Staff Report

Recommendation to De-list Crowley Lake for Nitrogen and Phosphorus

Crowley Lake, Mono County

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
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1 INTRODUCTION

In 1994, Crowley Lake (also known as Long Valley Reservoir) was listed as an impaired water body in accordance with Section 303(d) of the Clean Water Act (CWA) based on information and listing criteria available at that time. The most current 303(d) list, updated in 2002 by Lahontan Regional Water Quality Control Board (Regional Board), shows Crowley Lake to be impaired by nitrogen and phosphorous, with grazing, atmospheric deposition, internal nutrient cycling, erosion/siltation, and undifferentiated non-point and natural sources listed as the potential sources of nitrogen and/or phosphorous loading (LRWQCB, 2002). A November 1994 Water Body Fact Sheet prepared by the State Water Resources Control Board (SWRCB, 1994) described the impairment of Crowley Lake as eutrophication, "…with the hypolimnion anoxic in 1991."

Regional Board staff evaluated the conditions of Crowley Lake in accordance with *A Process for Addressing Impaired Waters in California*, which was adopted by the SWRCB in June 2005 as a guidance document for preparing Total Maximum Daily Loads (TMDLs) in California. Field studies were conducted in 2001 and 2002 to more accurately characterize water quality conditions in the lake, assess the sources of nitrogen and phosphorus loading, and determine whether applicable water quality standards are met. Regional Board staff prepared this report that summarizes the information from the research work and provides recommendations for future regulatory action. This report is organized into the following topics:

- Beneficial Uses and Water Quality Objectives,
- Crowley Lake Watershed,
- Crowley Lake Limnology,
- Nutrient Budget and Source Assessment,
- Evaluation of Beneficial Use and Water Quality Objective Attainment, and
- Regulatory Action Recommendation.

2 BENEFICIAL USES AND WATER QUALITY OBJECTIVES

Section 303 of the CWA defines water quality standards as both the uses of the waters involved and the water quality criteria applied to protect those uses. Under the Porter-Cologne Water Quality Control Act (California Water Code), beneficial uses and water quality objectives to protect those beneficial uses are considered separately and are established for all waters of the State. The beneficial uses and relevant water quality objectives set in the *Water Quality Control Plan for the Lahontan Region* (Basin Plan) are presented below and form the basis for evaluating water quality conditions in Crowley Lake.

2.1 Beneficial Uses

Crowley Lake is classified as a reservoir and is part of the Long Hydrologic Area (HU No. 603.10) within the Owens Hydrologic Unit (HU No. 603.00, Figure 1). The designated beneficial uses for Crowley Lake are listed in the Basin Plan (LRWQCB, 1995) and include the following:

- MUN - Municipal and Domestic Supply
- AGR - Agricultural Supply
- NAV - Navigation
- POW - Hydropower generation
- REC-1 - Recreation 1 – water contact recreation
- REC-2 - Recreation 2 – non-contact water recreation
- COMM - Commercial and Sportfishing
- COLD - Cold Freshwater Habitat
- WILD - Wildlife Habitat
- SPAWN - Spawning, Reproduction, and Development

2.2 Water Quality Objectives

Region-wide numeric and narrative water quality objectives (WQOs) are established in the Basin Plan and include the nutrient-related WQOs that apply to Crowley Lake. The relevant WQOs are presented below.

- **Ammonia**: The Basin Plan includes numeric ammonia objectives that are a function of temperature and pH. Tables 3-1 and 3-3 in the Basin Plan show one-hour average concentration limits and four-day average concentration limits, respectively, for water bodies designated as COLD and COLD with SPWN. The Basin Plan tables are reproduced in Appendix A.

- **Biostimulatory Substances**: "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance* or adversely affect the water for beneficial uses" (LRWQCB, 1995).

- **Dissolved Oxygen**: "The dissolved oxygen concentration, as percent saturation, shall not be depressed by more than 10 percent, nor shall the minimum dissolved oxygen concentrations be less than 80 percent of saturation. For waters with the beneficial uses of COLD, COLD with SPWN, WARM, and WARM with SPWN, the minimum dissolved oxygen concentration shall not be less than that specified in Table 3-6" (LRWQCB, 1995).

- **Taste and Odor**: "Waters shall not contain taste or odor-producing substances in concentrations that impart undesirable tastes or odors to fish or other edible products of aquatic origin, that cause nuisance*, or that adversely affect the water for beneficial uses. For naturally high quality waters, the taste and odor shall not be altered" (LRWQCB, 1995).

- **Turbidity**: "Waters shall be free of changes in turbidity that cause nuisance* or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by more than 10 percent" (LRWQCB, 1995).

* Nuisance is defined in the Basin Plan as a condition that "occurs during or as a result of the treatment or disposal of wastes" (LRWQCB, 1995, p. 3-15).

Study of Crowley Lake included sampling the major tributaries to the lake to evaluate potential source areas and overall nutrient loading characteristics. The Basin Plan includes WQOs for several tributaries to Crowley Lake. These tributaries and WQOs are summarized in Table 1 with analytical results from studies performed for this investigation. These results are discussed later in this report. Figure 2 is adapted from the Basin Plan (Figure 3-10; LRWQCB, 1995) and shows the locations of the tributaries with WQOs (listed below).

- Owens River (above East Portal), map ID 1
- Owens River (below East Portal), map ID 2
- Coldwater Creek, map ID 3
- Mammoth Creek (Twin Lakes Bridge), map ID 4
- Mammoth Creek (Old Mammoth Road), map ID 5
- Mammoth Creek (at Hwy 395), map ID 6
- Sherwin Creek, map ID 7
- Hot Creek (at County Road), map ID 8
- Convict Creek, map ID 9
- McGee Creek, map ID 10
- Hilton Creek, map ID 11

3 CROWLEY LAKE WATERSHED

The Crowley Lake watershed is approximately 380 square miles. The Sierra Nevada range bounds the watershed on the west, the Mono Craters area on the north and Glass Mountain on the east. Tributaries to the lake consist of the Upper Owens River, Leighton Springs, and McGee, Hilton, Whiskey and Crooked Creeks. Tributaries to the Upper Owens River consist of Hot, Mammoth, Deadman, and Glass Creeks. Figure 1 shows an overview of the Crowley Lake watershed.

3.1 Land Ownership and Uses

Land in the Crowley Lake watershed is predominately publicly owned. The largest landholder is the US Forest Service, Inyo National Forest. The Bureau of Land Management (BLM) and the City of Los Angeles are also major landholders in the watershed. The BLM's holdings are in the central portion of Long Valley. The City of Los Angeles owns lands immediately adjacent to the lake. Privately-owned land in the watershed occurs on the upper Owens River approximately 6 miles north of the lake, in the town of Mammoth Lakes, and in several smaller communities west and south of the lake. Land ownership is presented on Figure 1.

Land uses in the watershed include livestock grazing, fish hatcheries, geothermal development, and outdoor recreation including skiing, camping, and fishing.

3.2 Geology

The Sierra Nevada and White Mountain fault systems became active about 3 million years ago producing the relief of the eastern Sierra Nevada and White Mountain escarpments. The volcanic evolution of the area began with eruptions of basalt and andesite over much of the Long Valley and the Mono Basin between 2.8 and 3.8 million years ago. Volcanic activity became centered in the Long Valley area and eruptions became more silica rich over the next several million years. Glass Mountain, located on northeast portion of Long Valley, was formed around 1 million years ago from rhyolite eruptions. The Glass Mountain eruptions culminated in a large caldera-forming eruption approximately 760,000 years ago. Long Valley, a 17- by 32-kilometer oval-shaped depression, was formed during this eruption. The Mono-Inyo Craters volcanic chain extends from Mammoth Mountain to Mono Lake. The most recent eruptions in this chain occurred approximately 500 years ago (USGS, http://lvo.wr.usgs.gov).

In 1972, the US Geological Survey (USGS) established the Mono-Long Valley Known Geothermal Resource Area. In 1982, the USGS, under the Volcanics Hazards Program, began intensive efforts to monitor and study geologic unrest in Long Valley.

3.3 Climate and Hydrology

Long Valley hosts an active hydrothermal system that includes hot springs, fumaroles and mineral deposits. The system is primarily recharged from snowmelt in the higher elevations; the meteoric water infiltrates to depths of a few kilometers where it is heated by hot rock near geologically young intrusions. The heated, lower-density water then rises along fractures, eventually following the local hydraulic gradient, discharging to Hot Creek and Crowley Lake (USGS, http://lvo.wr.usgs.gov/hydrostudies.html). The largest hot springs are in the Hot Creek Gorge and account for about 80 percent of the total thermal water in the Valley.

Average annual precipitation at Crowley Lake is approximately 10 inches in the form of both rain and snow (Milliron, 1997). Precipitation at higher elevations is significantly greater and falls mainly as snow, although summer thunderstorms are common. Runoff from high elevation snowmelt generally peaks in June; however, runoff increases earlier in Long Valley streams from in-valley snowmelt.

Jellison and Dawson (2003) characterized the water budget for Crowley Lake using an array of Los Angeles Department of Water and Power (LADWP) gauging stations. Based on a 5-year average from 1995 to 2000, the Owens River and its tributaries (including diversions from the Mono Lake Basin) contribute about 58 percent (79,148 acre-feet per year) of the actual inflow (180,970 acre-feet per year) to Crowley Lake. Convict and McGee creeks each contribute approximately 15 percent of the inflow while Whiskey, Hilton, and Rock Creeks contribute a combined 11 percent. Direct precipitation into Crowley Lake is a minor part (less than 2 percent) of the water budget. Jellison and Dawson (2003) note that the Owens River input may be 10 to 20 percent higher than estimated because the LADWP gauges do not include contributions from Hot Creek Gorge.

Because the Owens River is supplemented by diversions from the Mono Lake Basin via the Mono Craters Tunnel (Figure 1), it does not show the seasonal variations exhibited by other tributaries to Crowley Lake. The other tributaries exhibit an order of magnitude seasonal flow variation, with approximately half of the annual flow of Convict, McGee, and Hot Creek (above the gorge and hatchery source springs) occurring in May and June during snowmelt (Jellison and Dawson, 2003).

Flow rates from geothermal springs such as Hot Creek Springs and Big Springs appear to be relatively constant. Michael Seefeldt, Hatchery Manager for DFG's Hot Creek Fish Hatchery, indicated that the flow rate from the Hot Creek springs is relatively constant throughout the year (pers. comm., Michael Seefeldt, 2005). Another local fish hatchery operator, Tim Alpers, also indicated that flows from Big Springs, which is the headwaters of the Owens River, is relatively constant, both throughout the year and from year to year (pers. comm., Tim Alpers, 2005).

3.4 Fisheries

Crowley Lake is the dominant fishery in the eastern Sierra Nevada in terms of angler use and fish production (Milliron, 1997). The Crowley Lake fishery is managed by the California Department of Fish and Game (DFG) for wild trout and "put and grow" hatchery trout (ibid). Game fish stocked in Crowley Lake in 1996 include Coleman Rainbow Trout (RT), Eagle Lake RT, Kamloops RT, Crowley Strain Brown Trout (BT), and Whitney BT. Crowley Lake also supports self-sustaining populations of Sacramento Perch.

Non-game fish in Crowley Lake include Owens sucker, Owens tui chub and speckled dace (ibid). Owens tui chub are listed as an endangered species under the Federal Endangered Species Act.

4 CROWLEY LAKE

Crowley Lake (Long Valley Reservoir) is situated on the eastern slope of the Sierra Nevada in Southern Mono County at an elevation of 6,781 feet. It was created by the impoundment of the Upper Owens River in 1941 by the City of Los Angeles. The reservoir inundated large areas of meadowland and sagebrush flats. Water reached the spillway elevation in the spring of 1946 (Pister, 1960).

With a surface area of approximately 5,300 acres, it is the largest reservoir in the Los Angeles Aqueduct system. The lake spill volume is 183,743 acre-feet and, when full, has a maximum depth of 126 feet and a mean depth of 35 feet.

4.1 Limnology

Crowley Lake is a dimictic reservoir, which means that it normally freezes over and goes through two stratifications and two mixing cycles a year. It typically freezes over in late December; the ice cover disappears in April. Ice-out is followed by a spring turnover, which results in a well-mixed lake with a temperature of around 4 degrees Celsius. The upper layer (epilimnion) warms quickly from May through July, while the underlying hypolimnion warms more slowly. Peak surface water temperatures are typically around 20 degrees Celsius. Peak temperatures at a depth of 20 meters are about 18 degrees Celsius. Surface water temperatures begin to decline around late August and the lake becomes isothermal around mid-October indicative of mixing during autumn overturn (Jellison and Dawson, 2003).

Dissolved oxygen (DO) concentrations also show seasonal variation in Crowley Lake. Jellison and Dawson (2003) found uniform DO concentrations with depth in November 2000 (~ 10 mg/L) and 2001 (~6 mg/L). While monitoring in August 2000 and 2001 showed a strong vertical gradient with the upper 8 meters containing approximately 7 mg/l DO and depths below 12 meters being essentially depleted (<1 mg/L) in DO.

Transparency as measured by Secchi depth shows seasonal variation. Jellison and Dawson (2003) found Secchi depth values as high as 7.5 meters following ice-out. Transparency generally decreases during the summer and early autumn to a Secchi depth of approximately 2 meters. Floating mats of algae in July 2000 and 2001 reduced the Secchi depth to near zero.

4.2 Trophic State of Crowley Lake

One commonly used approach to assessing water quality conditions in lakes and developing targets for improvement is through an existing classification system such as the Carlson trophic status classification system (USEPA, 1999). The trophic status refers to the level of productivity of a water body, with highly productive waters being eutrophic and unproductive waters being oligotrophic. Eutrophic, or highly productive, conditions are indicated by high nutrient enrichment, high productivity (planktonic growth), variable oxygen concentrations, presence of blue-green algae, and low water transparency (Horne and Goldman, 1994). These attributes are often associated with, or perceived as, man-induced nuisance conditions reflected by the presence of algal mats or other violations of water quality standards.

