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Final
Indian Creek Reservoir TMDL Implementation Plan

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Prepared for

South Tahoe Public Utility District
1275 Meadow Crest Drive
South Lake Tahoe, CA 96150

K/J Project No. 007019.17

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Executive Summary

This report presents the mitigation measures that will be implemented by the South Tahoe Public Utility District (District) to meet the numeric standards for water quality in Indian Creek Reservoir (ICR). These numeric standards were developed by the Lahontan Regional Water Quality Control Board (LRWQCB) in the July 2002 *Adopted Amendments to the Water Quality Control Plan for the Lahontan Region Concerning Total Maximum Daily Load and Implementation Plan for Indian Creek Reservoir, Alpine County, California* (LRWQCB 2002) to address eutrophication (increased algae production due to elevated nutrient levels resulting in lowered dissolved oxygen and potentially fish kills) in ICR. The LRWQCB concluded that phosphorus loading, principally from sediment residual associated with prior use of ICR for treated wastewater effluent storage, was the primary source of eutrophication.

This Implementation Plan presents the preferred mitigation alternatives for meeting the numeric standards in the Total Maximum Daily Load. To evaluate the potential for success of the mitigation measures and to monitor progress of the proposed measures, it was necessary to refine the loading estimates used in the TMDL. A critical missing piece of the TMDL is an accurate estimate of residual phosphorus in the lake sediment. To address this data need, the District and Kennedy/Jenks Consultants are currently implementing a sediment sampling and analysis program in ICR. The final results of this study will be included in an addendum to this report.

Other elements of the ICR total phosphorus mass balance not dependant on the sediment data were estimated for the reservoir to further explore the internal and external phosphorus loading and to aid in the evaluation of restoration alternatives. Kennedy/Jenks Consultants also prepared a water budget for ICR in support of the mass balance calculations.

Kennedy/Jenks Consultants previously reviewed known nutrient mitigation technologies and evaluated their feasibility for application to ICR. From this evaluation, preferred mitigation alternatives were selected for implementation at ICR. To help ensure that water quality standards are met, the implementation plan includes monitoring targets and adaptive management of mitigation strategies to provide course correction if the implemented mitigation alternative does not appear to be meeting the numeric targets. Additional mitigation measures may be implemented if interim goals are not met.

The implementation plan includes a schedule to implement one of the preferred mitigation alternatives by June 2007, a monitoring program to demonstrate effectiveness of the mitigation, and check points and interim goals for adaptive management of mitigation measures, if necessary.

Section 1: Introduction

Indian Creek Reservoir (ICR) was constructed in 1967-68 on an ephemeral tributary of Indian Creek, which is a tributary of the East Fork Carson River. The location of the reservoir within the Carson River watershed is shown in Figure 1. The reservoir was designed to store tertiary treated wastewater effluent exported from the Lake Tahoe watershed for subsequent reuse in pasture irrigation. South Tahoe Public Utility District (District) is responsible for operating and monitoring water quality at ICR. The U.S. Bureau of Land Management (BLM) operates a campground and day use facilities at the reservoir. The reservoir became eutrophic during the 1970s and was placed on the California Section 303(d) list of water quality impaired water bodies in the 1980s. ICR was converted from a treated effluent receiving reservoir to a freshwater recreation reservoir in 1989. Since then, its level is maintained with water diverted from the West Fork Carson River and Indian Creek.

1.1 Total Maximum Daily Load

The Lahontan Regional Water Quality Control Board (LRWQCB) developed numerical standards for water quality in ICR in its July 2002 *Adopted Amendments to the Water Quality Control Plan for the Lahontan Region Concerning Total Maximum Daily Load and Implementation Plan for Indian Creek Reservoir, Alpine County, California* (LRWQCB 2002a). The goal for the numerical standards is to restore ICR from a eutrophic system to a mesotrophic system. The basis of the TMDL is provided in LRWQCB's July 2001 Technical Staff Report (LRWQCB 2001) and May 2002 Supplement (LRWQCB 2002b).

1.2 TMDL Requirements

The TMDL includes a requirement that the District prepare this implementation plan. TMDL requirements directed at the District include:

- Immediately after final approval of the TMDL, Regional Board staff will request a report from the District on the method(s) it intends to use to reduce internal loading of phosphorus to Indian Creek Reservoir from the sediment and to optimize reservoir management for protection and enhancement of aquatic life and recreational uses.
- By 15 months after final approval of the TMDL, the District will investigate the feasibility of controls for internal phosphorus loading to Indian Creek Reservoir and the feasibility of other management measures to protect and enhance beneficial uses and will submit a plan for approval by the Regional Board. Depending upon the nature of the proposed action, the Regional Board may provide direction to staff for implementation, issue waste discharge requirements and/or a formal monitoring program for activities to control internal phosphorus loading, or take other appropriate action.
- By 2013, ICR must meet interim water quality standards, including a total phosphorus concentration of 0.04 mg/l.
- By 2024, ICR must meet final water quality standards, including a total phosphorus concentration of 0.02 mg/l.

INSERT SITE MAP HERE

NAME IT "**FIGURE 1"**

The TMDL also includes requirements for other stakeholders to control external loading:

- Within 4 months after final approval of the TMDL, Regional Board staff will convene a stakeholder group for ongoing communication about TMDL issues. The group should include, but will not be limited to, representatives of the District, the BLM, the U.S. Forest Service, Alpine County, and other public and private landowners in the subwatershed affected by the TMDL. Participation should also be invited from the U.S. Natural Resource Conservation Service, the Alpine Resource Conservation District, the Alpine County Watershed Group, and downstream stakeholders in California and Nevada, including the Nevada Division of Environmental Protection, the Upper Carson River Coordinated Resource Management Plan group and the Carson Water Subconservancy District.
- By 1 year after final approval of the TMDL, Regional Board staff and stakeholders will identify specific sites within the watershed contributing direct surface runoff to Indian Creek Reservoir that need Best Management Practices (BMPs) for phosphorus control.
- By 1 year after final approval of the TMDL, Regional Board staff and stakeholders will identify specific sites needing BMPs for phosphorus control on public and private lands within the watershed tributary to the irrigation ditch that provides inflow to Indian Creek Reservoir from Indian Creek and the West Fork Carson River. Problem assessment and planning for BMP implementation on non-federal rangelands will follow the implementation procedures in the California Rangeland Water Quality Management Plan.
- By 3 years after final approval of the TMDL, depending on progress toward BMP implementation under the 1995 California Rangeland Water Quality Management Plan and the 2000 California Nonpoint Source Plan, staff will consider the need for regulatory action to ensure implementation of BMPs to control external sources of phosphorus loading to Indian Creek Reservoir.
- By 2013, BMPs will be fully implemented for nonpoint sources of phosphorus loading to Indian Creek Reservoir within the subwatershed affected by the TMDL.

This implementation plan focuses on the actions that are the responsibility of the District; however, modeling of the internal loading control measures assume that external loading source reductions will also take place.

