental to coldwater fisheries appear to be common ecological components of productive trout fisheries in the area. Blue-green algae, for example, are considered a symptom of eutrophication (Unsicker and Schembri 2000). However, blue-green algae are the dominant phytoplankton in Marlette Lake, which supports a highly productive trout fishery and is classified as mesotrophic based on chlorophyll a concentration (Sater 1994). Another common symptom of eutrophication, an anoxic hypolimnion, also appears to be relatively common in reservoirs of the region. Marlette, Spooner, Heenan and Red Lakes have regularly anoxic hypolimnia and support productive fisheries. Heenan Lake is a good example of a highly productive fishery in a relatively eutrophic environment. In 1985, Heenan Lake showed symptoms of eutrophication that probably exceed those in ICR today, yet it supported a productive cutthroat fishery.

Comparison of ICR with other reservoirs in the area also sheds light on the relative importance of environmental and anthropomorphic factors on eutrophication. Although all reservoirs are artificial environments and cannot be expected to behave ecologically like natural systems, ICR is inherently limited more than the other reservoirs reviewed due to its construction in an ephemeral watershed. Yet even Marlette and Heenan Lakes, constructed in areas with more water, show many symptoms of eutrophication noted in the RWQCB Staff Report (there is no evidence of significant human disturbance in their watersheds). This is likely due to the pervasive influence of a relatively hot and dry climate, coupled with the inherent limitations of artificial reservoirs. Given the siting of ICR, it seems very likely that it would exhibit some signs of eutrophication had it never received effluent, probably more so than the other reservoirs analyzed. The addition of phosphorous and nitrogen in the effluent accelerated and accentuated eutrophication, resulting in habitat conditions in ICR that are more marginal for coldwater fish than in other area reservoirs.

### **Fish Kills**

Fish kills occurred with some regularity when the reservoir received effluent, although it appears that only one major kill has occurred since that time, in early June of 1999. A qualitative survey of the reservoir after the June 1999 kill indicated that all species present in the reservoir were killed, that several age classes of most species were involved, and that at least several thousand fish died (S. Lehr, CDFG, personal communication).

The cause of the kill in 1999 was not determined. Several different conditions can cause extensive fish kills. Possible environmental causes include low dissolved oxygen, high concentrations of free ammonia,

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

or high concentrations of hydrogen sulfide. All of these environmental conditions are caused by high productivity and eutrophic conditions. Biological factors such as disease can also cause extensive fish kills. The wide variety of species and age classes included in the 1999 kill suggest an environmental rather than a biological cause.

Because all species of fish and most age-classes were involved in this fish kill, the causative agent was probably widely distributed through all habitats in the reservoir, suggesting that the lake was mixing. Data collected by STPUD indicate that the reservoir was mixing or only mildly stratified on 5 May 1999, about a month prior to the fish kill. On 16 June 1999, the reservoir was stratified and anoxic in the hypolimnion. It is likely that mild stratification in late May, coupled with high productivity common in the spring following mixing, resulted in an anoxic hypolimnion. Anoxia in the hypolimnion favors the production of potentially toxic free ammonia or hydrogen sulfide, which could then have been distributed throughout the reservoir when the mild stratification was disrupted by wind.

The apparent abundance of tui chub in the kill might be the result of several factors. It could reflect the actual relative abundance of tui chub in the fish community of the reservoir at the time of the kill. Alternatively, tui chub might have been more susceptible than other fishes as a result of variable distribution of the toxic substance into habitat preferred by chub. Or tui chub might have been less successful at avoiding the substance than trout. Available data are insufficient to answer this question.

Available data are also insufficient to determine the proportion of fish in the reservoir killed. A successful fishing derby was held one week after the fish kill but it appears that the reservoir was stocked with trout in the interim (Dave McFarland, American Trout and Salmon, personal communication). The stocking, which occurred only a few days after the kill, appeared to be successful.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Fish kills in other area reservoirs do not appear to affect the entire population. A large kill occurred on Heenan Lake in the fall 1994. Over 2,000 dead cutthroat trout were counted (B. Sommer, CDFG, personal communication). Dissolved oxygen concentrations were measured between 1.9-3.0 mg/l for about one month during the kill. A significant portion of the cutthroat population found refugia sufficient for survival, as the following spring 2,000-3,000 cutthroat returned to the spawning station.