A eutrophic status can reflect a condition of use impairment (man-induced eutrophy) or it can reflect naturally occurring conditions. The former situation would indicate an impaired lake in the context of requiring a TMDL to be developed. The latter situation would indicate a water body that either meets its water quality standards or has inappropriate water quality standards and does not require a TMDL to be developed.

Although the characteristics of Crowley Lake appear to be conducive for naturally eutrophic conditions to occur, the lake was conservatively listed under the hypothesis that the lake is undergoing eutrophication as a result of man-induced nutrient loading. Therefore, the focus of this evaluation is to determine what nutrient sources contribute to the eutrophic status and to assess the magnitude of potential natural and man-induced loading. This information needed to assess future regulatory actions that may be warranted to protect water quality.

Available historical information on Crowley Lake water quality conditions was reviewed to help assess whether the eutrophic state of the lake is a use impaired condition or naturally occurring. Information from the late 1950s and early 1960s by E. P. Pister of the DGF, Region 5, Inland Fisheries division suggests that Crowley Lake has been eutrophic since its formation. Pister (1960) noted, “Heavy plankton blooms occur during the warm summer months,” and that “The unusually high productivity of bottom food is apparently becoming stabilized at a point somewhat lower than that which existed during the first few years after flooding, but is still considerably above the “average” of lakes at this general elevation.” The USEPA (1978) stated, based on data collected in 1975, “Survey data indicate that Lake Crowley is eutrophic.”

The most current information provides more detail on regarding the trophic status of the lake. Jellison and Dawson (2003), using the trophic state index developed by Carlson in 1977, determined the following mean mixed layer trophic state index (TSI) values:

TSI (SD) (2000/2001):	38 / 42	(Secchi depth [m]: 4.5 / 3.6)
TSI (TP) (2000/2001):	70 / 71	(TP [μg/L]: 94 / 100)
TSI (Chl) (2000 / 2001):	61 / 61	(Chl a [μg chl/L]: 21.8 / 21.7)

SD – Secchi Depth, TP – Total Phosphorus, Chl – Chlorophyll a

Using this classification system, TSI values greater than 45 indicate eutrophic status (USEPA, 1999). Therefore, chlorophyll and total phosphorous indicators point to eutrophic conditions while transparency (as Secchi depth) suggests mesotrophic (between eutrophic and oligotrophic) conditions.

Analysis of the ratio of carbon (C), nitrogen (N) and phosphorus (P) can also be useful for assessing nutrient sources and whether they are man-induced or naturally occurring. Marine phytoplankton show a relatively constant molar ratio of C:N:P of 106:16:1. This is known as the Redfield Ratio. In freshwater, however, N:P ratios in plankton are often correlated with N:P loading rates, and deviations from the Redfield Ratio provide an indication of the limiting nutrient (Jellision et al., 2003). The identification of the limiting nutrient can help reveal the relative importance of loading sources and the nature of key lake processes.

Recent work (Jellison and Dawson, 2003; Jellison et al., 2003) at Crowley Lake shows:

1. In tributary inputs to the lake, a mean molar TN:TP loading ratio of approximately 4 (significantly less than the Redfield Ratio) and high overall rates of phosphorous loading.

2. A mean TN:TP molar ratio of summer planktonic particulates in Crowley Lake of approximately 23 (significantly above the Redfield Ratio) with a range of 9 to 36.

3. A mean C:N ratio of 6.3 for summer planktonic particulates in Crowley Lake (very close to the 106:16 Redfield ratio).

The first finding above suggests that tributary loading is nitrogen limited and, therefore, Crowley Lake might be nitrogen limited. However, the second finding indicates that the plankton community in Crowley Lake contains significantly more nitrogen than would be expected based on nitrogen loading from tributaries, and suggests that the lake is phosphorus limited. The third finding further indicates that Crowley Lake is phosphorus limited.

These data suggest that phosphorus is the dominant nutrient associated with tributary loading to the lake, but in the lake, nitrogen becomes dominant due to internal processes. The presence of blue-green algae in Crowley Lake, which can fix nitrogen from the atmosphere, or nitrogen release from sediments are likely sources of the internal nitrogen production. Therefore, this analysis suggests that phosphorus inputs to the lake would need to be controlled to improve the trophic status of the lake. These general concepts are evaluated in more detail with respect to the tributary nitrogen and phosphorus loading data collected in 2001 and 2002, and are discussed in the following sections.

5 INTRODUCTION TO NUTRIENT BUDGET AND SOURCE ASSESSMENT

The nutrient loading estimates and limnological information in this report were based on data collected under contract between the Sierra Nevada Aquatic Research Laboratory (SNARL) and the Regional Board (Contract number 9-175-265-0 and number 0-196-160-0). SNARL provided the results of their work in two reports (Jellison and Dawson 2003, and Jellison et al., 2003). The sampling program consisted of lake and tributary sampling programs performed 2000 and 2001. There were three primary purposes of the program:

- evaluate internal nutrient loading in Crowley Lake
- establish a nutrient budget for Crowley Lake
- characterize nutrient sources to tributaries to Crowley Lake

These data are the results of comprehensive investigations specifically focused on quantifying nutrient delivery and internal loading to Crowley Lake and are considered the best current information available.

The nutrient budget developed by SNARL is summarized below and provides an overall assessment of nitrogen and phosphorous characteristics associated with Crowley Lake. The discussion of the nutrient budget is followed by discussions of external and internal nutrients sources affecting water quality in Crowley Lake.

6 NUTRIENT BUDGET

SNARL (Jellison and Dawson, 2003) developed a nutrient budget based on tributary inflows to and outflows from Crowley Lake. The tributaries, which consist of the Owens River (including inputs from Mammoth/Hot creeks), McGee Creek (including inputs from Convict Creek), Hilton Creek, Whiskey Creek, and Crooked Creek, were sampled approximately biweekly during the spring-summer period (May – September). The annual nutrient loading from streams was calculated using the period-weighted sample (PWS) method. In the PWS method, each two successive concentrations are averaged, multiplied by the cumulative discharge between sampling times and the resulting load increments summed over the water year.

Surface water samples were analyzed for ammonia-ammonium (NH_4), nitrate (NO_3), total nitrogen (TN), soluble reactive phosphorus (SRP), and total phosphorus (TP).

- Phosphorous: Total phosphorus loading to Crowley Lake ranged from approximately 41,000 to 46,000 pounds per year. Approximately 71 percent of the TP load is in the form of SRP. Inputs from the Owens River constituted approximately 96 percent of the TP load due to its relatively large flow rate and high TP concentrations. Big Springs, which is the headwaters of the Owens River, contained TP on the order of 0.35 mg/L and has a large influence on TP concentration downstream. Mammoth/Hot Creek, above Hot Creek Gorge and the Hot Creek Fish Hatchery, contained mean SRP and TP concentrations of 0.03 and 0.05 mg/L. The Owens River at Benton Crossing Bridge contained mean SRP and TP concentrations of 0.13 and 0.18 mg/L, respectively. The percent load for the other main tributaries is estimated at: 1) 1,200 pounds per year from McGee Creek; 2) 160 pounds per year from Hilton Creek; 3) 50 pounds per year from Crooked Creek; 4) 30 pounds per year form Whiskey Creek; and 5) 50 pounds per year from direct precipitation. SRP and TP were low (<0.02 mg/L) throughout the year in Convict, McGee, Hilton, Whiskey, and Crooked creeks

- Nitrogen: Total nitrogen loading ranged from approximately 75,000 to 78,000 pounds per year. Dissolved inorganic fractions of nitrogen (NH_4 and NO_3) constituted approximately 10 percent of the TN loading. The Owens River accounted for approximately 79 percent of nitrogen inputs; McGee Creek accounted for approximately 13 percent of the nitrogen load while Hilton and Crooked creeks accounted for approximately 3 percent each. Whiskey Creek contributed less than 0.5 percent of the nitrogen load and precipitation accounted for the remaining 2 percent of TN.

The nutrient loads exported from Crowley Lake were calculated by SNARL using outlet flows and concentrations in water years 2000-01 and 2001-02. These data showed that:

- Measured phosphorus outputs exceeded measured inputs by 15 to 20 percent; and

- Measured nitrogen exports were more than three times the measured inputs.

A conceptual diagram of nitrogen and phosphorus loading and export is shown on Figure 3.

7 NUTRIENT SOURCE EVALUATION

The objective of the nutrient source evaluation was to identify nutrient sources and quantify associated nutrient loads to Crowley Lake. This section discusses internal and tributary loading to Crowley Lake, and potential effects of land use on nutrient loading. Tributary samples were collected at several locations from each of the major tributaries to Crowley Lake. Sample locations were based on changes in land use, presence of springs, and at confluences along the tributaries to assist in evaluating changes in nutrient load with land use. A summary of the tributary sampling locations, including descriptions and number of samples collected in 2000 and 2001, is presented in Table 2. The tributary sampling locations are shown in Figure 4. Lake samples were collected from five locations and are shown in Figure 5.

7.1 Internal Sources

Based on the difference between inlet and outlet loads presented in the nutrient budget, the data indicate that unmeasured inputs of nitrogen are a significant load. These unmeasured inputs are likely from in-lake sources. The presence of nitrogen-fixing bacteria in Crowley Lake and recurring algal blooms, combined with low N:P tributary loading ratios indicate that fixation of atmospheric nitrogen is an important part of the overall nitrogen budget (Jellison and Dawson, 2003). The other likely in-lake source of nutrients is from decay of algal matter and sediment release. SNARL attempted to estimate the relative contributions of nutrients from sediment release and nitrogen fixation using laboratory tests and modeling approaches. The results were inconclusive.

7.2 Springs

The Crowley Lake watershed includes an active hydrothermal system. As part of this study, three important spring areas were sampled:

- Big Springs complex
- Alpers Spring
- Hot Creek Hatchery spring complex

7.2.1 Big Springs

The Big Springs complex is located near the headwaters of the Upper Owens River. It was sampled a total of 10 times in 2000 and 2001 (sample IDs OW8A and OW8B, Table 2). Total phosphorus concentrations in the Big Springs samples were consistent over the sampling period at a concentration of approximately 0.35 mg/L. This is about 7 times higher than concentrations in the Owens River above the springs, and increases, by about 3-fold, the Owens River TP concentrations downstream of the Big Springs input. Total nitrogen concentrations in Big Springs were also consistent during the sampling period with concentrations ranging from 0.13 to 0.18 mg/L.

Appendix B shows TP and TN concentration data from Jellison and Dawson (2003) in the upper Owens River area in 2000 and 2001. These concentration data show the strong influence of Big Springs on nutrient concentrations in the upper reaches of the Owens River. Figures 4.1 and 4.3 of Jellison and Dawson (2003) (reproduced in Appendix C) shows there are no other major inputs of TP to the Owens River between Big Springs and Crowley Lake and also support the fact that Big Springs is the major influence on TP concentrations in the Owens River reach.

7.2.2 Alpers Spring

Alpers Spring enters the Owens River near the upstream end of the Alpers Ranch. It was sampled a total of 5 times in 2000 and 2001 (sample ID OW-6B, Table 2). Concentrations of both TN and TP are similar to Big Springs. The Alpers Spring is relatively close to Big Springs and probably hydrologically related.

7.2.3 Hot Creek Hatchery Springs

The Hot Creek Hatchery springs contain "a small component (2 – 5%) of thermal water" (USGS, http:lvo.wr.USGS.gov/hydrostudies.html). Two springs, designated the AB and CD springs (Figure 6), located in the vicinity of the hatchery were each sampled 3 times in 2001. Both springs contained similar concentrations of nutrients and were high in TN (0.35 mg/L) and moderately high in TP (0.16 mg/L).

The main hot springs in the watershed discharge in Hot Creek Gorge downstream of the Hot Creek Hatchery at a rate of about 4,000 gallons per minute. The USGS estimates this to account for about 80 percent of the total thermal water discharge in Long Valley. These springs were not analyzed for nutrients.

7.3 Livestock Grazing

Livestock grazing was identified as a potential source of nutrients to Crowley Lake. Overgrazing can increase the delivery of sediment and nutrients to streams. Eroded soils and animal wastes can contribute both nitrogen and phosphorus to surface waters. The following section discusses changes in nutrient concentrations along several grazed tributaries to Crowley Lake; these areas are highlighted in Figure 5. Discussions of both dry pasture and irrigated pasture grazing are presented below.

To characterize the effects of dry pasture grazing on nutrient concentrations in tributaries to Crowley Lake, Board staff compared data from surface water samples upstream and downstream of three dry pasture (non-irrigated), livestock grazing areas:

- Upstream and downstream of SNARL fencing project (Table 3)
- Upstream and downstream of Arcularius Ranch (Table 4)
- Downstream of Arcularius Ranch and upstream of Hot Creek (LADWP-leased grazing lands) (Table 5)

Jellison and Dawson (2003) indicated that flow-weighted TP and TN concentrations show "small increases" through the stream reaches where dry grazing is conducted. Staff analysis of paired data sets support this assessment and the results are discussed below for each of the three dry pasture areas.

7.3.1 SNARL Fencing Project

As shown in Table 3, there are 33 sets of paired data from the SNARL fencing project on the Owens River. The average change in TN concentration from upstream to downstream was 3 percent, with a maximum change of +0.092 mg/L TN and an average change of +0.007 mg/L. The average change in TP concentration from upstream to downstream was 1 percent, with a maximum change of +0.024 mg/L TP and an average change of +0.001 mg/L TP. Because there are not consist increases in nutrient concentrations during the grazing season and the overall average concentration changes are very small, Board Staff do not consider this area as a source of nutrients. Therefore, no loading estimates were calculated.