Section 2: Problem Statement

After the District discontinued wastewater storage in Indian Creek Reservoir in 1989 and acquired water rights to support a minimum reservoir level for recreational uses, monitoring has showed decreases in the concentrations of most wastewater-related constituents, including total phosphorus (TP). While TP concentrations have decreased, they have remained at levels the scientific literature suggests will maintain eutrophic conditions. The reservoir has continued to show symptoms of eutrophication including blooms of blue-green algae, low transparency, and depletion of dissolved oxygen in the hypolimnion. The persistence of TP in the reservoir, in spite of the elimination of the significant external sources of phosphorus, may be the result of internal loading from the sediment.

In the TMDL, LRWQCB estimates that approximately 75 percent of the phosphorus load (about 350 pounds per year) to ICR is from the sediments. The sediments presumably accumulated nutrients while the reservoir was used for treated effluent storage. As the reservoir's hypolimnion becomes oxygen depleted as a result of biological activity (dissolved oxygen is consumed) and stratification (which isolates the hypolimnion from oxygen rich surface waters), anaerobic activity on detritus in the sediments releases dissolved phosphorus in the form of Ortho-phosphate (PO_4). This Ortho-phosphate is biologically available in the water column to promote algae growth and further the consumption of oxygen from the water column.

This implementation plan will focus on methods to manage the reservoir to limit the available phosphorus to the water column. There are various methods available to limit the available phosphorus. These methods may include intrusive methods such as hypolimnetic oxygenation, vegetation harvesting, dredging, and chemical fixation or sequestering and non-intrusive methods such as flushing. This implementation plan presents an approach for ICR that centers on an adaptive management that makes use of multiple approaches based of their efficacy, cost of implementation, and aggressiveness.

Section 3: Numerical Limits

The TMDL includes numerical interim and final limits for total phosphorus and dissolved oxygen; and final limits for chlorophyll a (an indicator of algae concentration and production), Secchi depth (a measure of light penetration, also an indicator of algae production), and the Carlson Trophic Status Index, a measure of lake tropic level based on ratios of phosphorus, chlorophyll a, and Secchi depth. These limits are summarized in Table 1 below.

Table 1. Numeric Targets and Indicators for Indian Creek Reservoir TMDL

Indicator[1]	Target Value	Reference
Total P concentration (Interim[2])	No greater than 0.04 mg/l, annual mean Current water quality objective (mean of monthly means);	see Basin Plan[3] Table 3-14
Total P concentration (Long term[2])	No greater than 0.02 mg/l, annual mean	USEPA, 1988, 1999.
Dissolved oxygen concentration (Interim[2])	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; see Basin Plan Table 3-6
Dissolved oxygen concentration (Long term[2])	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; see Basin Plan Chapter 3
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

1. 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 technical staff report.
2. Interim targets are expected to be attained by 2013. Long term targets are expected to be attained by 2024. See the Implementation Plan below.
3. Water Quality Control Plan for the Lahontan Region (LRWQCB 2004).

Section 4: Source Loading Evaluation

4.1 Water Budget

To estimate the external and internal loading of total phosphorus to ICR, it is necessary to understand ICR's hydrology. To this end, a water budget for ICR was calculated to quantify sources to and discharges from ICR. This section presents the methodology used and summarizes the results of the water budget analysis performed for ICR.

4.1.1 Calculation of Water Budget

The water budget is based on a mass balance equation as follows:

$$\Delta V = W + R + P - E - Q - GW \qquad [1]$$

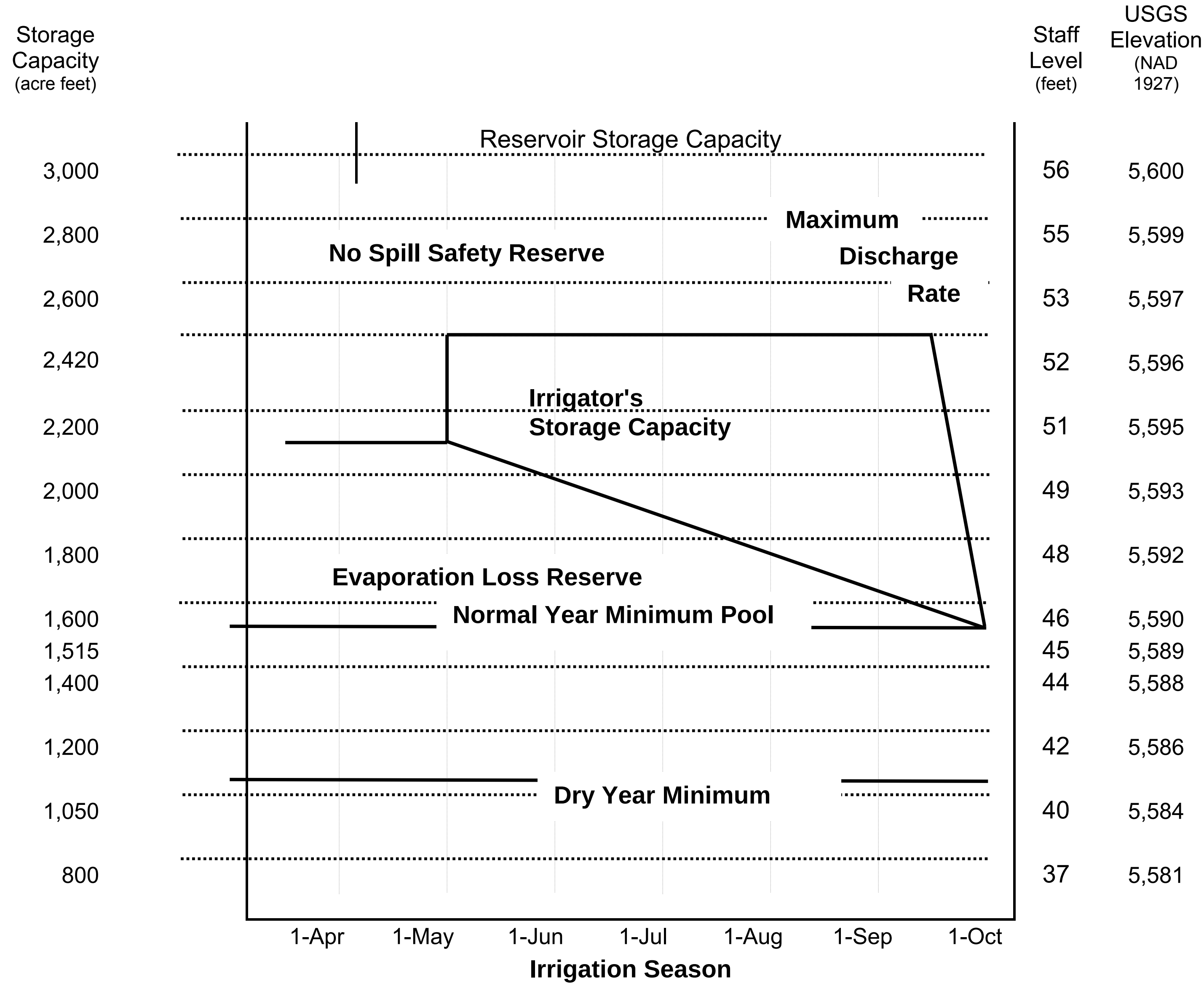
Where: ΔV is the change in storage; W are inflows into the reservoir from Indian Creek and West Fork Carson River; R is stormwater runoff entering ICR from the surrounding watershed; P is precipitation falling directly on the inundated portion of ICR; E is evaporation from ICR; Q is the release from ICR; and GW is the net water exchange with groundwater in the underlying aquifer. The analysis and computation of each of these components is discussed in the sections below.