Many area reservoirs experience periodic fish kills (kills have also occurred in Knott Creek Reservoir, and Spooner and Kirman Lakes, for example). All of these events appear to be tied to unusual climactic conditions, such as extreme drought or intense heat. As noted earlier, though area reservoirs can be very productive trout fisheries, they tend to be marginal coldwater habitats, especially those in areas of low rainfall, long summers, and high summer temperatures. Periodic short-term extremes in climate result in fish kills because there is little margin for reduction in water quality with respect to average conditions.

It is not possible to predict the frequency of future fish kills in ICR, as climate plays a major role. Prolonged droughts will almost certainly increase fish kill frequency, while wet, cool weather will tend to reduce the frequency of fish kills. It is likely, however, that the inherent morphology and inflow characteristics of ICR make it more prone to fish kills than other area reservoirs. Furthermore, the nutrient-rich sediment in ICR probably makes fish kills even more likely by enhancing productivity. Nonetheless, based on the experience of other area reservoirs, fish kills would be likely to occur even if nutrient-rich sediment were removed from ICR.

### **Fish Ecology**

Although definitive data are lacking, gill net surveys and species composition in fish kills suggest that the fish community in ICR is dominated by non-game fish, including Tahoe sucker and tui chub. Their dominance is not unexpected given environmental conditions; non-game fish have a competitive advantage over trout due to their tolerance of higher water temperature and higher levels of toxic substances. Moreover, the non-game fish are probably able to reproduce successfully in the reservoir. Other area reservoirs have similar population dynamics. Spooner Lake, for example, has a large population of tui chub, which are likely competing with trout for food and space (K. Tisdale, NDOW, personal communication).

The dominance of non-game fish has implications for management of the trout. Stocked trout probably compete with larger tui chub and suckers for food and space, resulting in lower growth and survival for the trout when non-game fish populations are high. This impact is probably more important for smaller trout; juvenile trout and non-game fish of all ages use similar habitat and food sources. The survival of juvenile trout plants would likely be low due to high populations of non-game fish.

High populations of non-game fish could also be beneficial to larger adult trout as they represent a potentially important food source. Cutthroat trout in Pyramid Lake feed largely on insects and zooplankton until they reach a size of about 300-330 mm, when fish becomes an important part of their diet. The diet of fish 500-750 mm in length is about 94% fish, almost all of which are tui chub (Sigler and Sigler 1983).

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Another potentially important effect of high populations of non-game fish concerns water quality. The non-game fish in ICR, particularly tui chub, feed extensively on zooplankton, especially as juveniles. Extensive feeding on zooplankton, particularly the larger-bodied species, can result in shifts in the abundance of phytoplankton on which the zooplankton feed. Larger phytoplankton may become more abundant in response to the shift in zooplankton size. A net increase in phytoplankton abundance may even occur (Baker et al. 1993), with potential water quality impacts.

### IMPAIRMENT OF BENEFICIAL USES

The RWQCB Technical Staff Report for the ICR TMDL states that eutrophic conditions at the levels found in ICR are not compatible with long-term support of a recreational trout fishery, for several reasons:

- § Trout require relatively low temperatures and high levels of dissolved oxygen;
- § The organisms used by trout as food are adversely affected by eutrophication;
- § Fouling of fishing gear by high levels of algae and other plants; and
- § Odors in fish flesh and water caused by blue-green algae.

Each of these impairments of the recreational trout fishery is discussed below.

#### Temperature and Dissolved Oxygen

Although trout generally require lower temperatures and higher levels of DO, the specific requirements of trout have been discussed in detail in previous sections. Like many area reservoirs, trout production in ICR is probably limited at some times of the year by either DO or temperature. However, DO limitation is inherent in reservoirs of the region, which are marginal coldwater habitat due to climate, yet still support productive fisheries.