7.3.2 Arcularius Ranch

Six pairs of samples were collected in 2000 and 2001 upstream and downstream of the Arcularius Ranch (Table 4). The average change in TN concentration from upstream to downstream was approximately 11 percent, with a maximum change of +0.032 mg/L TN and an average change of +0.015 mg/L. The average change in TP concentration from upstream to downstream was approximately 1 percent, with a maximum change of +0.018 mg/L TP and an average change of +0.015 mg/L TP. As shown in Table 4, Board Staff estimated that grazing along this stretch of the Owens River may contribute up to 1500 pounds of TN and 300 pounds of TP per year based on a 6-month grazing season.

7.3.3 LADWP-Leased Grazing Lands

Three sets of paired samples were collected in 2001 upstream and downstream of land leased by LADWP for grazing (Table 5). The samples sites were located downstream of Arcularius Ranch and upstream of the confluence of Hot Creek and the Owens River. Both TN and TP concentrations were lower downstream than upstream of this grazed area. Board Staff do not consider this area as a source of nutrients. Therefore, no loading estimates were calculated.

7.3.4 Irrigated Pastures

Livestock grazing in irrigated pasture occurs along the lower reaches of McGee and Convict creeks, and along the lower reaches of Hot Creek.

- Jellison and Dawson (2003) calculated volume-weighted mean concentrations of TN and TP upstream of irrigated pastures on McGee and Convict Creeks using data from sample locations MG3 and CO2, and concentrations of TN and TP in McGee Creek where it enters Crowley Lake (sample location MG0). The data are summarized in Table 6. Analysis of data sets for representative upstream and downstream locations show downstream average increases of 0.11 and 0.02 mg/L of TN and TP, respectively. As shown in Table 6, Board Staff estimate that grazing along the irrigated pastures of McGee and Convict Creeks may contribute up to 4800 pounds of TN and 900 pounds of TP per year based on a 6-month grazing season.

- Jellison and Dawson (2003) collected data in 2001 downstream of the Hot Creek gorge (sample MA1) and just above Hot Creek's confluence with the Owens River (sample MA0A). TN concentrations increased by 50 percent (0.22 mg/L) and 23 percent (0.11 mg/L) in May and July, respectively, but declined by 26 percent (0.09 mg/L) in October. TP declined across the same stretch during all three sampling events. As shown in Table 7, Board Staff estimate that grazing along the irrigated pastures of Hot Creek may contribute up to 3100 pounds of TN. There is no indication that grazing affects TP concentrations or loads.

The results suggest that livestock grazing in irrigated pastures may cause small increases in nitrogen loading. TP loading is not consistently increased at these two sites.

7.4 Fish Hatcheries

There are two fish hatcheries on tributaries to Crowley Lake. The Hot Creek Fish Hatchery is located at the headwaters of Hot Creek. The Alpers Fish Hatchery is located near the headwaters of the Owens River.

7.4.1 Hot Creek Fish Hatchery

The Hot Creek Fish Hatchery began operation in 1930 and is one of California's most productive trout hatcheries. The facility produces over 250,000 pounds of catchable trout annually. The Hot Creek Hatchery is fed by several major warm springs that produce water at temperatures between 14 and 20 degrees C. The spring water is routed through the hatchery operations and settling ponds before the water enters Hot Creek.

SNARL collected samples at five locations (Figure 6) in the vicinity of the hatchery to characterize hatchery effects on water quality:

MA2.5A	AB Spring, upgradient of the hatchery (2001 only)
MA2.5C	CD spring, upgradient of the hatchery (2001 only)
MA2B	Hatchery effluent immediately upgradient of confluence with Mammoth Creek
MA2A	Mammoth Creek immediately upgradient of the confluence with Hot Creek
MA2C	Hot Creek below the confluence of hatchery effluent and Mammoth Creek

Staff used average concentrations from MA2.5A and MA2.5C to estimate background nutrient concentrations. The springs are relatively high in both nitrogen and phosphorus with the following average concentrations:

TN - 0.37 mg/L TP - 0.16 mg/L NO_3 - 1.55 mg/L NH_4 - 0.001 mg/L

Using the average nutrient concentrations at site MA2B (surface water downstream of the hatchery) the potential contribution of nutrients from the hatchery was estimated. Calculations are shown in Table 8. The downstream concentrations of TN, TP, and NH_4 are:

TN	0.49 mg/L (0.12 mg/L increase),
TP	0.20 mg/L (0.04 mg/L increase),
NO_3	1.2 mg/L (0.35 mg/L decrease), and
NH_4	0.06 mg/L (0.059 mg/L increase).

Using the DFG's (California Stream Bioassessment Procedure for Hot Creek Hatchery) flow estimate of 18 to 35 cubic feet per second (cfs) (4.4×10^7 to 8.6×10^7 L/day) for the springs that feed the hatchery and the concentration data presented above, Board Staff estimate that the Hot

Creek Hatchery could contribute up to 6,300 pounds per year TN and 2,000 pounds per year TP to Crowley Lake. Calculations are shown in Table 8.

7.4.2 Alpers Hatchery

The Alpers Fish Hatchery is a part of the Alpers Ranch. The ranch encompasses approximately 2 miles of the Owens River. The hatchery uses spring water and diversions from the Owens River to support the private fish hatchery. SNARL collected samples at three locations to evaluate the effects of the Alpers Fish Hatchery on water quality:

- OW-6A – located on the Owens River upstream of the Alpers Ranch
- OW-6B – Alpers Spring, discharges to the Owens River on the Alpers Ranch
- OW-5 – located on the Owens River downstream of the Alpers Ranch

Appendix B shows TN and TP concentrations in the upper reaches of the Owens River in 2000 and 2001.

The Alpers Spring (OW-6B) contains TN concentrations that are approximately equal to those found in the Owens River at OW-6A (located above the hatchery). No significant increase in TN concentrations in downstream samples (OW-5) was observed in four of the six sample pairs collected. One sample pair showed a slight increase in TN concentration (from 0.09 mg/L to 0.13 mg/L) and one downstream sample showed a significant increase in TN concentration (from 0.18 mg/L to 0.29 mg/L). The downstream Owens River samples showed no significant increases in TP concentrations from those observed in the upstream samples.

Because four of the six sampling events show no significant TN increase across the Alpers Ranch and the hatchery operation is small in scale, Board Staff believe that the Alpers Fish Hatchery is not a significant source of TN to the upper Owens River system.

7.5 Nutrient Sources and Trophic Status

The nutrient source assessment provided data to evaluate the potential effect of man-induced nutrient load on the trophic status of Crowley Lake. The following discharges were identified as human-induced sources that, although relatively small compared to the total load leaving the lake system, could affect the trophic status of Crowley Lake:

- Hot Creek Fish Hatchery operations (TN and TP)
- McGee/Convict Creeks irrigated pasture (TN and TP)
- Hot Creek irrigated pasture (TN)
- Arcularius Ranch dry grazing (TN and TP)

The contribution of each of these sources was evaluated using the trophic status classification system discussed previously. This evaluation is presented in Table 9.

The calculations show that, if 100 percent of the potentially human induced loading were removed, the TSI for both TN and TP would be lower by 1 point and still indicate a eutrophic lake. This analysis further supports the conclusions that Crowley Lake is naturally eutrophic and that the eutrophic state of Crowley Lake is unlikely to be significantly altered without reducing the inputs of TP derived from natural sources along Hot Creek and the Owens River.

8 EVALUATION OF WATER QUALITY STANDARDS

In light of the natural eutrophic conditions, Board Staff believe it is appropriate to remove Crowley Lake from the 303(d) list. To remove Crowley Lake from the 303(d) list, it must be demonstrated that the lake is attaining water quality standards. Water quality standards consist of beneficial uses and numeric and narrative WQOs.

8.1 Beneficial Use Attainment

The designated beneficial uses for Crowley Lake are:

- MUN - Municipal and Domestic Supply
- AGR - Agricultural Supply
- NAV - Navigation
- POW - Hydropower generation
- REC-1 - Recreation 1 – water contact recreation
- REC-2 - Recreation 2 – non-contact water recreation
- COMM - Commercial and Sportfishing
- COLD - Cold Freshwater Habitat
- SPAWN - Spawning, Reproduction, and Development
- WILD - Wildlife Habitat

Since Crowley Lake is the largest reservoir in the LADWP aqueduct system and provides water for municipal and domestic supply, downstream irrigation, and hydroelectric power generation, the MUN, AGR, and POW beneficial uses are being attained.

Crowley Lake is a very popular fishing and boating venue. While seasonal algal blooms may have occasional negative effects on boating and swimming, Board Staff believe that algal blooms are sufficiently sporadic in time and extent such that they do not significantly impair the recreation and fishing beneficial uses. This is supported by results of a survey conducted as part of the Mono Basin Environmental Impact Report (Jones & Stokes, 1993), which showed that 188 of 243 respondents were “generally satisfied” or “very satisfied” with Crowley Lake recreation opportunities. Therefore, the information suggests that NAV, REC-1, REC-2, and COMM beneficial uses are met.

Crowley Lake is, and has been since its creation, a very productive fishery. Although there have been fish kills as indicated by Pister (1960):

> “This oxygen deficiency at lower depths may very possibly be one of the factors contributing to the mortality of considerable numbers of rough fish and an occasional trout during the mid-summer months. This die-off is not believed to be serious enough to

> cause any concern regarding the survival of the fishery, but is large enough to offensive to anglers when dead fish drift in to shore and decompose."

Milliron (1997) in his fisheries management plan for Crowley Lake, described a large kill of Sacramento perch in 1989. He attributed the kill to a rapid drawdown of the lake during drought conditions and noted that the Sacramento perch fishery "appeared to have fully recovered by the 1993 season." He also stated:

> "Temperatures at the surface during the survey period were above those optimal for trout growth. This condition coincides with depleted DO below the thermocline. Despite these occurrences, suitable habitat remained available for trout in the reservoir. This condition is common in eutrophic reservoirs in California."

Based on the findings of Milliron and Pister, made almost 30 years apart, Staff believe that the COLD, COMM, SPAWN, WILD beneficial uses are also met.

8.2 Narrative Water Quality Objectives

The narrative WQOs that pertain to potential nitrogen and phosphorous impairment were presented, with their full definitions from the Basin Plan, early in this document. The narrative WQOs, Biostimulatory Substances, Taste and Odor, and Turbidity all prohibit nuisance conditions or adversely affecting the water for beneficial uses.

Nuisance conditions, as defined in the Basin Plan, include the requirement that the impairment "occurs during or as a result of the treatment or disposal of wastes." (LRWQCB, 1995, p. 3-15). Because the nitrogen and phosphorous loading to, and associated algal blooms in, Crowley Lake are the result of natural conditions, the algal blooms do not cause nuisance conditions by definition. As presented above, the designated beneficial uses for Crowley Lake are being attained. Therefore, Staff concludes that Crowley Lake is in compliance with these narrative WQOs.

8.3 Numeric Water Quality Objectives

The Basin Plan has numeric values for the dissolved oxygen (DO) and ammonia WQOs that apply to Crowley Lake.

8.3.1 Dissolved Oxygen

The Basin Plan water quality criteria (Basin Plan Table 3-6, reproduced in Appendix A of this report) for dissolved oxygen in water bodies designated as COLD and SPWN is an instantaneous concentration minimum of 5 mg/L. Jellison and Dawson (2003) showed that during the summer months at depths below approximately 10 meters, Crowley Lake does not meet this criterion. These data are summarized in Appendix D and a map showing the Crowley Lake sample locations is presented as Figure 7. The presence of low DO at Crowley Lake is consistent with its eutrophic state, and has been shown to be a persistent summer occurrence (e.g., Pister, 1960)

8.3.2 Ammonia

The Basin Plan includes numeric ammonia water quality objectives that are a function of temperature and pH. Tables 3-1 and 3-3 in the Basin Plan show one-hour average concentration limits and four-day average concentration limits, respectively, for water bodies designated as COLD and COLD with SPWN. The Basin Plan tables are reproduced in Appendix A.

Board Staff reviewed all the ammonia data from Jellison and Dawson (2003). These data were edited to include only data that had corresponding temperature and pH measurements taken at the time of sample collection. This allowed Board Staff to calculate: (1) the unionized ammonia fraction of each sample, and (2) the 1-hour and 4-day unionized ammonia criteria for the specific temperature and pH at the time of sample collection. The results showed:

- none of the samples exceeded the one-hour criteria.
- none of the samples from the tributaries exceeded the one-hour or 4-day criteria
- Every sample collected from Crowley Lake and its outlet during the summer months exceeded the 4-day criteria, for total of seven exceedences.

The data from Crowley Lake and its outlet are tabulated in Appendix E and consist of 38 total ammonia samples.

8.3.3 Tributary Waters

The numeric WQOs for the tributaries to Crowley Lake are summarized in Table 1 along with averaged results from Jellison and Dawson (2003). There are two exceedences of WQOs for the tributaries to Crowley Lake.

1. The 90th percentile value for orthophosphate at Sherwin Creek (0.10 mg/L) slightly exceeded its WQO (0.08 mg/L) in 2001; this WQO was met in 2000. The annual average orthophosphate WQO for Sherwin Creek was achieved in both 2000 and 2001.

2. The 2001 annual average TN concentration (0.5 mg/L) in Hot Creek exceeded its WQO (0.3 mg/L). This WQO was met in 2000. The 90th percentile TN value at Hot Creek was met in 2000 and 2001.

Board Staff interprets these results to indicate that the waters tributary to Crowley Lake are in compliance with Basin Plan WQOs. The rare exceedences described above appear to be minor and not persistent from year to year. Board Staff believe this is further evidence that the eutrophic conditions at Crowley Lake are not related to anthropogenic causes.