The water budget analysis was performed on a daily time scale. Where daily data was not available, monthly averages were used in the calculations.

4.1.1.1 Change in Storage

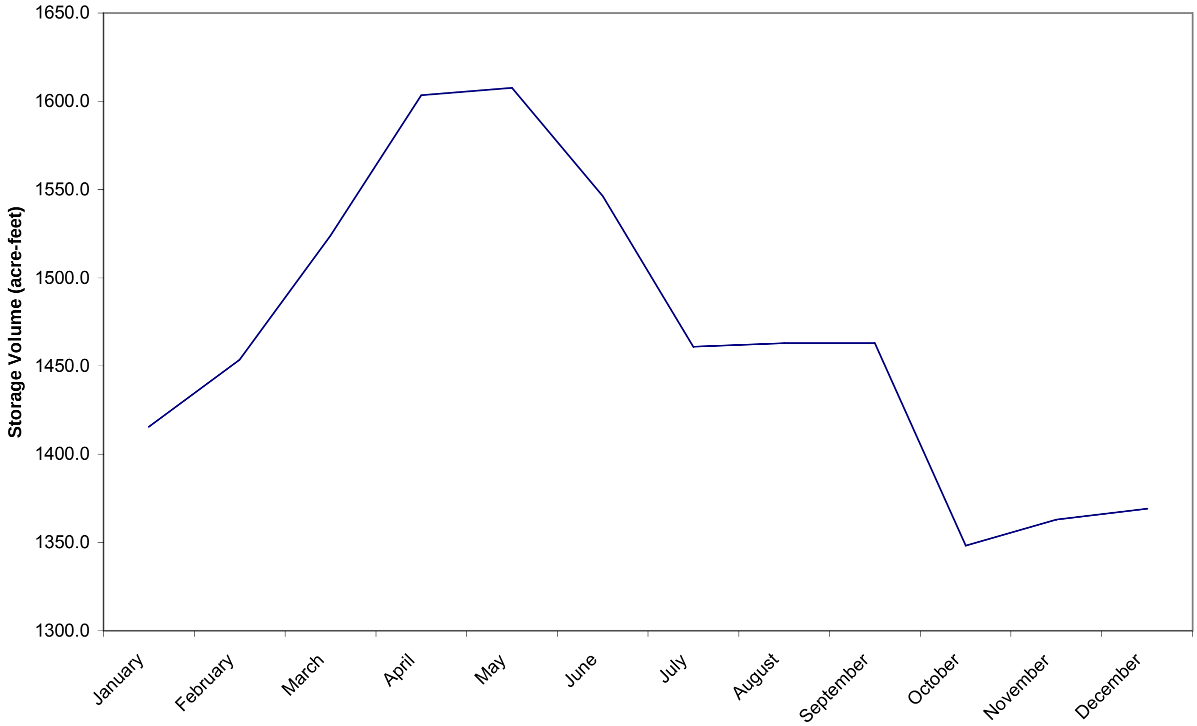
Changes in storage at ICR can be estimated using readings of the staff gauge mounted on the dam face. District staff observe and record the staff gauge readings on the first day of each month. These readings are recorded in the Water Master's Monthly Reports. Monthly observations have been recorded for the period August 1996 through July 2004. Using the ICR storage curve developed by Kennedy/Jenks Consultants (Figure 2), the volume held in storage can be determined using the staff gauge readings. The change in storage during each month is determined by subtracting the volume at the end of the month from the volume at the beginning of the month.

FIGURE 2: Indian Creek Reservoir Storage and Operating Curve



The mean monthly volume held in storage was calculated for each month over the period of record. The mean monthly volumes held in storage range from a low of 1,348 acre-feet (ac-ft) in October to a high of 1,608 ac-ft in May. Figure 3 presents the mean monthly volumes held in storage. For calculation of the daily water budget, it is assumed that changes to stored water are distributed evenly throughout each month.

Figure 3: Monthly Mean Storage Volumes



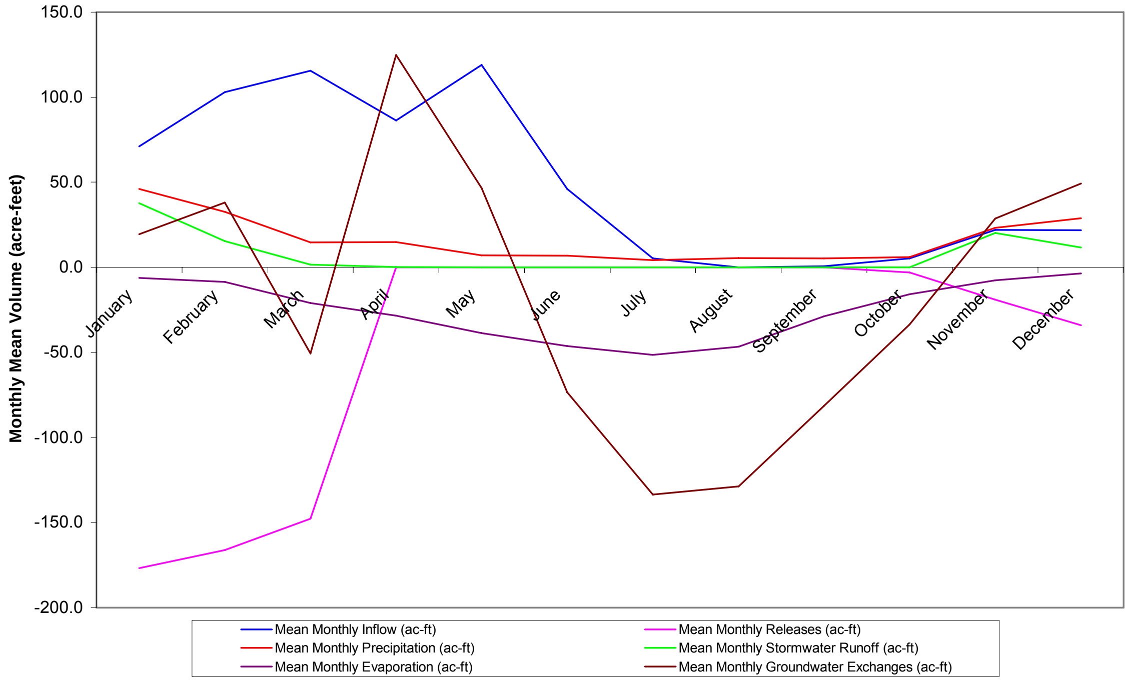
4.1.1.2 Inflows

Inflows to ICR consist of diversions from Indian Creek and West Fork Carson River. These inflows are conveyed to ICR via the Snowshoe Thompson No.1 Ditch and the Upper Dressler Ditch. District staff monitor and record the volume of water diverted from these sources each month. The total volume of water diverted from each stream is recorded in the Water Master's Monthly Report. Monthly monitoring results have been recorded for the period August 1996 through July 2004. Flow measurements are taken at the points of diversion. As a result, gains and losses in flow that occur between the gauges and ICR are not quantified and are ignored in the calculation of the water budget.