#### Impacts to the Food Chain

No data are available to substantiate this potential impact. In fact, most anecdotal evidence from fisherman suggests that growth rates of trout are good. Nine anglers who regularly use the reservoir were interviewed for this analysis to assess their experience at ICR. All of them responded that fish appear to be in good condition, with no evidence of malnutrition. Most stated that the fish caught in ICR were in better condition than fish caught in Topaz or other area reservoirs.

#### Fouling of Gear

All anglers interviewed noted that ICR has relatively high levels of algae. However, only one of the nine forgoes fishing at the reservoir due to weeds or algae, and then only at certain times of the year.

## **TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION**

---

### Odors in Fish Flesh

Seven of the nine anglers interviewed have consumed fish from the reservoir. None noted any unusual taste in the fish. One angler interviewed has been consuming fish from the reservoir for over 17 years.

The link between eutrophic conditions and impairment of the beneficial use of a recreational trout fishery is not clear in ICR because many factors other than water quality influence the angler's perception of a fishery. While the interviews conducted show that eutrophic conditions are apparent to anglers, these conditions do not appear to discourage fishing use. Many factors other than water quality influence the quality of the fishing experience, including ease of access, the proximity to local population centers, and especially the quality of the fishing. Many of the anglers interviewed noted that they fished at ICR because it was close to their home and access was easy. But the most common comment from anglers interviewed was that the availability of fish outweighed any concerns with algae or other conditions associated with eutrophication.

Data on use of ICR also suggest that symptoms of eutrophic conditions are not substantially limiting fishing use. Visitor use at the BLM campground is among the highest for all areas in the Carson District of the BLM (A. Callan, BLM, personal communication). One of the anglers interviewed, who guided clients on fishing trips to ICR in the early 1990's, noted that the ICR fishery was "discovered" in the mid-1990's and use increased during that time to the point that it began to affect the quality of the fishing experience.

Thus most of the available evidence indicates that ICR is substantially meeting the desired condition of a recreational trout fishery. However, it is also clear that ICR is limited in its ability to support the beneficial use at all times over the long-term, due to several factors. The local climate, siting and design of the reservoir, low amount of surface water inflow, and nutrient enrichment due to effluent discharge all contribute to high productivity and the potential for fish kills. While habitat and management improvements may improve the ability of ICR to support a trout fishery, the inherent climactic and design limitations place some limits on the reservoir as coldwater habitat.

### **THE ICR FISHERY AND TMDL STANDARDS**

The Lahontan Regional Water Quality Control Board listed ICR and Indian Creek on the list of State Impaired Water Bodies (303d list). This listing prioritizes the development of Total Maximum Daily Loads (TMDL) to control and mitigate the pollutant(s) of concern. Indian Creek Reservoir is designated a cold water fishery; this entails water quality parameters consistent with low production lakes. Because of the ambient nutrient load in the reservoir sediments and water column, the reservoir is highly productive, or eutrophic. The management strategy to improve water quality by decreasing algal production is focused around the management of phosphorus. The following table, Table 3, is a summary of the numeric targets and indicators for ICR, based on the Total Maximum Daily Load and Implementation Plan for ICR, by the California Regional Water Quality Control Board, Lahontan Region, July 2002 <[http://www.swrcb.ca.gov/lahontan/water\\_issues/programs/tmdl](http://www.swrcb.ca.gov/lahontan/water_issues/programs/tmdl)>.

# TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

**Table 3: Indian Creek Reservoir Water Quality Targets.**

Indicator*	Target Value	Reference
Total P concentration	(Interim**) No greater than 0.04 mg/L, annual mean	Current water quality objective (mean of monthly means)
Total P concentration	(Long term**) No greater than 0.02 mg/L, annual mean	USEPA, 1988, 1999
Dissolved oxygen concentration	(Interim**) 30 Day Mean 6.5 mg/L; 7 Day Mean Minimum 5.0 mg/L; 1 Day Minimum 4.0 mg/L	Region-wide water quality objective for waters designated for COLD use
Dissolved oxygen concentration	(Long term**) Shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L at any time, whichever is more restrictive	Water quality objective for surface waters of Indian Creek watershed
Secchi depth	Summer mean no less than 2 meters	USEPA, 1988, 1999
Chlorophyll A	Summer mean no greater than 10 ug/l	USEPA, 1988, 1999
Carlson Trophic Status Index	Composite index no greater than 45 units	USEPA, 1988, 1999

\*These indicators will be measured for at least one depth profile sampling station in Indian Creek Reservoir. The Carlson Trophic Status Index will be computed from other parameters as explained in the TMDL implementation plan technical staff report.

\*\*Interim targets are expected to be attained by 2013. Long term targets are expected to be attained by 2024.

### **TP Concentration**

The TMDL standard for TP is 0.02 mg/l, annual mean concentration. While data for Marlette and Spooner Lakes are not sufficient to calculate an annual mean for TP, summer monthly means in these reservoirs typically exceed the standard, while winter means are generally lower than the standard (Sater 1994). Annual mean TP concentration in these lakes is probably near the ICR TMDL standard. However, as was noted earlier, both of these reservoirs possess morphological and hydrologic characteristics that reduce their inherent productivity with respect to ICR. Marlette, for example, has a much higher mean depth and receives much larger inflows of surface water. It does not seem reasonable to expect ICR to have similar concentrations of TP.

The current TP concentrations in ICR are likely contributing to limitations on coldwater habitat. Reduction of TP to current standards (0.04 mg/l) is probably reasonably attainable and would have positive effects on the ICR fishery.

### **Dissolved Oxygen**

The TMDL standard for DO is 7 mg/l, an instantaneous objective to be achieved at all times throughout the water column. None of the reservoirs included in this analysis would meet this objective. Most have anoxic hypolimnia at some time during the year. All of the reservoirs analyzed also have depleted DO throughout the water column (below the ICR standard) for short periods at times throughout the year. Low DO concentrations are an inherent feature of small reservoirs in the area.

## **TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION**

---

All of the area reservoirs analyzed are productive fisheries, so DO concentration alone does not appear to predict fish habitat or fishery potential in any meaningful way. It should also be noted that adherence to this standard would require continuous artificial enhancement of ICR rather than restoration to conditions that might reasonably be expected had effluent never been placed in the reservoir.

As discussed earlier in this document, temperature and DO certainly interact in ICR to limit coldwater habitat more than in other area reservoirs. Reduction of TP available would probably improve conditions by reducing the demand for oxygen in the hypolimnion, though it is very unlikely to eliminate anoxia.

### **Secchi Disk Depth**

The TMDL standard for secchi disk depth is a summer mean depth no less than 2.0 m. Secchi depth is low in ICR compared to other area reservoirs, but it is not likely that Heenan or Red Lakes would have met this standard in 1985. The impact of low secchi disk depth on the ICR fishery is unknown. Low visibility may affect the ability of sight-feeding fish to detect prey, but no data are available to evaluate trout growth rates. It would probably not be possible in any event to relate growth rates specifically to secchi depth. Reduction of TP would probably improve secchi depth.

### **Carlson Trophic Status Index (CSI) and Chlorophyll a Concentration**

Both of these parameters are measures of productivity. With the exception of Heenan and Red Lakes, other area reservoirs appear to meet these standards based on existing data. However, it is probably not reasonable to expect ICR to have similar productivity characteristics given its morphology and surface water inputs. ICR will likely have higher values for each of these parameters than other area reservoirs, and perhaps higher than the TMDL standards, even if TP meets the TMDL standards.

The link between these parameters and the coldwater fishery is contradictory. High productivity has positive benefits in terms of food availability for trout, but also has negative impacts because the conditions that cause fish kills are likely to be enhanced by high productivity. One of the primary reasons cited in the RWQCB Technical Staff Report for establishing the standard for CSI in ICR is that under mesotrophic conditions (CSI from 40 to 50) there is increasing probability of anoxia in the hypolimnion. However, area reservoirs classified as mesotrophic (with CSI values less than the standard proposed for ICR) have anoxic hypolimnia, yet support productive fisheries.