9 RECOMMENDATIONS

9.1 De-listing Crowley Lake for Nitrogen and Phosphorus

At the time Crowley Lake was included on the 303(d) list, Board Staff considered the waterbody to be impaired by nutrient inputs based on observations of seasonal algal blooms. Land uses such as grazing, fish hatcheries, and residential development were thought to be contributing excess nutrients that caused the perceived impairment. However, subsequent studies and evaluation reveal that the lake is naturally eutrophic and that controllable, man-induced nutrient inputs are not significantly affecting the trophic state of the lake such that they are impairing beneficial uses. Seasonal algal blooms will likely persist in the lake into the future, but they are natural conditions of the lake due to its construction on former marshland and the naturally high inputs of nutrients.

Land uses in the watershed do not significantly affect the trophic status of Crowley Lake. Fish hatchery operations have been regulated for some time under the Regional Board's NPDES regulatory authority. Although sedimentation impacts have been identified in Hot Creek from hatchery operations, the data do not indicate that hatchery operations impair Crowley Lake. Additionally, grazing activities have been controlled in many parts of the watershed through a combination of corridor fencing, reduction of livestock numbers, livestock exclusion, rest-rotation practices, and irrigation improvements. The data do not indicated that grazing activities impair Crowley Lake.

Based on these findings, Board Staff recommend that the listings for nitrogen and phosphorus be de-listed in accordance with the criteria for "Trends in Water Quality" and "Situation-Specific Weight of Evidence Delisting Factor" (Sections 4.10 and 4.11, respectively) of the SWRCB's *Water Quality Control Policy For Developing California's Clean Water Act Section 303(d) List* (SWRCB, 2004).

Information supporting Board Staff's recommendation to de-list Crowley Lake for nitrogen and phosphorus is summarized below.

- Crowley Lake has been eutrophic essentially since it was constructed as evidenced by documented by several reports from the CA DFG. Board Staff was unable to conclude that the trophic state of the lake has changed significantly over the last 40 years.

- Phosphorus loading to Crowley Lake is due, almost entirely, to natural sources. The Big Springs complex, which is the headwaters of the Owens River, is naturally high in phosphorus. The Hot Creek Hatchery springs are also naturally high in phosphorus and high in nitrogen. Crowley Lake receives a large annual load of phosphorus from natural sources. Control of naturally-occurring high levels of phosphorus is not within the scope of the TMDL process.

- The high natural phosphorus load and low TN:TP loading ratio to Crowley Lake favors blue-green algae growth. A few genera of blue-green algae found in Crowley Lake can fix dissolved atmospheric nitrogen gas. Therefore, sufficient nitrogen, as evidenced by summer plankton C:N ratios, is available and is essentially uncontrollable.

- Table 9 shows calculations of Trophic State Index using estimated maximum reductions of anthropogenic influent TN and TP. The calculations show that the trophic state would be essentially unchanged even under conservative assumptions.

- Water quality objectives for nitrogen and phosphorus and designated beneficial uses for Crowley Lake appear to be met.

9.2 Listing for Dissolved Oxygen and Ammonia

Board Staff recognize that the dissolved oxygen and ammonia WQOs in the Basin Plan are not being attained at depths below approximately 10 meters during the summer in Crowley Lake. These data characterize the summer season as the critical condition in Crowley Lake.

The minimum number of measured exceedences to place a waterbody on the 303(d) list for conventional pollutants such as ammonia is 7 exceedences, based on a dataset of 37 to 42 samples. Because the data (Appendix E) showed 7 exceedences in 38 in-lake and outlet samples, it is appropriate to list Crowley Lake for ammonia.

Of 112 samples collected from various in-lake locations, 36 depth-averaged dissolved oxygen measurements were less than 5 mg/L. The minimum number of measured exceedences to place a waterbody on the 303(d) list for a conventional pollutant such as dissolved oxygen is 19 exceedences, based on a dataset of 110 to 115 samples (Appendix D).

The occurrence of elevated ammonia and depressed dissolved oxygen concentrations are associated with the natural eutrophic condition of Crowley Lake. Therefore, Board Staff recommend the preparation of site-specific objectives or other basin planning amendments that recognize and account for natural conditions. We do not anticipate preparing a TMDL for these constituents for Crowley Lake. Because this work is not currently in the Region's work plan, it is appropriate to list Crowley Lake for dissolved oxygen and ammonia until this issue is reconciled with the water quality objectives in the Basin Plan.

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TABLES

Table 1

Comparison of Study Results with Basin Plan Water Quality Objectives for Tributaries of Crowley Lake [1, 2]

Crowley Lake, California

Surface Water Body	Water Quality Objectives[3]			Crowley Study - 2000			Crowley Study - 2001			Station(s) Used	Number of Samples (2000 / 2001)
	NO3-N[4]	Total N[5]	PO4[6]	NO3-N	Total N	SRP[7]	NO3-N	Total N	SRP		
Owens River (above East Portal)	0.1 / 0.1	0.2 / 0.5	0.90 / 3.75	0.07 / 0.1	0.1 / 0.2	0.81 / 0.97	0.1 / 0.1	0.2 / 0.3	0.85 / 1.01	OW4A, OW5, OW6A, OW7, OW9	13 / 13
Owens River (below East Portal)	0.5 / 1.0	0.6 / 1.5	0.73 / 0.94	0.01 / 0.03	0.2 / 0.3	0.45 / 0.60	0.02 / 0.06	0.3 / 0.4	0.45 / 0.57	OW4C, OW3, OW2, OW1.5A (2001 only), OW1.5C (2001 only), OW1, OW0	39 / 55
Coldwater Creek	0.5 / 1.0	0.5 / 1.0	0.02 / 0.03	NT[9]	NT	NT	NT	NT	NT	-	-
Mammoth Creek (Twin Lakes Bridge)	0.4 / 0.8	0.5 / 1.0	0.03 / 0.05	<0.01 / <0.01	0.2 / 0.2	0.02 / 0.02	<0.01 / <0.01	0.2 / 0.2	0.02 / 0.02	MA6	3 / 3
Mammoth Creek (Old Mammoth Road)	0.4 / 0.8	0.6 / 1.0	0.27 / 0.50	<0.01 / 0.01	0.1 / 0.1	0.11 / 0.14	0.03 / 0.06	0.2 / 0.2	0.09 / 0.15	MA5A	3 / 3
Mammoth Creek (at Hwy. 395)	0.4 / 0.8	0.6 / 1.0	0.11 / 0.22	0.02 / 0.04	0.1 / 0.2	0.08 / 0.10	0.03 / 0.06	0.2 / 0.3	0.11 / 0.17	MA3	15 / 23
Sherwin Creek	0.4 / 0.6	0.5 / 0.7	0.05 / 0.08	0.04 / 0.05	0.09 / 0.1	0.01 / 0.02	0.05 / 0.06	0.2 / 0.4	0.05 / **0.10**	MA5B	3 / 3
Hot Creek (at County Road)	0.2 / 0.4	0.3 / 1.5	0.65 / 1.22	0.1 / 0.2	0.3 / 0.4	0.35 / 0.45	0.2 / 0.3	**0.5** / 0.6	0.36 / 0.48	MA2C, MA1, MA0A (2001 only)	6 / 9
Convict Creek	0.2 / 0.5	0.3 / 0.5	0.03 / 0.05	<0.01 / <0.01	0.07 / 0.08	0.02 / 0.03	<0.01 / <0.01	0.1 / 0.1	0.01 / 0.02	CO0, CO1, CO2, CO3, CO4 (2001 only)	25 / 32
McGee Creek	0.3 / 0.4	0.4 / 0.5	0.02 / 0.03	0.03 / 0.07	0.08 / 0.1	0.02 / 0.03	0.03 / 0.06	0.1 / 0.2	0.02 / 0.02	MG2, MG3, MG4, MG5	25 / 29
Hilton Creek	0.3 / 0.5	0.5 / 0.6	0.03 / 0.05	<0.01 / 0.01	0.12 / 0.16	0.02 / 0.02	0.01 / 0.02	0.1 / 0.2	0.01 / 0.02	HL0, HL1A, HL1B (2000 only), HL1C, HL1D (2000 only), HL2A, HL2B (2000 only), HL2C (2000 only), HL2D (2000 only), HL2E (2000 only), HL2F, HL3	71 / 35

Notes:

1. Results and water quality objectives in milligrams per liter (mg/L)
2. First number listed is annual average value. Second number listed is 90th percentile value
3. Water Quality Objectives (WQOs) from Table 3-17 of Water Quality Control Plan for Lahontan Region.
4. NO3-N = nitrate reported as nitrogen
5. Total N = total nitrogen
6. PO4 = dissolved orthophophosphate
7. Crowley Lake studies analyzed samples for soluble reactive phosphorous (SRP). Therefore, SRP results are used for the comparison to the PO4 water quality objective.
8. **Bold** indicates number exceeds WQO
9. NT = not tested

Table 2
Summary of Samples used for Tributary Nutrient Source Analysis
Crowley Lake, Mono County

Station Code	Tributary	Station Description	Number of Samples collected in 2000	Number of Samples collected in 2001
CO0	Convict	Upstream of confluence with McGee	3	3
CO1	Convict	Downstream property line of SNARL	16	20
CO2	Convict	Upstream property line of SNARL	3	3
CO3	Convict	Outlet from Convict Lake	3	3
CO4	Convict	Inlet to Convict Lake	0	3
CR1	Crooked	Just below US395	14	19
OUT	Dam	Outlet from Crowley Lake. LA Gauging Station No. 4018	14	17
OW10B	Deadman	Just above confluence with Glass Creek	1	1
OW10A	Glass	Just above confluence with Deadman Creek	3	3
HL0A	Hilton	Easternmost channel at inlet to lake	16	20
HL1A	Hilton	Easternmost channel at US395	10	3
HL1B	Hilton	2nd easternmost channel at US395	10	0
HL1C	Hilton	3rd Easternmost channel at US395	9	3
HL1D	Hilton	4th easternmost channel at US395	9	0
HL2A	Hilton	Easternmost channel at Old US395	3	3
HL2B	Hilton	2nd easternmost channel at Old US395	1	0
HL2C	Hilton	3rd easternmost channel at Old US395	3	0
HL2D	Hilton	4th easternmost channel at Old US395	1	0
HL2E	Hilton	5th easternmost channel at Old US395	2	0
HL2F	Hilton	6th easternmost channel at Old US395	4	3
HL3	Hilton	Above community. LA Gauging Station No. 4019	3	3
MA0A	Hot	Northern most channel of Hot Creek just above confluence with Owens	0	3
MA1	Hot	Flume below thermal area	3	3
MA2.5A	Hot	AB Springs of Hot Creek at Hatchery	0	3
MA2.5C	Hot	CD Springs of Hot Creek at Hatchery	0	3
MA2A	Hot	Immediately above confluence of Hot Creek and hatchery inputs	3	3
MA2B	Hot	Hatchery inputs immediately above confluence with Hot Creek	3	3
MA2C	Hot	Immediately below confluence of Hot Creek and hatchery inputs	3	3
MA3	Mammoth	Gaging station at US395 LA Gauging Station No. 4026	15	22
MA5A	Mammoth	Above confluence with Sherwin Creek	3	3
MA5C	Mammoth	Immediately downstream of confluence with Sherwin Creek	3	3
MA6	Mammoth	Twin Lake outlet	3	3
MG0	McGee	Inlet to lake	9	14
MG1	McGee	Below confluence with Convict	3	3
MG2	McGee	Above confluence with Convict	3	3
MG3	McGee	Just below US395	16	20
MG4	McGee	Above community	3	3
MG5	McGee	Above pack station and campground	3	3
OW1	Owens	Benton Crossing bridge	17	25
OW1.5A	Owens	Owens river above confluence with the northern most channel of Hot Creek	0	3
OW1.5C	Owens	Owens river below confluence with the northern most channel of Hot Creek	0	3
OW2	Owens	Downstream property line of Arcularius ranch (upper DWP property line)	3	3
OW3	Owens	Upstream property line of Arcularius ranch	3	3
OW4A	Owens	East Portal (Owens River immediately above East Portal)	3	3
OW4B	Owens	East Portal (tunnel water) LA Gauging Station No. 5053	3	3
OW4C	Owens	East Portal (below confluence of East Portal and Owens River) LA Gauging Station	3	3
OW5	Owens	Downstream property line of Alper's Ranch	3	3
OW6A	Owens	Upstream property line of Alper's Ranch	3	3
OW6B	Owens	Alper's Spring	2	3
OW7	Owens	Culvert immediately downstream of Big Springs	3	3
OW8A	Owens	Big Springs A (easternmost of two sampled)	3	2
OW8B	Owens	Big Springs B (westernmost of two sampled)	2	3
OW9	Owens	Below confluence of Glass and Deadman Creeks	1	1
OWO	Owens	Inlet to lake	13	19
MA5B	Sherwin	Sherwin Creek at confluence with Mammoth Creek	3	3
WH1	Whiskey	Just below US395	14	19

Table 3
Comparison of Nutrient Concentrations Upstream and Downstream of SNARL Fencing Project on the Owens River
Crowley Lake, Mono County