Monthly inflows range between 0 and 119 ac-ft with a mean inflow of about 50 ac-ft per month. The mean annual inflow is about 597 ac-ft per year. The daily inflows for the period of record were estimated assuming inflows are distributed evenly throughout each month. Mean monthly inflows are presented on Figure 4.

It should be noted that the District does not have the right to store flows from Indian Creek, and must pass Indian Creek water through the reservoir with no net storage from this source. In general the volume of inflow water from Indian Creek is significantly less than inflow from the West Fork of the Carson River, and less quantifiable. The pass through inflow volume of Indian Creek water does not appreciably impact the total storage volume of the reservoir and is reflected in the release rate volume. Stored water from the West Fork Carson is not released from the reservoir unless the storage volume exceeds the maximum storage volume allowed by contract on October 15th of each year.

Figure 4: Monthly Means of Water Sources and Releases



4.1.1.3 Precipitation

Precipitation falling directly on ICR contributes a small but, over the duration of a year, significant volume of water. The volume of water contributed by precipitation was estimated by multiplying the ICR's surface area by the depth of precipitation. ICR's surface area was determined from the stage measurements presented in the Water Master's Monthly Reports. Changes in stage elevations were assumed to vary evenly over each month.

Daily precipitation data was obtained from the National Climatic Data Center (NCDC) for the Markleeville meteorological station (COOID #45356). The period of record covered from 1 January 1950 through 31 March 2004. Mean monthly precipitation amounts entering ICR are also shown on Figure 4. The mean monthly precipitation volume entering ICR is about 16 ac-ft per month. The mean annual precipitation volume entering ICR is about 195 ac-ft per year.

4.1.1.4 Stormwater Runoff

ICR is located within a small watershed, approximately 1,503 acres, that contributes a small amount of stormwater runoff to ICR. ICR's surface area ranges from about 85 acres at minimum pool level to about 164 acres at maximum pool level. The Draft TMDL estimates a typical surface area of 110 acres.

The Snowshoe Thompson No. 1 Ditch extends through three nearby watersheds that, due to natural topographic gradients, would not normally contribute stormwater runoff to ICR. However, stormwater runoff occurring in these watersheds topographically upgradient of the Snowshoe Thompson No. 1 Ditch is captured by the ditch and conveyed to ICR. Thus, these additional areas must be considered in the estimation of stormwater runoff entering ICR.

The volume of stormwater runoff entering ICR from the four watersheds was estimated following the SCS Hydrologic Method and using daily precipitation depths measured at the nearby Markleeville meteorological station. Composite curve numbers for the four contributing areas were estimated using US Department of Agriculture Soil Survey maps showing the hydrologic soil groups within the four watersheds and an assessment of vegetation types determined from site visits and review of aerial photographs showing ICR and the surrounding areas. The surface areas and the estimated runoff curve numbers attributed to the four watersheds are provided in Table 2 below.

Table 2: Watershed Areas and Runoff Curve Numbers

Watershed	Area (acres)	Curve Number
Indian Creek Reservoir	1,503	57
Snowshoe Thompson No.1	405	64
Scott Creek	873	64
Indian Creek	3,695	61

Combined mean monthly runoff volumes are also shown on Figure 4. The combined mean monthly runoff rate is about 7 ac-ft per month. The mean annual runoff rate is about 87 ac-ft per year. Mean monthly stormwater runoff volumes are also shown on Figure 4.

4.1.1.5 Evaporation

Estimates of evaporation losses from ICR were made using the Penman Combination Method (Dingman 1994). Meteorological data used in the calculations was obtained from NCDC and included mean daily air temperature (Markleeville station), relative humidity (South Lake Tahoe station, Cooperative ID # 48762, and augmented with monthly mean values reported by NCDC for Reno, Nevada), wind speed (South Lake Tahoe station and augmented with monthly mean values reported by NCDC for Reno, Nevada), and percent possible sunshine (reported for Reno, Nevada). Other data used in the calculations included mean monthly water surface temperatures (calculated from water quality monitoring data provided by the District), ICR surface area, and water surface albedo. Net incoming radiation was calculated following the methodology presented in *Physical Hydrology* (Dingman 1994).

Mean monthly losses due to evaporation were estimated to range from about 4 ac-ft per month to 52 ac-ft per month with a mean monthly loss of about 25 ac-ft per month and a mean annual loss of about 303 ac-ft per year. These estimates are approximately twice the mean evaporation rates reported by NCDC for Topaz Lake. While actual evaporation rates are likely to be much closer to the rates observed at Topaz Lake, the evaporation rates calculated for ICR present a maximum evaporation rate. Mean monthly evaporation volumes are also shown on Figure 4.

4.1.1.6 Reservoir Releases

Inflows diverted from Indian Creek cannot be held in storage. Thus, all Indian Creek diversions are released from ICR. Releases exit ICR through an outlet structure located at the base of the dam. District staff control the release rates and monitor and record the total volume of water released. The total volume of water released is recorded in the Water Master's Monthly Report. Monthly releases have been recorded for the period August 1996 through July 2004.

Monthly releases range between 0 and 177 ac-ft with a mean monthly release of about 46 ac-ft per month. The mean annual release is about 551 ac-ft per year. Daily releases for the period of record were estimated assuming the releases are distributed evenly throughout each month. Mean monthly releases are presented on Figure 4.

4.1.1.7 Net Groundwater Exchange

Accurately measuring gains or loss of water to area groundwater is extremely difficult due to variations in underlying geology, seasonal changes in water levels within the reservoir and within the underlying aquifer, and the technical difficulty of measuring water fluxes at the bottom of a reservoir. Therefore, the net exchange is often estimated by recognizing that the net groundwater exchange term in the water budget equation (Equation #1) is the only unknown term and can be solved for if the other gain and loss terms are known.

Monthly mean exchanges with groundwater were estimated to range between a net gain of about 125 ac-ft per month to a net loss of about 133 ac-ft per month. The mean monthly net loss is about 16 ac-ft per month. The mean annual exchange was estimated to be a net loss of about 194 ac-ft per year. Mean monthly net exchanges with groundwater are also shown on Figure 4. Because the estimate of evaporation is, in all likelihood, an overestimation of the actual volume of water lost through evaporation, the actual net groundwater exchange is likely to be a much greater net loss than what was calculated. Thus, it is likely the reservoir supplies water to underlying groundwater throughout the year.

4.1.2 Summary of Water Budget

Using the estimates of the individual sources and discharges of water to and from ICR, Table 3 was developed. Table 3 presents a summary of the mean monthly and mean annual water sources and discharges in a side-by-side manner, so their relative magnitude can be readily compared.

Table 3: Summary of ICR Water Sources and Discharges

Source/Discharge	Mean Month (ac-ft)	Mean Annual (ac-ft)
Inflows	50	597
Precipitation	16	195
Stormwater Runoff	7	87
Evaporation	-25	-303
Releases	-46	-551
Groundwater Exchange	-16	-194

As can be seen in Table 3, ICR is not a self-sustaining reservoir and is entirely dependant on the introduction of the inflows.