Reducing TP concentrations in ICR would likely result in lower values for each of these standards, and would also reduce the occurrence of conditions which lead to fish kills.

## **PROTECTION OF BENEFICIAL USES**

Several fishery management and habitat improvements might be implemented to improve coldwater habitat or otherwise help protect the beneficial uses of ICR. These fishery management and habitat improvements are outlined below and qualitatively evaluated. They will be described in more detail in a subsequent fishery management plan.

### **Fishery Management**

#### Fisheries Monitoring

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Monitoring of the ICR fishery is an important requirement for maximizing production of the fishery and protecting the beneficial use. Fishery data collection could answer many questions important to the management of the ICR fishery, including:

- § How well do stocked fish grow and survive?
- § What food sources are trout and non-game fish using?
- § Do larger trout prey on non-game fish?
- § How many of the stocked trout are caught by anglers?
- § If fish kills occur, which species and age-classes are involved?

A monitoring program should include spring and fall gill net surveys to assess relative abundance, growth rates, and food habits. The monitoring program should also include angler surveys, which could consist of questionnaires included with BLM camping permits. Also, existing creel surveys should include length and weight of fish, and perhaps dietary information to ascertain if trout are using non-game fish as forage.

### Stricter Regulations (Trophy Fishery)

As discussed earlier in this document, control of the non-game fish population could have positive benefits for water quality. One effective way to control non-game fish is by managing for larger trout that prey primarily on other fish. Creel restrictions are often an effective tool for increasing the number of large fish. For example, limits that require the release of larger fish or allow the retention of fewer larger fish are often effective. However, the fishery should be carefully monitored prior to instituting protective limits to ascertain if trout are surviving to a large size and if they are preying on non-game fish.

### Lahontan Cutthroat Introduction

Stocking Lahontan cutthroat trout in ICR fishery may have positive benefits. These fish may perform better than rainbow trout in ICR; they evolved in the Great Basin and are tolerant of high alkalinity. A strong cutthroat population might also provide water quality benefits; at large sizes, they are known to prey extensively on tui chub in Pyramid Lake and might do the same in ICR. A trophy cutthroat fishery would also be a unique fishing experience in the area.

### **Habitat Improvements**

Several physical improvements might be considered to benefit coldwater habitat in ICR. Generally, these physical improvements will be aimed at either reducing nutrient concentration or adding additional water. The advantages and disadvantages of physical improvements are described below.

### Inactivation of Phosphorous in Bottom Sediment

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

Phosphorous in the sediment can be inactivated with substances such as alum (Unsicker and Schembri 2000). The intent is to reduce internal loading of phosphorous, resulting in lower productivity and less eutrophic habitat conditions.

### *Advantages*

- § Reduced algae populations and biological oxygen demand, resulting in higher DO concentrations.
- § Environmental conditions less likely to result in fish kills.
- § Clearer water, less aquatic weeds.

### *Disadvantages*

- § Uncertainty in how well inactivation would work.
- § Expense.
- § Requires the addition of further substances into the reservoir whose long-term fate is unknown.

### Removal of Sediment

Phosphorous-rich sediment could be either dredged or removed from the reservoir after it is drawn down. Removal of sediment would result in lower productivity and less eutrophic habitat conditions.

### *Advantages*

- § Reduced algae populations and biological oxygen demand, resulting in higher DO concentrations.
- § Environmental conditions less likely to result in fish kills.
- § Clearer water, less aquatic weeds.
- § Does not require the addition of chemicals or other substances.
- § If the reservoir is drawn down, non-game fish could be eliminated.

### *Disadvantages*

- § High expense.
- § May result in increasing leakage from the reservoir, or require a liner.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

- § If reservoir is drawn down, it may be difficult to refill it given current water availability.
- § Whether reservoir is dredged or drawn down, it would likely be unusable for recreational purposes for at least one year.
- § Draw down could eliminate large trout that have survived over several seasons.