Date	Station	NH4	NO3	TN	SRP	TP	TN % Change	TP % Change
6/7/2000	OW1	0.004	<0.001	0.227	0.119	0.155		
6/7/2000	OW0	0.004	0.005	0.228	0.125	0.162	1	5
6/21/2000	OW1	0.003	0.014	0.269	0.150	0.160		
6/21/2000	OW0	0.005	0.014	0.277	0.153	0.166	3	4
7/5/2000	OW1	0.005	0.009	0.189	0.149	0.176		
7/5/2000	OW0	0.003	0.014	0.196	0.153	0.185	4	5
7/19/2000	OW1	0.010	0.016	0.280	0.150	0.194		
7/19/2000	OW0	0.002	0.010	0.289	0.172	0.218	3	12
8/2/2000	OW1	0.004	0.015	0.238	0.138	0.161		
8/2/2000	OW0	0.004	0.028	0.259	0.135	0.165	9	3
8/8/2000	OW1	0.010	0.018	0.346	0.130	0.166		
8/8/2000	OW0	0.008	0.013	0.299	0.127	0.163	-14	-2
8/16/2000	OW1	0.002	0.048	0.291	0.126	0.154		
8/16/2000	OW0	0.002	0.014	0.312	0.128	0.158	7	3
8/29/2000	OW1	0.002	0.034	0.322	0.126	0.186		
8/29/2000	OW0	0.002	0.025	0.306	0.125	0.161	-5	-14
9/13/2000	OW1	0.003	0.043	0.127	0.135	0.175		
9/13/2000	OW0	0.001	0.015	0.129	0.133	0.182	2	4
9/27/2000	OW1	0.003	0.061	0.261	0.128	0.176		
9/27/2000	OW0	0.001	0.010	0.301	0.124	0.169	15	-4
10/18/2000	OW1	0.001	0.078	0.121	0.130	0.187		
10/17/2000	OW0	0.002	0.016	0.110	0.130	0.184	-9	-1
11/22/2000	OW1	0.003	0.007	0.141	0.133	0.175		
11/22/2000	OW0	0.002	0.068	0.158	0.133	0.173	12	-1
12/20/2000	OW1	0.002	0.045	0.150	0.132	0.185		
12/20/2000	OW0	0.001	0.009	0.112	0.130	0.178	-25	-4
1/17/2001	OW1	0.010	0.461	0.319	0.137	0.202		
1/17/2001	OW0	0.009	0.444	0.343	0.135	0.210	8	4
2/14/2001	OW1	0.010	0.278	0.297	0.138	0.202		
2/14/2001	OW0	0.008	0.257	0.338	0.138	0.214	14	6
3/14/2001	OW1	0.005	0.093	0.241	0.146	0.199		
3/14/2001	OW0	0.006	0.080	0.286	0.147	0.205	19	3
4/12/2001	OW1	0.001	0.027	0.289	0.170	0.217		
4/12/2001	OW0	0.003	0.029	0.381	0.180	0.226	32	4
5/8/2001	OW1	0.008	0.043	0.450	0.146	0.209		
5/8/2001	OW0	0.005	0.030	0.456	0.150	0.221	1	6
5/23/2001	OW1	0.003	0.022	0.284	0.113	0.154		
5/23/2001	OW0	0.004	0.019	0.282	0.111	0.157	-1	2
6/6/2001	OW1	0.006	0.025	0.308	0.116	0.161		
6/6/2001	OW0	0.003	0.022	0.331	0.117	0.162	8	1
6/20/2001	OW1	0.002	0.016	0.237	0.114	0.152		
6/20/2001	OW0	0.001	0.019	0.263	0.113	0.158	11	4

Table 3
Comparison of Nutrient Concentrations Upstream and Downstream of SNARL Fencing Project on the Owens River
Crowley Lake, Mono County

Date	Station	NH4	NO3	TN	SRP	TP	TN % Change	TP % Change
7/3/2001	OW1	0.006	0.027	0.357	0.181	0.221		
7/3/2001	OW0	0.001	0.023	0.338	0.151	0.194	-5	-12
7/17/2001	OW1	0.003	0.021	0.370	0.127	0.174		
7/17/2001	OW0	0.001	0.027	0.338	0.129	0.180	-9	3
8/1/2001	OW1	0.003	0.024	0.381	0.132	0.174		
8/1/2001	OW0	0.001	0.027	0.467	0.136	0.185	23	6
8/15/2001	OW1	0.004	0.022	0.285	0.140	0.175		
8/15/2001	OW0	0.000	0.021	0.265	0.144	0.171	-7	-2
8/29/2001	OW1	0.000	0.014	0.351	0.136	0.185		
8/29/2001	OW0	<0.001	0.013	0.291	0.136	0.179	-17	-3
9/12/2001	OW1	<0.001	0.014	0.157	0.134	0.168		
9/12/2001	OW0	<0.001	0.018	0.173	0.131	0.166	10	-1
9/26/2001	OW1	0.005	0.022	0.147	0.143	0.176		
9/26/2001	OW0	0.002	0.025	0.161	0.142	0.174	9	-1
10/10/2001	OW1	0.005	0.030	0.124	0.130	0.166		
10/10/2001	OW0	0.002	0.014	0.151	0.130	0.164	22	-1
10/23/2001	OW1	0.006	0.035	0.143	0.131	0.170		
10/23/2001	OW0	0.002	0.014	0.142	0.127	0.166	-1	-2
11/7/2001	OW1	0.002	0.098	0.151	0.134	0.174		
11/7/2001	OW0	0.001	0.016	0.118	0.133	0.172	-22	-1
12/5/2001	OW1	0.010	0.184	0.186	0.133	0.173		
12/5/2001	OW0	0.005	0.050	0.172	0.126	0.171	-8	-1
Average Percent Change							3	1

Notes:

Results in milligrams per liter (mg/L)

TN and TP percent change compares downstream concentrations relative to upstream concentrations

OW1 - upstream location (located at Benton Crossing Bridge)

OW0 - downstream location (located near inlet to Crowley Lake)

NH4 - Ammonia

NO3 - Nitrate

TN - Total Nitrogen

SRP - Soluble Reactive Phosphorus

TP - Total Phosphorus

Table 4
Nutrient Concentrations and TN and TP Load Estimates
Arcularius Ranch / Owens River
Crowley Lake, Mono County

Date	Station	NH4	NO3	TN	SRP	TP	TN Change	TP Change
6/9/2000	OW3	0.004	0.005	0.100	0.207	0.187		
6/9/2000	OW2	0.001	0.004	0.122	0.204	0.190	0.022	0.003
8/8/2000	OW3	0.006	0.006	0.150	0.155	0.174		
8/8/2000	OW2	0.007	0.004	0.156	0.155	0.166	0.006	-0.008
10/18/2000	OW3	0.002	0.023	0.137	0.159	0.187		
10/18/2000	OW2	0.002	0.020	0.130	0.160	0.188	-0.007	0.001
5/9/2001	OW3	0.003	0.002	0.191	0.193	0.220		
5/9/2001	OW2	0.003	0.002	0.217	0.191	0.238	0.026	0.017
7/18/2001	OW3	0.007	0.003	0.153	0.166	0.173		
7/18/2001	OW2	0.009	0.002	0.185	0.167	0.177	0.032	0.004
10/23/2001	OW3	0.006	0.025	0.151	0.150	0.168		
10/23/2001	OW2	0.008	0.022	0.166	0.149	0.169	0.015	0.001
						Average	**0.016**	**0.003**

FLOW IN OWENS RIVER

April 01 - March 02	75473	acre-ft, which is approximately	93,100,000,000	liters
April 00 - March 01	68897	acre-ft, which is approximately	85,000,000,000	liters
		Average Annual flow	89,050,000,000	liters

ANNUAL LOADING TO HOT CREEK

Assume 6 months of grazing and an average TN increase of 0.016 mg/L

1500 pounds TN from grazing along Arcularius Ranch on Owens River

Assume 6 months of grazing and an average TP increase of 0.003 mg/L

300 pounds of TP from grazing along Arcularius Ranch on Owens River

Notes:
Results in milligrams per liter (mg/L) and from Jellison and Dawson (2003)
TN and TP change compares downstream concentrations relative to upstream concentrations
OW3 - upstream location (located above Arcularius Ranch)
OW2 - downstream location (located below Arcularius Ranch))
NH4 - Ammonia
NO3 - Nitrate
TN - Total Nitrogen
SRP - Soluble Reactive Phosphorus
TP - Total Phosphorus
Flow from Jellison and Dawson (2003)

Table 5

Comparison of Nutrient Concentrations Downstream of Arcularius Ranch and Upstream of Hot Creek

(LADWP-Leased Grazing Land)

Crowley Lake, Mono County

Date	Station	NH4	NO3	TN	SRP	TP	TN % Change	TP % Change
5/9/2001	OW2	0.003	0.018	0.217	0.191	0.238		
5/9/2001	OW1.5A	0.002	0.021	0.204	0.192	0.219	-6	-8
7/18/2001	OW2	0.009	0.024	0.185	0.167	0.177		
7/18/2001	OW1.5A	0.004	0.014	0.163	0.166	0.175	-12	-1
10/23/2001	OW2	0.008	0.218	0.166	0.149	0.169		
10/23/2001	OW1.5A	0.005	0.104	0.117	0.145	0.157	-30	-7

Notes:

Results in milligrams per liter (mg/L)

TN and TP percent change compares downstream concentrations relative to upstream concentrations

OW2 - upstream location (located below Arcularius Ranch)

OW1.5 - downstream location (located immediately upstream of the confluence of the Owens River and Hot Creek)

NH4 - Ammonia

NO3 - Nitrate

TN - Total Nitrogen

SRP - Soluble Reactive Phosphorus

TP - Total Phosphorus

Table 6
Surface Water Sampling Results With TN and TP Loading Estimates
Convict and McGee Creeks
Upstream and Downstream of Irrigated Pastures
Crowley Lake, Mono County

Date	Station	NH4	NO3	TN	SRP	TP
Concentrations Upstream of Irrigated Pasture (1)						
6/6/2000	CO2	0.001	0.009	0.056	0.008	0.003
8/9/2000	CO2	0.005	0.015	0.122	0.006	0.005
10/17/2000	CO2	<0.001	0.002	0.040	0.003	0.005
5/9/2001	CO2	0.003	0.013	0.131	0.007	0.016
7/17/2001	CO2	0.003	0.019	0.066	0.001	0.009
10/23/2001	CO2	0.002	0.011	0.080	0.004	0.007
AVERAGE		**0.002**	**0.011**	**0.082**	**0.005**	**0.007**
5/10/2000	MG3	0.003	0.098	0.076	0.002	0.010
5/24/2000	MG3	0.001	0.217	0.122	0.004	0.015
6/6/2000	MG3	<0.001	0.343	0.079	0.007	0.007
6/21/2000	MG3	0.036	0.244	0.100	0.013	0.009
7/5/2000	MG3	0.005	0.184	0.073	0.007	0.004
7/19/2000	MG3	0.003	0.138	0.061	0.007	0.003
8/2/2000	MG3	0.004	0.083	0.100	0.004	0.006
8/9/2000	MG3	0.003	0.084	0.070	0.006	0.006
8/16/2000	MG3	0.002	0.156	0.061	0.004	0.003
10/18/2000	MG3	<0.001	0.006	0.034	0.002	0.002
5/23/2001	MG3	0.001	0.262	0.112	0.003	0.009
6/6/2001	MG3	0.003	0.237	0.108	0.003	0.005
6/20/2001	MG3	0.002	0.184	0.107	0.003	0.004
7/3/2001	MG3	0.003	0.160	0.100	0.005	0.009
7/18/2001	MG3	0.004	0.244	0.093	0.004	0.013
8/1/2001	MG3	0.003	0.202	0.086	0.004	0.006
8/15/2001	MG3	0.003	0.033	0.076	0.007	0.008
8/29/2001	MG3	0.001	0.076	0.055	0.002	0.006
9/12/2001	MG3	0.001	0.063	0.056	0.005	0.006
9/26/2001	MG3	0.002	0.007	0.046	0.007	0.005
10/10/2001	MG3	0.001	0.009	0.040	0.003	0.006
10/23/2001	MG3	0.002	0.018	0.037	0.005	0.006
AVERAGE		**0.004**	**0.139**	**0.077**	**0.005**	**0.007**
Concentrations Downstream of Irrigated Pasture (1)						
5/24/2000	MG0	<0.001	0.153	0.245	0.006	0.052
6/9/2000	MG0	0.001	0.123	0.116	0.003	0.016
6/21/2000	MG0	0.004	0.131	0.155	0.015	0.015
7/5/2000	MG0	0.009	0.080	0.140	0.010	0.011
7/19/2000	MG0	0.005	0.068	0.319	0.010	0.064
8/2/2000	MG0	0.013	0.030	0.257	0.008	0.040
8/9/2000	MG0	0.011	0.043	0.274	0.011	0.053
8/16/2000	MG0	0.004	0.042	0.216	0.007	0.042
10/18/2000	MG0	0.003	0.076	0.104	0.007	0.013
5/9/2001	MG0	0.005	0.156	0.176	0.011	0.021
5/23/2001	MG0	0.005	0.153	0.188	0.004	0.020
6/6/2001	MG0	0.009	0.164	0.125	0.005	0.010
6/20/2001	MG0	0.007	0.102	0.129	0.006	0.007
7/3/2001	MG0	0.005	0.081	0.157	0.004	0.014
7/17/2001	MG0	0.010	0.111	0.132	0.003	0.013
8/1/2001	MG0	0.009	0.078	0.226	0.007	0.029
8/15/2001	MG0	0.005	0.041	0.154	0.007	0.017
8/29/2001	MG0	0.002	0.049	0.144	0.005	0.022
9/12/2001	MG0	0.002	0.067	0.118	0.007	0.016
9/26/2001	MG0	0.007	0.080	0.257	0.007	0.034
10/10/2001	MG0	0.028	0.094	0.242	0.004	0.047
10/24/2001	MG0	0.009	0.092	0.347	0.007	0.068
AVERAGE		**0.007**	**0.092**	**0.192**	**0.007**	**0.028**

ANNUAL FLOW IN McGEE CREEK				
April 2000 - March 2001:	15,438	acre-ft, which is approximately	19,000,000,000	liters
April 2001 - March 2002:	19,178	acre-ft, which is approximately	23,700,000,000	liters
		average annual flow	21,350,000,000	liters
ANNUAL FLOW IN CONVICT CREEK				
April 2000 - March 2001:	12,643	acre-ft, which is approximately	15,600,000,000	liters
April 2001 - March 2002:	14,944	acre-ft, which is approximately	18,400,000,000	liters
		average annual flow	17,000,000,000	liters