4.2 Total Phosphorus Mass Balance

Sources of TP can be divided into two categories, external sources and internal sources. External sources include precipitation, stormwater runoff from contributing watersheds, inflows, and other small miscellaneous sources. Internal sources include releases from sediments and recycling of organic matter present in the water column. Phosphorus sinks include outflows, sediment burial, exchange with groundwater, and other small miscellaneous sinks. The quantification of these sources and sinks, including the methodologies used and the assumptions made, are described in the following sections.

4.2.1 Sediment Sampling and Analysis Program

To aid in the quantification of the TP sources and sinks and to better understand TP distribution throughout the reservoir, the District is currently implementing a sediment sample collection and analysis program. The specifics of the sediment sampling and analysis program are presented in Kennedy/Jenks Consultants, Technical Memorandum *South Tahoe Public Utilities District, Indian Creek Reservoir Sampling Protocols* (Appendix A). The results of the program will be used in the final design and analysis of the various management alternatives.

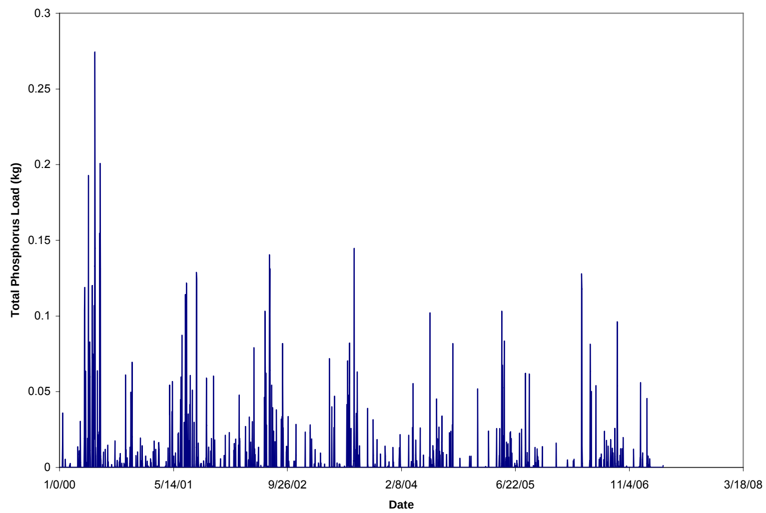
4.2.2 External Sources

4.2.2.1 Precipitation

Precipitation falling on the reservoir surface contains phosphorus that contributes to the reservoir loading. The TMDL and Implementation Plan (LRWQCB 2000) estimated a total phosphorus load from precipitation of 3 pounds (1.36 kilograms [kg]) per year assuming a reservoir surface area of 110 acres, an annual precipitation depth of 1.66 feet, and a TP concentration of 6.5 micrograms per liter (µg/l). The TP concentration was reportedly taken from unpublished data for precipitation TP concentrations in the Lake Tahoe watershed provided by John Reuter of the University of California, Davis' Lake Tahoe Research Group. This TP concentration is likely representative of precipitation falling on ICR given the proximity of Lake Tahoe to ICR.

Using precipitation data (daily summary) obtained from the NCDC for the Markleeville meteorological station (COOID #45356), the TP concentration referenced above, and the actual surface area determined for ICR (as determined from monthly water level reading and the stage-area reservoir curve); daily loads were calculated for the period 1 August 1996 through 31 October 2003. These loading rates are shown on Figure 5.

Figure 5: Daily Total Phosphorus Load in Precipitation



The mean loading rate for each month, calculated using the daily loads, are summarized below in Table 4. The mean monthly and mean annual loading rates were calculated to be 0.13 kg per month and 1.56 kg per year, respectively. The estimated mean annual loading rate is consistent with, although slightly greater than, the rate presented in LRWQCB's TMDL and Implementation Plan.

Table 4: Mean Monthly Total Phosphorus Loading Rate in Precipitation (kg)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.37	0.25	0.12	0.12	0.06	0.06	0.03	0.04	0.04	0.05	0.19	0.23

4.2.2.2 Stormwater Runoff

Stormwater runoff from contributing watersheds generally contains TP as a result of its contact with phosphorus containing soils and organic materials. As a result of this action, stormwater runoff entering ICR also adds to the overall loading to the reservoir.

Daily stormwater runoff volumes from the contributing watersheds were previously estimated for the period August 1996 through November 2003 in the water balance discussion above, and are used in the estimation of TP contained in stormwater runoff entering ICR.

In the TMDL and Implementation Plan (LRWQCB 2000), the LRWQCB estimated the mean annual TP loading to ICR from its immediate contributing watershed to be approximately 68 pounds per year, assuming a runoff rate of 762 ac-feet per year (estimated from an annual precipitation rate of about 20 inches per year). By back calculation, the mean TP concentration in stormwater runoff used by LRWQCB to estimate the annual loading was approximately 0.033

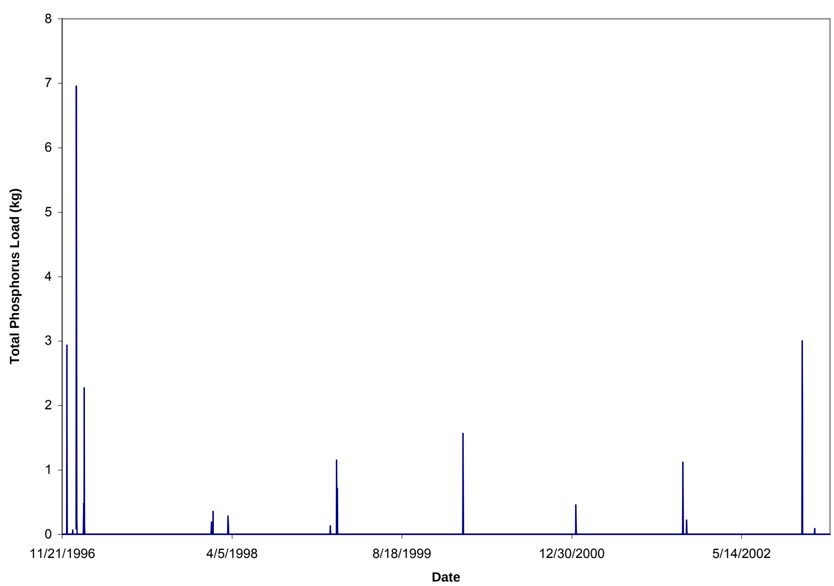
mg/l. The TMDL and Implementation Plan indicates that the TP was estimated using stormwater runoff phosphate concentrations obtained from a study conducted in relatively undisturbed lands in the Lake Tahoe Basin. The phosphate concentrations were reportedly converted to TP concentrations using the molecular weights of phosphorus and oxygen.

For comparison purposes, the median TP concentration observed over the duration of a runoff event from open/non-urban areas reported by the Nationwide Urban Runoff Program (NURP) conducted by the US Environmental Protection Agency (U.S. EPA, 1983) is about 0.12 mg/l. This concentration represents a median concentration calculated from stormwater data collected at sites located throughout the United States. Review of the data reveals that a great deal of variance is present in the NURP data, presumably as a result of the variability of the sampling sites.