### Use of Additional Water for Flushing Flows

Additional water would improve coldwater habitat by improving water temperature and dissolved oxygen concentration. Additional water might also reduce total nutrient concentration.

#### *Advantages*

- § Additional water rights for flushing flows have been secured with the purchase of the Diamond Valley Ranch.
- § Reduced algae populations and biological oxygen demand, resulting in higher DO concentrations.
- § Expanded refugia for trout from adverse environmental conditions, making fish kills less likely.
- § Clearer water, less aquatic weeds.
- § Does not require the addition of chemicals or other substances.

#### *Disadvantages*

- § Aquatic habitat in the source of water may be harmed by diversions. Reproducing populations of wild trout should not be harmed to divert additional water to the ICR put-and-take fishery.

### Hypolimnetic Oxygenation

The District's current program of injecting oxygen directly into the hypolimnion could improve fish habitat by reducing the internal loading of phosphorous and by providing additional oxygen.

#### *Advantages*

- § Hypolimnion oxygen concentrations would be raised directly, providing improved trout habitat.
- § Reduced algae populations and biological oxygen demand, resulting in higher DO concentrations.
- § Expanded refugia for trout from adverse environmental conditions, making fish kills less likely.

## TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT EVALUATION

---

- § Clearer water, less aquatic weeds.

### *Disadvantages*

- § Long-term maintenance cost.
- § Requires constant input of energy and oxygen; failure of the system is probable over long-time frames, which could result in fish kills.

*The original draft of this technical memorandum was prepared by Kennedy/Jenks Consultants in 2003 and updated by Stantec Consulting in 2008.*

### REFERENCES CITED

- Baker, J.P., H. Olem, C.S. Creager, M.D. Marcus, and B.R. Parkhurst. 1993. *Fish and fisheries management in lakes and reservoirs*. EPA 841-R-93-002. Terrene Institute and U. S. Environmental Protection Agency, Washington, DC.
- Greene, S.L. 1990. *Species composition and nutrition requirements in the phytoplankton communities of Heenan, Red and Lower Blue Lakes*. Master of Science Thesis, California State University Sacramento, Sacramento, CA.
- Jones and Stokes Associates, Inc. 1983. *Final supplemental environmental impact report, South Tahoe Public Utility District Wastewater Facilities Planning Program*. May 1893, SCH No. 83020702.
- Kennedy/Jenks Consultants, Inc. 2001. *Comments in response to draft total maximum daily loads to Indian Creek Reservoir*. 3 January 2001. Kennedy/Jenks Consultants, Reno, NV.
- Moyle, P.B. and J.J. Cech. 1982. *An introduction to ichthyology*. Prentice-Hall, Inc., Englewood Cliffs, NJ.
- Porcella, D.B., V.D. Adams, and E.J. Middlebrooks. 1978. *South Tahoe Public Utility District effluent effects on Indian Creek Reservoir*. Final report to South Tahoe Public Utility District. Middlebrooks and Associates, Logan, UT.
- Sater, E.M. 1994. *Seasonal nutrient limitation at four high altitude, shallow reservoirs of the Tahoe basin and northern Nevada*. Tahoe Research Group, University of California, Davis, CA.
- Sigler, W.F. and J.W. Sigler. 1987. *Fishes of the Great Basin: a natural history*. University of Nevada-Reno Press, Reno, NV.
- Spence, B. C., G. A. Lomnický, R. M. Highes, and R. P. Novitzki. 1996. *An ecosystem approach to salmonid conservation*. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

**TECHNICAL MEMORANDUM – INDIAN CREEK RESERVOIR FISHERY HABITAT  
EVALUATION**

---

Unsicker, J., and H. Schembri. 2000. *Technical staff report: Total maximum daily load and implementation plan, Indian Creek Reservoir, Alpine County, California*. California Regional Water Quality Control Board, Lahontan Region, South Lake Tahoe, CA.