Table 6
Surface Water Sampling Results With TN and TP Loading Estimates
Convict and McGee Creeks
Upstream and Downstream of Irrigated Pastures
Crowley Lake, Mono County

ESTIMATE OF ANNUAL TN LOADING FROM GRAZING						
McGee Creek - Upstream of Grazing Area						
0.077	mg/L TN *	21,350,000,000.000	liters/yr *	0.500	820,820,159	mg TN /yr
Convict Creek - Upstream of Grazing Area						
0.082	mg/L TN *	17,000,000,000.000	liters/yr *	0.500	700,116,670	mg TN /yr
			Sum of TN above grazing area		**1,520,936,829**	mg TN /yr
McGee Creek - Downstream of McGee / Convict confluence and Grazing Area						
0.192	mg/L TN *	38,350,000,000.000	liters/yr *	0.500	**3,680,327,508**	mg TN /yr
Annual TN Loading from Grazing						
3680327508 mg - 1520936829 mg = 2,160,000,000 mg, which equals					**4,800**	pounds TN

ESTIMATE OF ANNUAL TP LOADING FROM GRAZING						
McGee Creek - Upstream of Grazing Area						
0.007	mg/L TP *	21,350,000,000.000	liters/yr *	0.500	72,051,398	mg TN /yr
Convict Creek - Upstream of Grazing Area						
0.007	mg/L TP *	17,000,000,000.000	liters/yr *	0.500	62,361,667	mg TN /yr
			Sum of TP above grazing area		**134,413,065**	mg TN /yr
McGee Creek - Downstream of McGee / Convict confluence and Grazing Area						
0.028	mg/L TP *	38,350,000,000.000	liters/yr *	0.500	**542,547,907**	mg TN /yr
Annual TP Loading from Grazing						
542547907 mg - 134413065 mg = 408134842 mg, which equals					**900**	pounds TN

Notes

Results in milligrams per liter (mg/L); only includes data collected from May through October
Average - One half the detection limit used for non-detect results in average calculation
NH4 - Ammonia
NO3 - Nitrate
TN - Total Nitrogen
SRP - Soluble Reactive Phosphorus
TP - Total Phosphorus
Flow rates from Jellison and Dawson (2003).
Flow rate below confluence of McGee and Convict creeksis assumed to be the sum of the flows of each creek measured above the confluence.

Table 7

Surface Water Sampling Results with TN and TP Loading Estimates

Hot Creek

Upstream and Downstream of Irrigated Pastures

Crowley Lake, Mono County

Date	Station	TN (mg/L)	TP (mg/L)	TN % Change	TP % Change
5/8/2001	MA1	0.431	0.197		
5/9/2001	MAOA	0.651	0.168	51	-15
7/17/2001	MA1	0.499	0.201		
7/18/2001	MAOA	0.616	0.140	23	-31
10/24/2001	MA1	0.345	0.212		
10/23/2001	MAOA	0.256	0.210	-26	-1

ESTIMATE OF TN LOADING

May-01	TN Concentration (mg/L)
Hot Creek above irrigated pasture	0.431
Hot Creek TN below irrigated pasture	0.651
Increase in TN Concentration	0.220

July-01	TN Concentration (mg/L)
Hot Creek above irrigated pasture	0.499
Hot Creek TN below irrigated pasture	0.616
Increase in TN Concentration	0.117

Average Increase in TN Concentration 0.168

Flow in Hot Creek

13,481 acre-feet/yr, which is approximately 16,600,000,000 liters/year (Jellison and Dawson, 2003)

Annual Loading to Hot Creek

Assume 6 months of grazing and an average TN increase of 0.168 mg/L

3100 pounds TN from grazing along irrigated pasture at Hot Creek

Notes

1) mg/L = milligrams per liter

2) TN = total nitrogen; TP = total phosphorous

3) TN and TP percent change compares downstream concentrations relative to upstream concentrations

4) MA1 is the upstream sampling site and MA0 is the downstream sampling site

5) Flow rate is from Jellison and Dawson (2003) for the period April 2001 to March 2002 for the Mammoth / Hot Creek gauging station at US 395.

Table 8

Estimates of Total Nitrogen and Total Phosphorous Annual Loads from Hot Creek Hatchery

Crowley Lake, Mono County

	mg/L *	L/day *	days/yr *	g/mg *	kg/g *	lbs/kg =	lbs/yr
TN in Hatchery Springs (low flow)	0.37	4.40E+07	365	0.001	0.001	2.2	13073
TN in Hatchery Springs (high flow)	0.37	8.60E+07	365	0.001	0.001	2.2	25551
		Estimated average TN annual load from Hatchery Springs					19312
TN below Hatchery (low flow)	0.49	4.40E+07	365	0.001	0.001	2.2	17313
TN below Hatchery (high flow)	0.49	8.60E+07	365	0.001	0.001	2.2	33838
		Estimated average TN annual load below Hatchery					25576
Estimated Average TN annual load from Hot Creek Hatchery			25600	-	19300	=	**6300**

	mg/L *	L/day *	days/yr *	g/mg *	kg/g *	lbs/kg =	lbs/yr
TP in Hatchery Springs (low flow)	0.16	4.40E+07	365	0.001	0.001	2.2	5653
TP in Hatchery Springs (high flow)	0.16	8.60E+07	365	0.001	0.001	2.2	11049
		Estimated average TP annual load from Hatchery Springs					8351
TP below Hatchery (low flow)	0.20	4.40E+07	365	0.001	0.001	2.2	7066
TP below Hatchery (high flow)	0.20	8.60E+07	365	0.001	0.001	2.2	13812
		Estimated average TP annual load below Hatchery					10439
Estimated Average TP annual load from Hot Creek Hatchery			10400	-	8400	=	**2000**

Notes:

1) TN and TP in "Hatchery Springs" concentration is based on an average of six total samples collected at sites MA2.5A and MA2.5B in 2001

2) TN and TP "below Hatchery" concentration is based on an average of six total samples collected at site MA2B in 2000 and 2001

3) High and low flow estimates are taken from California Department of Fish and Game "California Steam Bioassessment Procedure for Hot Creek Hatchery, Mono County" dated 11/22/04.

Table 9
Effects of Potential Load Reductions on Trophic State Index
Crowley Lake, Mono County

TOTAL NITROGEN	
240,000	pounds Total Nitrogen annual load in Crowley Lake (Figure 3)
Potentially Controllable Nitrogen Loads	
6,300	lbs influent TN Load from Hot Creek Hatchery (Table 8)
4,800	lbs influent TN Load from McGee/Convict irrigated pasture (Table 6)
3,100	lbs influent TN load from Hot Creek irrigated pasture (Table 7)
1,500	lbs influent TN load from dry grazing on Arcularius Ranch (Table 4)
15,700	lbs influent TN load from potentially controllable sources

15,700 lbs TN / 240,000 lbs TN = **6.5** percent load reduction

Trophic State Evaluation - Total Nitrogen:
Calculation used (USEPA, 1999): TSI (TN) = 54.45 + 14.43*ln(TN in ug/L)

TSI (TN)	TN (mg/L)	Comments:
47	0.62	Average in-lake TN Concentration (Jellison and Dawson, 2003)
46	0.58	Assumes 6.5 percent of TN Load is eliminated

TOTAL PHOSPHOROUS	
50,500	pounds Total Phosphorous annual load in Crowley Lake (Figure 3).
Potentially Controllable Phosphorous Loads	
2,100	lbs influent TP Load from Hot Creek Hatchery (Table 8)
900	lbs influent TP Load from McGee/Convict irrigated pasture (Table 6)
300	lbs influent TP load from dry grazing on Arcularius Ranch (Table 4)
3,300	lbs influent TP load from potentially controllable sources

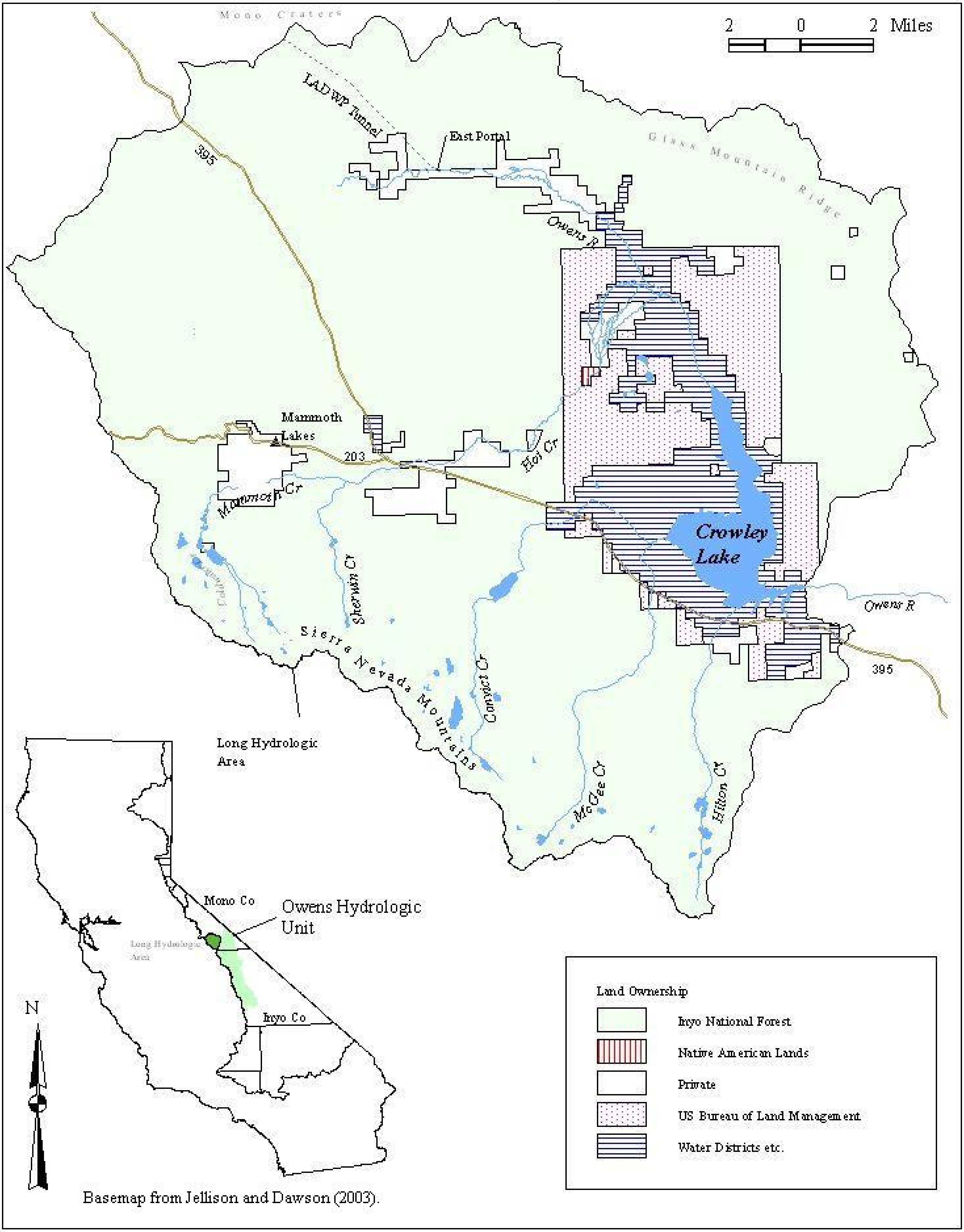
3,300 lbs TP / 50,500 lbs TP = **6.5** percent load reduction

Trophic State Evaluation - Total Phosphorous:
Calculation used (USEPA, 1999): TSI (TP) = 4.15 + 14.42*ln(TP in ug/L)

TSI (TP)	TP (ug/L)	
70	94	Mean TP Concentration in Crowley Lake (Jellison and Dawson, 2003)
69	88	Assumes a reduction of 6.5% in TP load to Crowley Lake

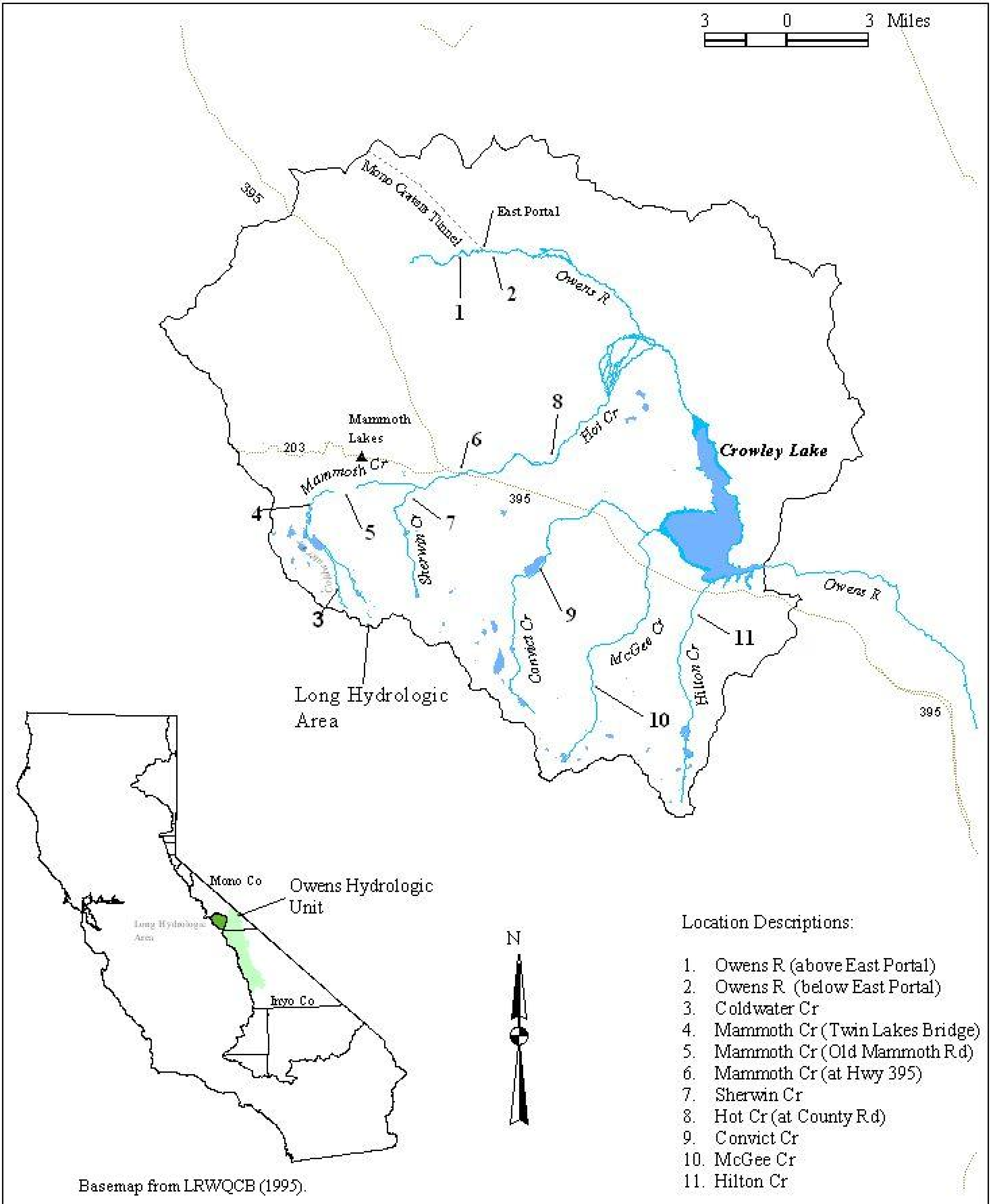
FIGURES

FIGURE 1.
CROWLEY LAKE WATERSHED, MONO COUNTY



Basemap from Jellison and Dawson (2003).