Because the Lake Tahoe Basin study was conducted relatively close to ICR; the urbanization, geologic, and vegetative characteristics of the watershed are expected to have greater similarity to the ICR contributing watersheds compared to the NURP sampling sites. The LRWQCB TP concentration of 0.033 mg/l is expected to be more representative of stormwater runoff in the vicinity of ICR than the NURP value and, thus, is used in this analysis to estimate TP loading contained in stormwater runoff.

TP stormwater runoff loading rates were estimated by multiplying the daily stormwater runoff rates by a TP concentration of 0.033 mg/l and by a unit conversion factor. The daily TP loads for the period of record are shown on Figure 6.

Figure 6: Daily Total Phosphorus Load in Stormwater Runoff.



Using the daily loading rates, the monthly mean and mean annual TP loading rates were calculated. These rates are shown on Table 5 below.

Table 5: Mean Monthly Total Phosphorus Load in Stormwater Runoff (kg)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.53	0.57	0.07	0.01	0	0	0	0	0	0	0.80	0.48

The mean annual loading rate associated with stormwater runoff (based on the estimated daily loading rates) is 2.10 kg per year (or 4.63 pounds per year). This estimate is significantly lower than the estimate developed by LRWQCB (64 pounds per year). The source of the discrepancy is the estimated runoff volume.

To estimate runoff volumes, this analysis used the EPA Stormwater Management Model (SWMM) and historical rainfall rates to estimate daily runoff volumes, from which mean monthly and mean annual runoff volumes were estimated previously. The LRWQCB approach relied on an annual mean precipitation rate, watershed area, and a runoff curve number. The methodology used by the LRWQCB often over estimates actual runoff rates, thus, it is expected that the loading rate predicted by the LRWQCB methodology is also an over-prediction of the actual loading rate. However, the LRWQCB estimate does provide an upper bound of the expected loading rate. For the purpose of this analysis; however, an annual loading rate associated with stormwater runoff of 2.10 kg per year will be used.

4.2.2.3 Inflows

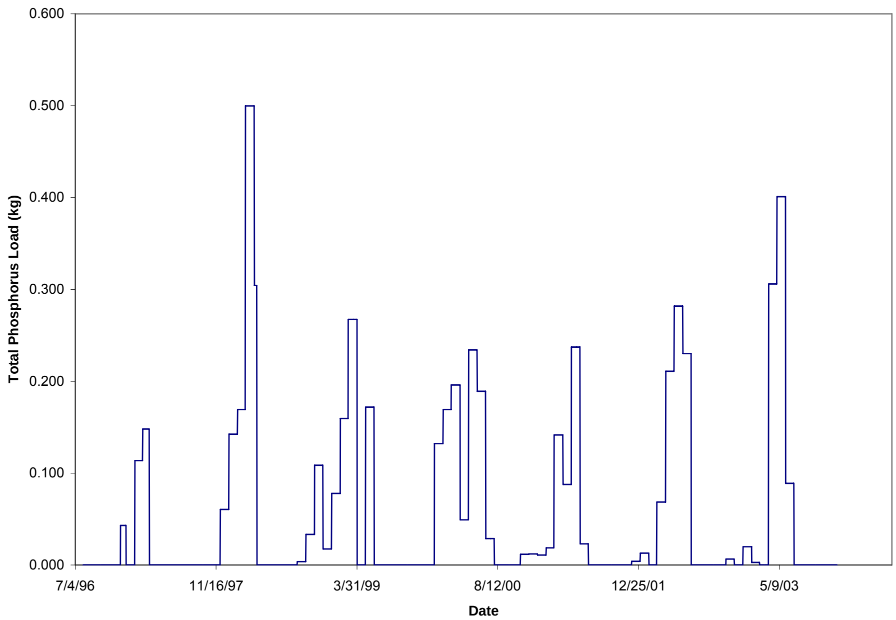
Daily ICR loading rates associated with inflows from Indian Creek and West Fork Carson River were calculated using the diversions recorded by District staff and mean monthly TP concentrations measured in the West Fork Carson River by the District. The mean monthly TP concentrations measured by the District range between 0.02 and 0.04 mg/l, and have a mean annual concentration of 0.03 mg/l. The mean monthly concentrations are shown in Table 6 below.

Table 6: Mean Monthly Total Phosphorus Concentrations in West Fork Carson (mg/l)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.02	0.02	0.04	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02

The estimated daily loading rates calculated using the above mean TP concentrations and the inflow rates reported by the District are shown in Figure 7 below.

Figure 7: Daily Total Phosphorus Load in Diversions to ICR.



Using the daily loads, the mean monthly loads associated with inflows were calculated and are presented in Table 7 below.

Table 7: Mean Monthly Total Phosphorus Load in Diversions to ICR (kg)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.75	2.54	5.70	3.19	5.87	2.28	0.13	0	0.01	0.13	0.47	0.54

The mean annual TP load associated with inflows was calculated using the daily loads and found to be 22.62 kg per year.

4.2.2.4 Miscellaneous Sources

Other potential sources of TP loading to ICR include atmospheric deposition (dust, organic material, etc blown on to the reservoir), anthropogenic waste (garbage, food waste, human waste, etc.), animal waste, and other naturally occurring sources. There is a possibility that septic systems for the BLM campgrounds also contribute to phosphorous loading in ICR. However, with the possible exception of the septic loading, these sources are considered negligible relative to the other sources and sinks of TP and were therefore not quantified.

4.2.3 Internal Sources

4.2.3.1 Sediment Releases

It is well acknowledged that the release of TP from sediments is a significant source, if not the largest source, of TP to ICR. Because the release rate is so overwhelmingly large relative to other sources, making an accurate estimation of the load is vital to the estimation of a mass TP balance in ICR.

To better understand the potential sediment release rate, the District is currently implementing a sediment sample collection and analysis project intended to provide site specific data for estimating the sediment release rate at ICR. Upon completion of the sediment sampling and analysis, the sediment release rate will be estimated and the results summarized in a technical memorandum..

4.2.3.2 Water Column Releases

Algal mass and other organic matter present in the water column contribute TP during cell lysis, excretion, and the decay of dead organisms. While the quantity of TP bound up in organic matter suspended in the water column is likely considerable, the recycling of TP from organic matter in the water column is not treated as a separate load source to ICR, but rather is treated as part of the total water column concentration.

4.2.4 Phosphorus Sinks

4.2.4.1 Outflows

The ICR outlet structure is located near the dam, with the opening at the bottom of the reservoir. Because of its deep location, releases through the outlet structure are drawn from the bottom of the reservoir. As a result, during periods of stratification, releases are assumed to be withdrawn solely from the hypolimnion; and, during periods when the reservoir is mixed, releases are assumed to be representative of the reservoir at-large.

Total phosphorus is discharged from ICR through outflows that contain biomass and other dissolved and undissolved forms of phosphorus. For the purpose of estimating the total mass of discharged TP, it is assumed that releases from ICR have a TP concentration consistent with the mean hypolimnion concentration (during periods of stratification) or with the mean water column concentration during periods of mixing.

The District is currently implementing a sediment sample collection and analysis project intended to provide site specific data. This includes data concerning TP concentrations present in the light floc material that may collect around the outlet structure and the TP sediment release rate. These rates may have a significant effect on the estimation of phosphorus discharge rates through outflows. Upon completion of the sediment sampling and analysis, the outflow discharge rates will be estimated and the results provided in a technical memorandum..

4.2.4.2 Sediment Burial

Sediment burial is the rate at which TP contained in the sediments becomes unavailable to the water column (no longer available for resuspension of sediments, advevection/diffusion of dissolved phosphorus, or other means of entraining phosphorus held in the sediments into the water column) as a result of being buried under accumulating sediments. Sediment burial represents a net loss of TP available to the water column.

The District is currently implementing a sample collection and analysis project intended to provide site specific information that will aid in the estimation of that rate at which TP becomes unavailable to the reservoir through sediment burial. The results will be summarized in a technical memorandum.

4.2.4.3 Groundwater Exchange

The interchange of water between the underlying aquifer and ICR carries phosphorus from one to the other. The water budget calculated for ICR found a net discharge of water from ICR to groundwater. Thus, the groundwater exchange is expected to result in a net loss of phosphorus from ICR to groundwater. The net exchange of phosphorus between ICR and groundwater can be determined knowing the phosphorus concentration of ICR and groundwater and the water exchange rates between ICR and groundwater.

Three groundwater samples have been collected from the US Forest Service's potable water well located at the adjacent Indian Creek Reservoir Campground and analyzed for total phosphorus. The measured concentrations ranged from 0.039 mg/l to 0.051 mg/l. The mean concentration is 0.046 mg/l.

Like outflows, water discharged from ICR to groundwater is expected to be characteristic of the hypolimnion during periods of stratification and of the mean water column concentration during periods of mixing.

The District is currently implementing a sampling and analysis project that will provide site specific information that will assist in estimating the rate at which ICR phosphorus is either gained or lost as a result of groundwater exchange. The result of the sampling and analysis will be summarized in a technical memorandum.

4.2.4.4 Miscellaneous Sinks

In addition to the sinks described above, there are other relatively minor phosphorus sinks, such as removal of biomass (fishing, inadvertent removal of weed growth or algae, etc.) and removal of water via aerosol action (during periods of high wind) or during recreational activities. However, because these sinks are very relative to the other sources and sinks; they are considered insignificant and have not been quantified.

Section 5: Proposed Management Plan

5.1 Review of Potential Mitigation Alternatives

Kennedy/Jenks Consultants prepared a technical memorandum dated 30 July 2004 that reviewed and evaluated potential mitigation alternatives for ICR in terms of feasibility, potential adverse affects (such as toxicity or habitat loss), ability to meet target levels by the LRWQCB deadlines, permanence, and cost. The evaluation resulted in identifying promising restoration methods. Combinations of restoration methods were also considered to provide a reliable, cost effective approach to TP reduction. A copy of the memorandum is provided in Appendix B. Of the potential restoration methods reviewed in the memorandum, several were selected as viable remediation technologies for ICR because of their efficacy, likely cost of implementation, and feasibility.

5.1.1 Preferred Alternatives

Technologies considered in the technical memorandum included hypolimnetic oxygenation, flushing, dredging, chemical fixation, biological treatment, and periphyton harvesting. The alternatives included measures to control internal loading from sediment and external loading from source water and runoff.

Of the reviewed alternatives to control internal loading, several were selected for possible implementation at ICR. These include hypolimnetic oxygenation, limited dredging, periphyton harvesting, flushing, and chemical treatment. These alternatives were selected because they appear to have the greatest promise for reducing TP at ICR within the TMDL target dates for the least cost and with the least impact on the reservoir and its aquatic life. Each of these alternatives is briefly discussed in the following sections, in their order of preference.

5.1.1.1 Hypolimnetic Oxygenation

Hypolimnetic oxygenation would consist of pumping water saturated with dissolved oxygen through diffusers into the hypolimnion during periods of low dissolved to inhibit the release of Ortho-phosphate due to biological activity under anoxic conditions.

Prior to implementing hypolimnetic oxygenation, the District will need to conduct a predesign study that provides needed information for the design. Required information would include defining the sediment oxygen demand rate, seasonal hypolimnion volumes, total area of exposed sediments, available electrical power, and other relevant design criteria.

5.1.1.2 Limited Dredging

Preliminary results of the District's current sediment sampling and analysis program suggest that sediments in the reservoir margin (i.e., the reservoir bank area between the low and high water lines) may have high levels of available phosphorus. According to the District, historical management of periphyton that collected along the banks and presented a nuisance was tilled in place. Such activity may have accumulated significant amounts organic material into sediments within the reservoir's margin. As this organic material is decomposed, it may serve as a significant source of phosphorus.

A preliminary estimate of the area affected by these past management activates was made and found to cover approximately 37 acres. Assuming the effective till depth was six inches, perhaps as much as 30,000 cubic yards of sediments were affected.

Because these sediments are readily accessible during low water periods, it would be readily feasible to excavate and dispose of offsite the sediments.

Prior to conducting such an operation, a predesign study should be conducted to confirm the aerial and vertical extent of sediments containing elevated levels of organic material, assess the presence of potentially hazardous chemicals in the sediments, identify appropriate offsite disposal locations, and identify critical or sensitive areas requiring protection.

5.1.1.3 Reservoir Flushing

Reservoir flushing consists of using relatively low phosphorus laden waters to flush out biomass and dissolved phosphorus. Timing of flushing flows is critical to the success of the flushing methodology. Releases of stored water from ICR should be timed for summer stratification when dissolved phosphorus concentrations are at their highest in the hypolimnion.

Water currently potentially available for flushing is available during the spring and has relatively higher TP concentrations. Since the availably of low TP water is very limited during the summer stratification period, implementation of flushing is not be practical unless a reliable source of water can be located.

The sediment and sampling program currently being implemented by the District will provide additional information needed to assess the effectiveness of this alternative and to estimate the length of time needed to flush to reach the target TMDL concentrations.

Prior to implementing reservoir flushing, the District would need to identify suitable sources of water, construct conveyance structures (as necessary), and evaluate the need for identifying land to receive nutrient laden water not appropriate for discharging to waters of the state.

5.1.1.4 Periphyton Harvesting

Periphyton harvesting presents a simple and direct opportunity to remove phosphorus from the reservoir. However, periphyton harvesting can be labor intensive and intrusive. Prior to implementing periphyton harvesting, the District will need to identify an appropriate disposal site and perform a cost analysis to consider the total benefit versus cost.

5.1.1.5 Chemical Treatment

Chemical treatment consists of chemically sequestering or fixating phosphorus compounds in a manner that makes them unavailable, biologically. Chemical treatment is the least favored of the preferred alternatives.

Prior to implementing chemical treatment, the District will need to select the appropriate chemical and application method. This will likely involve bench scale testing to identify the most effective and economical chemical and to confirm appropriate application rates.