Figure 2.
Locations of Water Bodies Tributary
to Crowley Lake With Numeric Water Quality Objectives.
Crowley Lake, Mono County

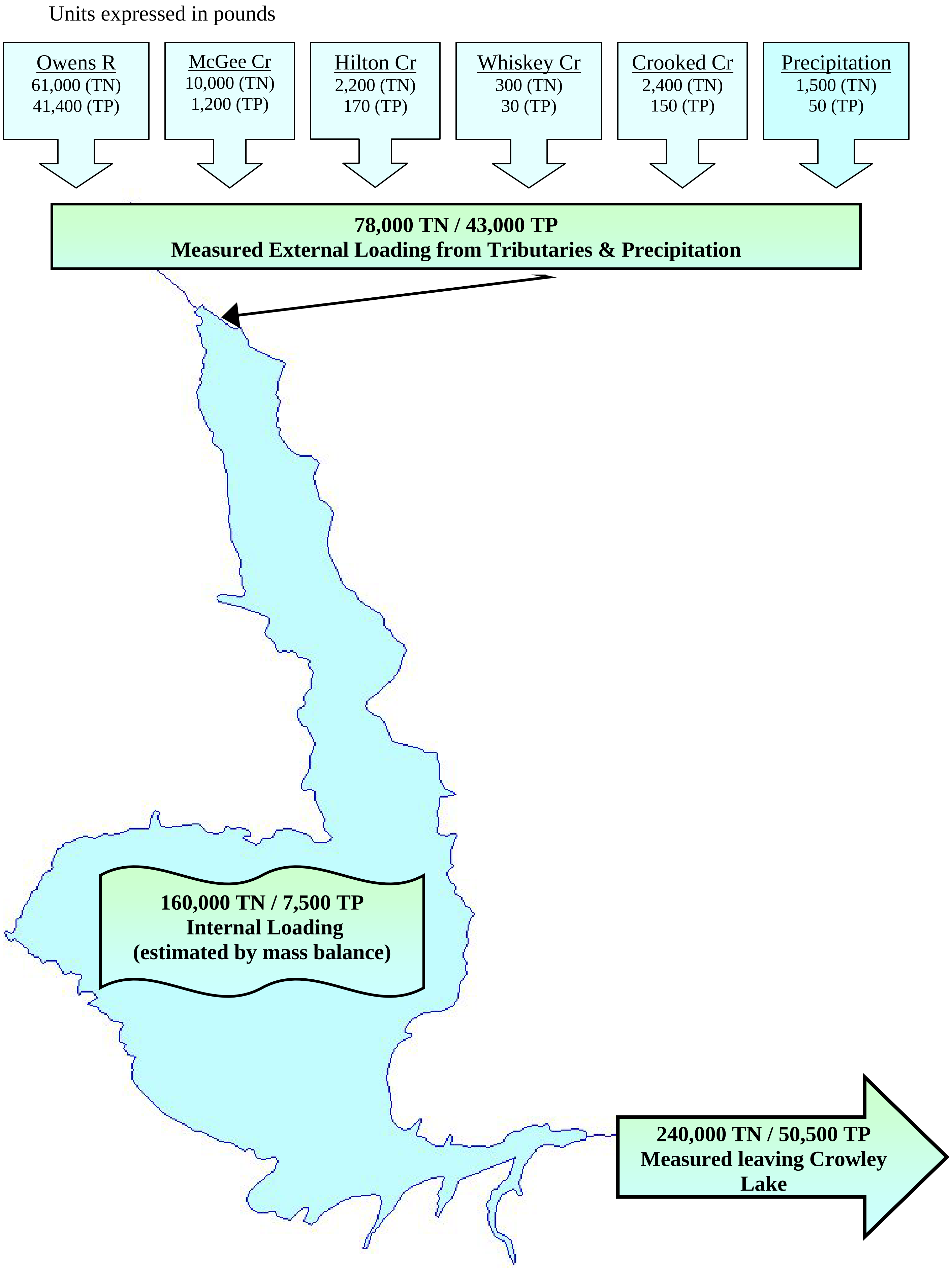


Location Descriptions:

1. Owens R (above East Portal)
2. Owens R (below East Portal)
3. Coldwater Cr
4. Mammoth Cr (Twin Lakes Bridge)
5. Mammoth Cr (Old Mammoth Rd)
6. Mammoth Cr (at Hwy 395)
7. Sherwin Cr
8. Hot Cr (at County Rd)
9. Convict Cr
10. McGee Cr
11. Hilton Cr

Basemap from LRWQCB (1995).

Figure 3.
Conceptual Diagram of Total Nitrogen And Phosphorus Budget
Crowley Lake



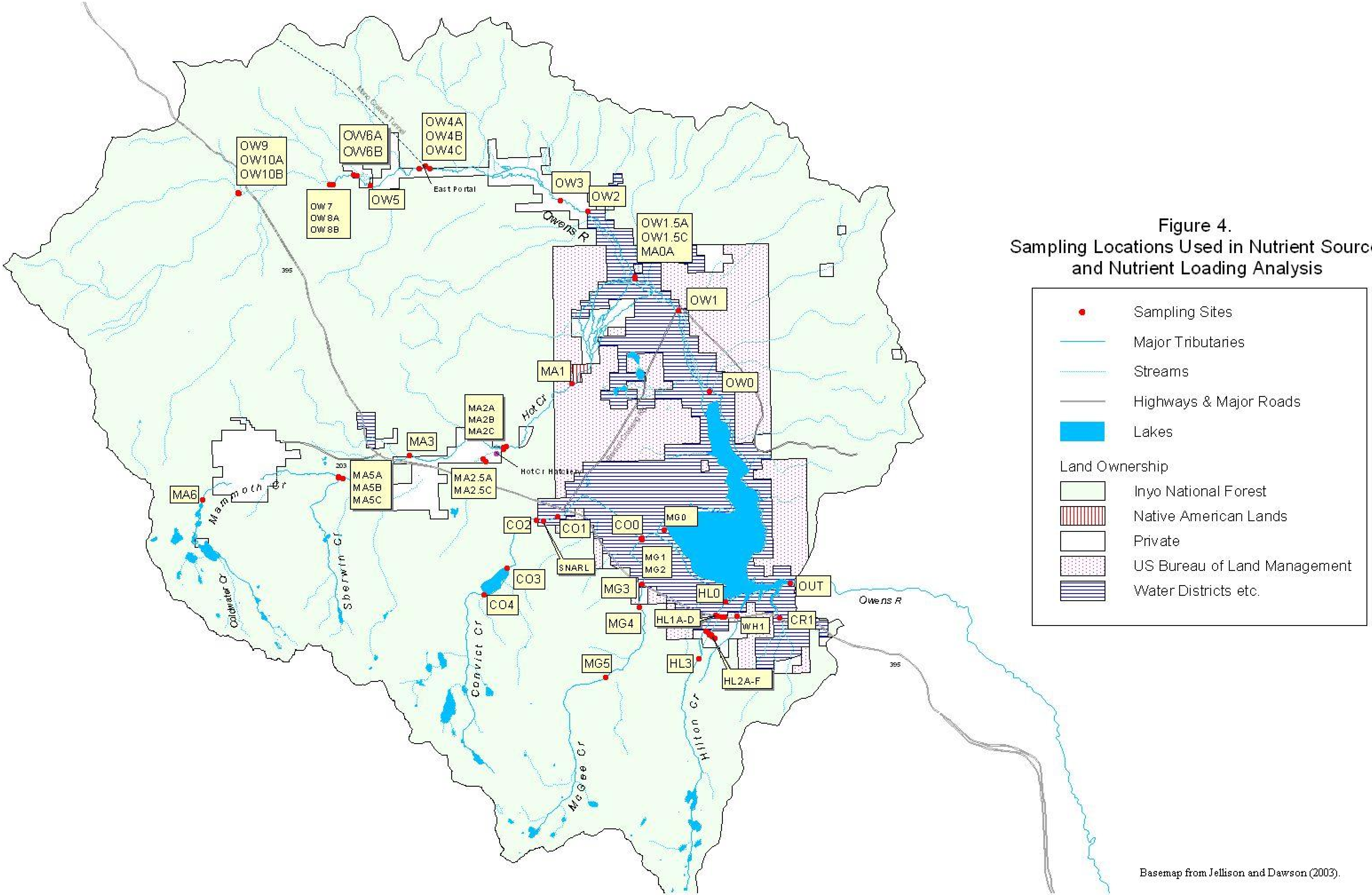
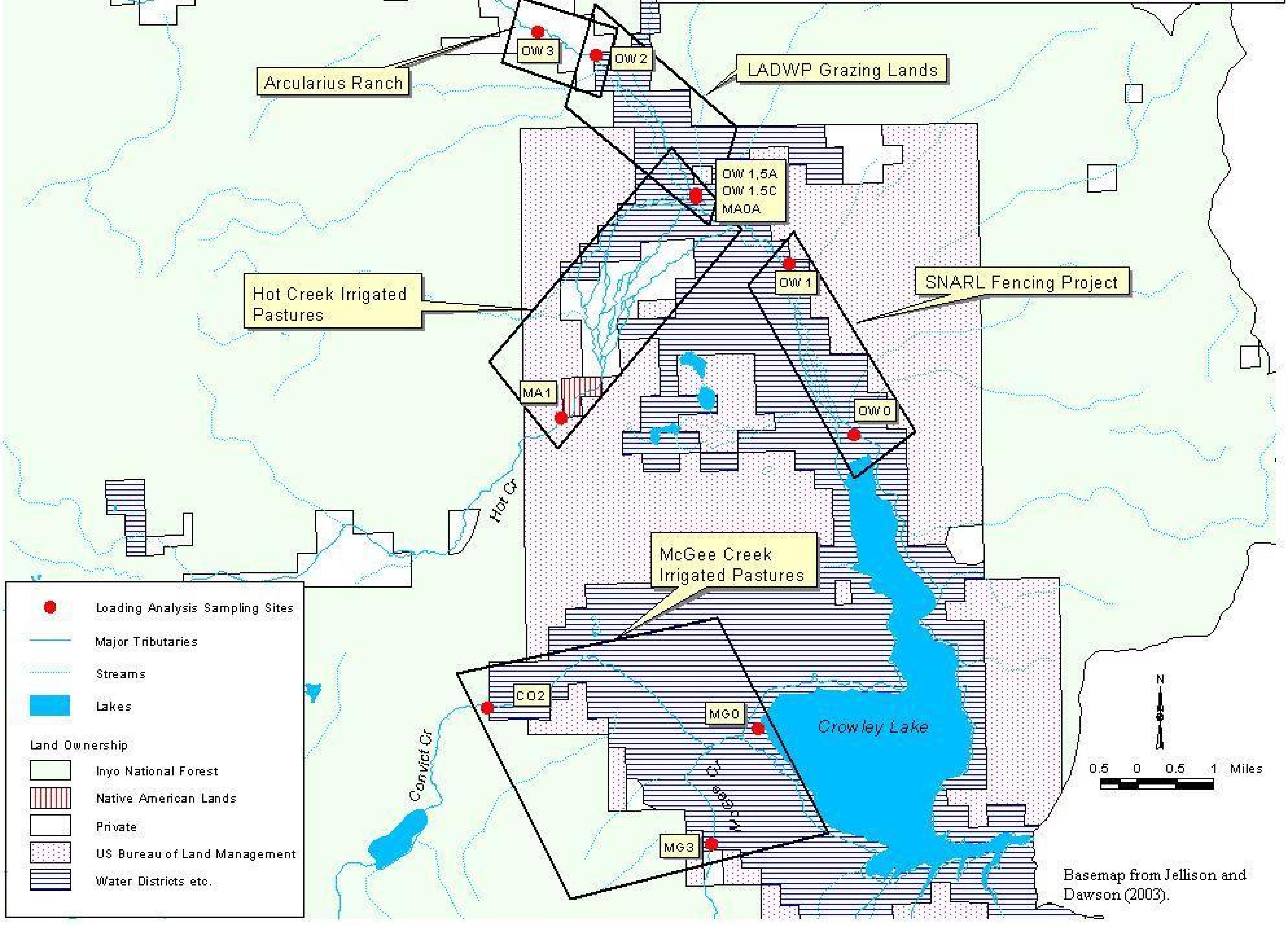