5.2 Development of Mitigation Plan

The effectiveness of each of the preferred mitigation alternatives is somewhat uncertain due the inherent variability between ICR and other lakes and reservoirs where the alternatives have been successfully implemented. As a result, the District proposes an implementation strategy that allows for the use of one or more of the preferred alternatives, rather than be confined to the selection of a single technology, only to later discover it does not provide sufficient improvement to water quality and not have a rapid means of address. Therefore, the District proposes to implement a plan that allows for an adaptive approach that responds to the results of the monitoring plan.

The current ICR monitoring program will be continued to monitor water quality for compliance with the interim and final numeric water quality limits in ICR. The monitoring methods provide information on all required numeric limits and can be used to calculate the Carlton Trophic Index. If, after implementing a preferred alternative, the monitoring plan suggests that water quality is not improving sufficiently to meet the TMDL target concentrations within the deadlines; the District may elect to implement additional preferred alternatives or replace the existing alternative with one of the other preferred alternatives.

Under this management strategy, the District will evaluate reservoir water quality, with respect to the TMDL, on an annual basis to determine if water quality has improved. If no or very little improvement is detected over a two-year period, the District may elect to evaluate and implement one of the other preferred alternatives. The analysis may include a cost/benefit analysis of in an effort to determine the most cost efficient way for the District to meet the TMDL requirements.

Section 6: Implementation Schedule

Key milestones for the implementation of the mitigation/restoration measures for ICR are provided in Table 8 below. These milestones include deliverables to LRWQCB and key decision points.

Table 8. Indian Creek Reservoir Restoration Schedule

Date	Milestone	Remarks
June each year	ICR Water Quality Monitoring Report for Previous Year	
January 2005	I A. Approval of Implementation Plan by LRWQCB	Start date for all following tasks.
April 2005	I B. Lead Agency identified and makes exemption decision	If exempted, milestones 1 C and 1 D are not required
June 2005	1 C. Submit CEQA checklist, request Negative Declaration	Only required if project not exempted from CEQA
August 2005	1D. Decision of Non-Significance	Only required if project not exempted from CEQA. If significant environmental impact identified and EIS is required, new schedule will have to be developed
February 2005	Predesign for hypolimnetic oxygenation	Quantify data necessary for sizing packaged system
May 2005	Prioritize areas to receive limited dredging	Identify disposal locations
October 2005	Complete limited dredging	
December 2005	Implement hypolimnetic oxygenation system	
July each year	Mitigation Assessment Decision Point.	Review data to assess effectiveness of mitigation alternative(s). Select alternate mitigation alternative

		if warranted
June 2013	III B. Target Achievement Assessment.	Provide documentation that 2013 numeric limits are consistently being met.
June 2020	IIIC. Mitigation Assessment Decision Point.	If numeric limits are not within 10 percent of 2024 target goals, additional restoration measures will be proposed and implemented[1].
June 2023	III D. Target Achievement Assessment	Provide documentation that 2024 numeric limits are consistently being met.

Notes:

1. Additional adaptive management mitigation plans to meet 2024 limits have not been identified in this implementation plan because need is unlikely, data is not available, and all potential technologies cannot be identified at this time. A supplemental implementation plan would be submitted if additional mitigation is needed to meet 2024 numerical limits.

Section 7: California Environmental Quality Act Requirements

The California Environmental Quality Act (CEQA, California Code of Regulations, Title 14 Chapter 3) requires a review of potential environmental and social impacts of projects and governmental actions. Governmental action may involve:

1. Activities directly undertaken by a governmental agency,
2. Activities financed in whole or in part by a governmental agency, or
3. Private activities which require approval from a governmental agency.

Private action is not subject to CEQA unless the action involves governmental participation, financing, or approval. ICR TMDL Implementation is subject to CEQA because LRWQCB approval of the proposed mitigation/restoration is required. In addition, alterations to water rights and flows may be subject to approval by the California State Department of Water Resources and California State Department of Fish and Wildlife.

LRWQCB passed resolution No. R6T-2002-0047 in July 2002, amending the Lahontan Water Quality Control Plan (Basin Plan) to include the IRC TMDL and Implementation Plan. The resolution includes a statement that the process used to amend the Basin Plan is functionally equivalent to the preparation of an Environmental Impact Report under CEQA. Thus, the target numerical limits for ICR, the implementation process, and schedule are not subject to further review under CEQA. However, the mitigation and restoration actions necessary to meet these limits are subject to CEQA.

7.1.1.1 CEQA Objectives

The purpose of CEQA is to:

1. Inform governmental decision-makers and the public about the potential, significant environmental effects of proposed activities.
2. Identify the ways that environmental damage can be avoided or significantly reduced.
3. Prevent significant, avoidable damage to the environment by requiring changes in projects through the use of alternatives or mitigation measures when the governmental agency finds the changes to be feasible.
4. Disclose to the public the reasons why a governmental agency approved the project in the manner the agency chose if significant environmental effects are involved.

7.1.1.2 Lead Agency

The project will require identification of the lead agency that will make decisions about the projects impact and render a declaration of non-significance or require and approve an Environmental Impact Report. According to CCR 15051, Criteria for Identifying the Lead Agency, part (b), "…if the project is to be carried out by a nongovernmental person or entity, the Lead Agency shall be the public agency with the greatest responsibility for supervising or approving the project as a whole". Hence, it appears that the LRWQCB would be the lead agency for the CEQA review.

7.1.1.3 Potential Exemptions

CEQA includes statutory (Sections 15260 to 15285) and categorical (Sections 15300 to 15332) exemptions for certain projects. One potentially applicable categorical exemption is 15304. Minor Alterations to Land:

> *Class 4 consists of minor public or private alterations in the condition of land, water, and/or vegetation which do not involve removal of healthy, mature, scenic trees except for forestry or agricultural purposes. Examples include, but are not limited to:*
>
> > *…(d) Minor alterations in land, water, and vegetation on existing officially designated wildlife management areas or fish production facilities which result in improvement of habitat for fish and wildlife resources or greater fish production*.

It appears that this exemption may be applicable to the proposed mitigation/restoration measures for ICR. The lead agency will have to make the exemption determination and publish the finding. The recommended process for CEQA is discussed in the following section.

7.1.1.4 Recommended Actions Under CEQA

To meet CEQA requirements, Kennedy/Jenks Consultants recommends the following steps:

1. Confirm that LRWQCB is the Lead Agency, consult and confirm with other potential Lead Agencies including California Department of Water Resources and California Department of Fish and Wildlife.
2. Conduct a pre-application consultation with the Lead Agency pursuant to section 15060.5 and provide project information in the form of this Implementation Plan.
3. Include a request for exemption under section 15304 (d).
4. If the Lead Agency agrees with the exemption, it will file a notice of exemption as required in section 15062.
5. If the Lead Agency does not agree with the exemption, provide project initial study information in the form of this plan and a CEQA checklist. Request a Negative Declaration based on the checklist.

7.1.1.5 Additional Requirements Under National Environmental Policy Act

The National Environmental Policy Act (NEPA, 40 CFR 1500) requires impact analysis for projects that involve federal funding or actions. The mitigation/restoration actions proposed by the District do not directly involve a federal nexus. However, ICR is located on U.S. Bureau of Land Management (BLM) property and BLM operates a campground on the lake. Best management practices for external source control on the part of BLM are considered a separate project and NEPA requirements would be the responsibility of BLM.

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