Figure 4.
Sampling Locations Used in Nutrient Source and Nutrient Loading Analysis

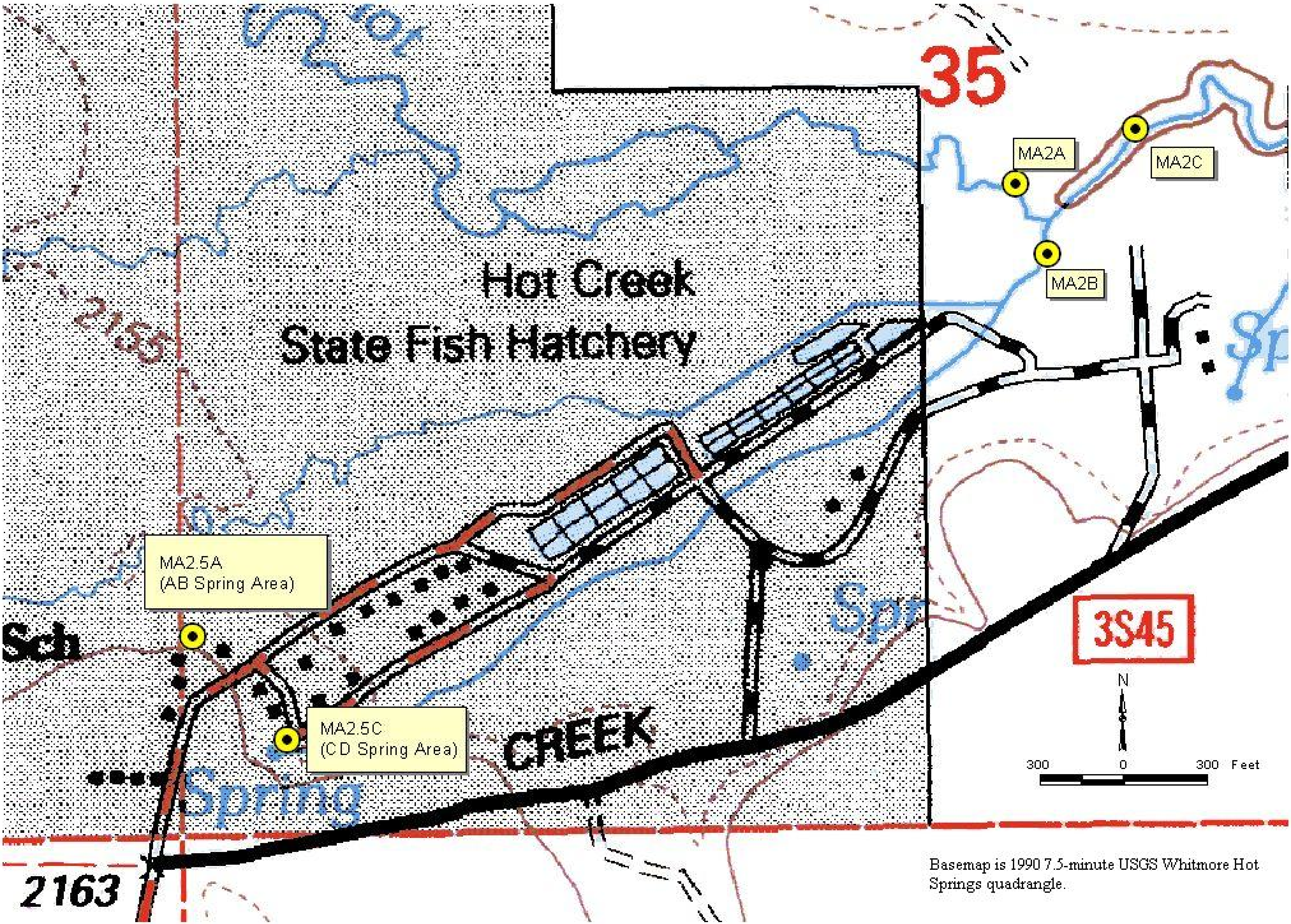
Basemap from Jellison and Dawson (2003).

Figure 5.
Sample Locations Used in Nutrient Loading Evaluation of Grazed Areas.



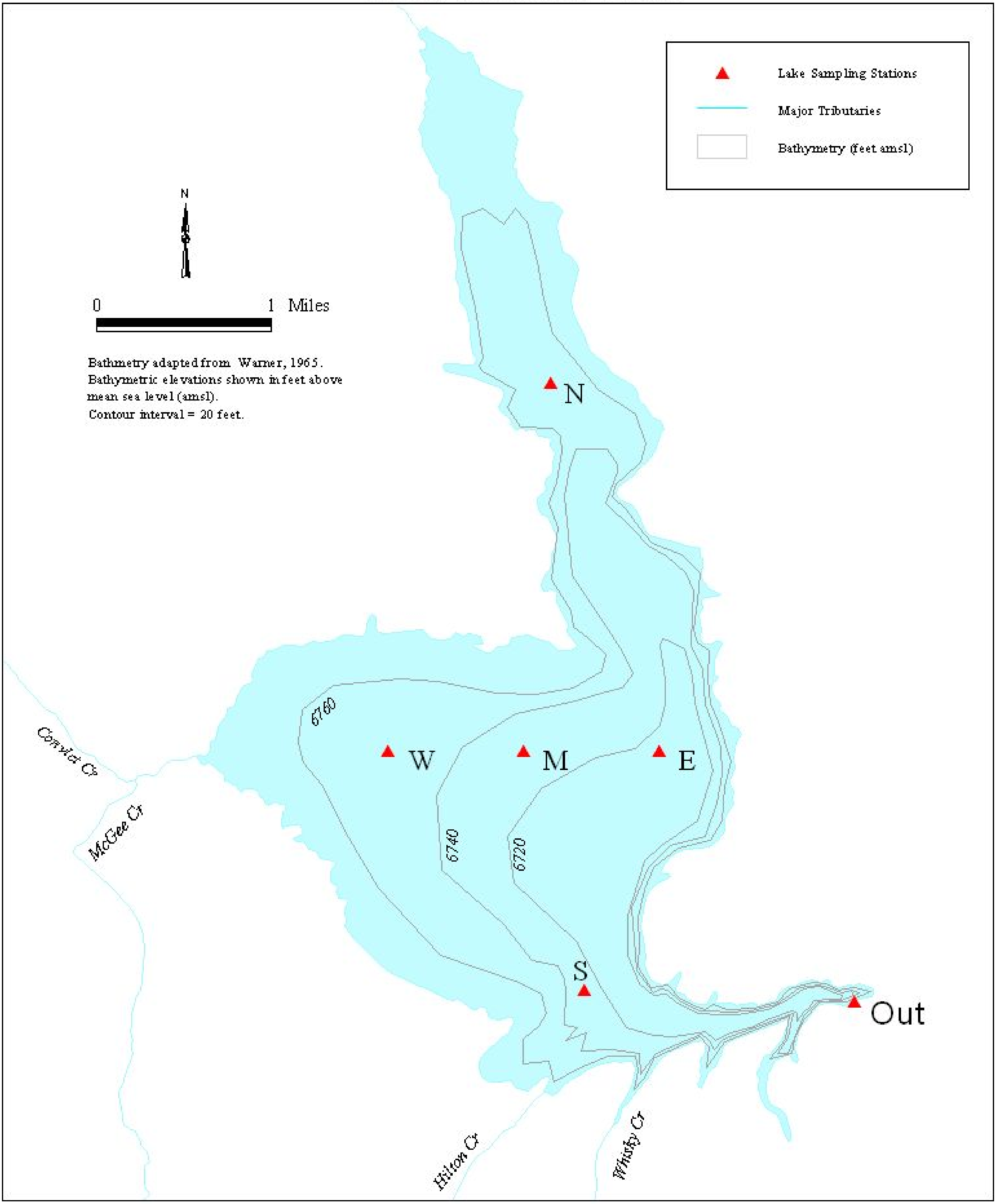
Basemap from Jellison and Dawson (2003).

Figure 6. Hot Creek Hatchery Nutrient Loading Evaluation Sites



Basemap is 1990 7.5-minute USGS Whitmore Hot Springs quadrangle.

Figure 7.
Crowley Lake Sampling Locations and Bathmetry.
Crowley Lake, Mono County.



Appendix A

Table 3-1, Table 3-3, and Table 3-6 Reproduced from the Water Quality Control Plan for the Lahontan Region

Table 3-1
ONE-HOUR AVERAGE CONCENTRATION FOR AMMONIA[1,2]

Waters Designated as COLD, COLD with SPWN, COLD with MIGR (Salmonids or other sensitive coldwater species present)

	Temperature, C						
pH	0	5	10	15	20	25	30
Un-ionized Ammonia (mg/liter NH_3)							
6.50	0.0091	0.0129	0.0182	0.026	0.036	0.036	0.036
6.75	0.0149	0.021	0.030	0.042	0.059	0.059	0.059
7.00	0.023	0.033	0.046	0.066	0.093	0.093	0.093
7.25	0.034	0.048	0.068	0.095	0.135	0.135	0.135
7.50	0.045	0.064	0.091	0.128	0.181	0.181	0.181
7.75	0.056	0.080	0.113	0.159	0.22	0.22	0.22
8.00	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.25	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.50	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.75	0.065	0.092	0.130	0.184	0.26	0.26	0.26
9.00	0.065	0.092	0.130	0.184	0.26	0.26	0.26
Total Ammonia (mg/liter NH_3)							
6.50	35	33	31	30	29	20	14.3
6.75	32	30	28	27	27	18.6	13.2
7.00	28	26	25	24	23	16.4	11.6
7.25	23	22	20	19.7	19.2	13.4	9.5
7.50	17.4	16.3	15.5	14.9	14.6	10.2	7.3
7.75	12.2	11.4	10.9	10.5	10.3	7.2	5.2
8.00	8.0	7.5	7.1	6.9	6.8	4.8	3.5
8.25	4.5	4.2	4.1	4.0	3.9	2.8	2.1
8.50	2.6	2.4	2.3	2.3	2.3	1.71	1.28
8.75	1.47	1.40	1.37	1.38	1.42	1.07	0.83
9.00	0.86	0.83	0.83	0.86	0.91	0.72	0.58

[1] To convert these values to mg/liter N, multiply by 0.822

[2] Source: U. S. Environmental Protection Agency. 1986. Quality criteria for water, 1986. EPA 440/5-86-001.

Table 3-3
FOUR DAY AVERAGE CONCENTRATION FOR AMMONIA[1,2]

Waters Designated as COLD, COLD with SPWN, COLD with MIGR (Salmonids or other sensitive coldwater species present)

	Temperature, °C						
pH	0	5	10	15	20	25	30
Un-ionized Ammonia (mg/liter NH_3)							
6.50	0.0008	0.0011	0.0016	0.0022	0.0022	0.0022	0.0022
6.75	0.0014	0.0020	0.0028	0.0039	0.0039	0.0039	0.0039
7.00	0.0025	0.0035	0.0049	0.0070	0.0070	0.0070	0.0070
7.25	0.0044	0.0062	0.0088	0.0124	0.0124	0.0124	0.0124
7.50	0.0078	0.0111	0.0156	0.022	0.022	0.022	0.022
7.75	0.0129	0.0182	0.026	0.036	0.036	0.036	0.036
8.00	0.0149	0.021	0.030	0.042	0.042	0.042	0.042
8.25	0.0149	0.021	0.030	0.042	0.042	0.042	0.042
8.50	0.0149	0.021	0.030	0.042	0.042	0.042	0.042
8.75	0.0149	0.021	0.030	0.042	0.042	0.042	0.042
9.00	0.0149	0.021	0.030	0.042	0.042	0.042	0.042
Total Ammonia (mg/liter NH_3)							
6.50	3.0	2.8	2.7	2.5	1.76	1.23	0.87
6.75	3.0	2.8	2.7	2.6	1.76	1.23	0.87
7.00	3.0	2.8	2.7	2.6	1.76	1.23	0.87
7.25	3.0	2.8	2.7	2.6	1.77	1.24	0.88
7.50	3.0	2.8	2.7	2.6	1.78	1.25	0.89
7.75	2.8	2.6	2.5	2.4	1.66	1.17	0.84
8.00	1.82	1.70	1.62	1.57	1.10	0.78	0.56
8.25	1.03	0.97	0.93	0.90	0.64	0.46	0.33
8.50	0.58	0.55	0.53	0.53	0.38	0.28	0.21
8.75	0.34	0.32	0.31	0.31	0.23	0.173	0.135
9.00	0.195	0.189	0.189	0.195	0.148	0.116	0.094

[1] To convert these values to mg/liter N, multiply by 0.822.
[2] Source: U. S. Environmental Protection Agency. 1992. Revised tables for determining average freshwater ammonia concentrations. USEPA Office of Water Memorandum, July 30, 1992.

Table 3-6
WATER QUALITY CRITERIA FOR
AMBIENT DISSOLVED OXYGEN CONCENTRATION[1,2]

	Beneficial Use Class			
	COLD & SPWN[3]	COLD	WARM & SPWN[3]	WARM
30 Day Mean	NA[4]	6.5	NA	5.5
7 Day Mean	9.5 (6.5)	NA	6.0	NA
7 Day Mean Minimum	NA	5.0	NA	4.0
1 Day Minimum[5,6]	8.0 (5.0)	4.0	5.0	3.0

1 From: USEPA. 1986. Ambient water quality criteria for dissolved oxygen. Values are in mg/L.

2 These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. For species that have early life stages exposed directly to the water column (SPWN), the figures in parentheses apply.

3 Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching (SPWN).

4 NA (Not Applicable).

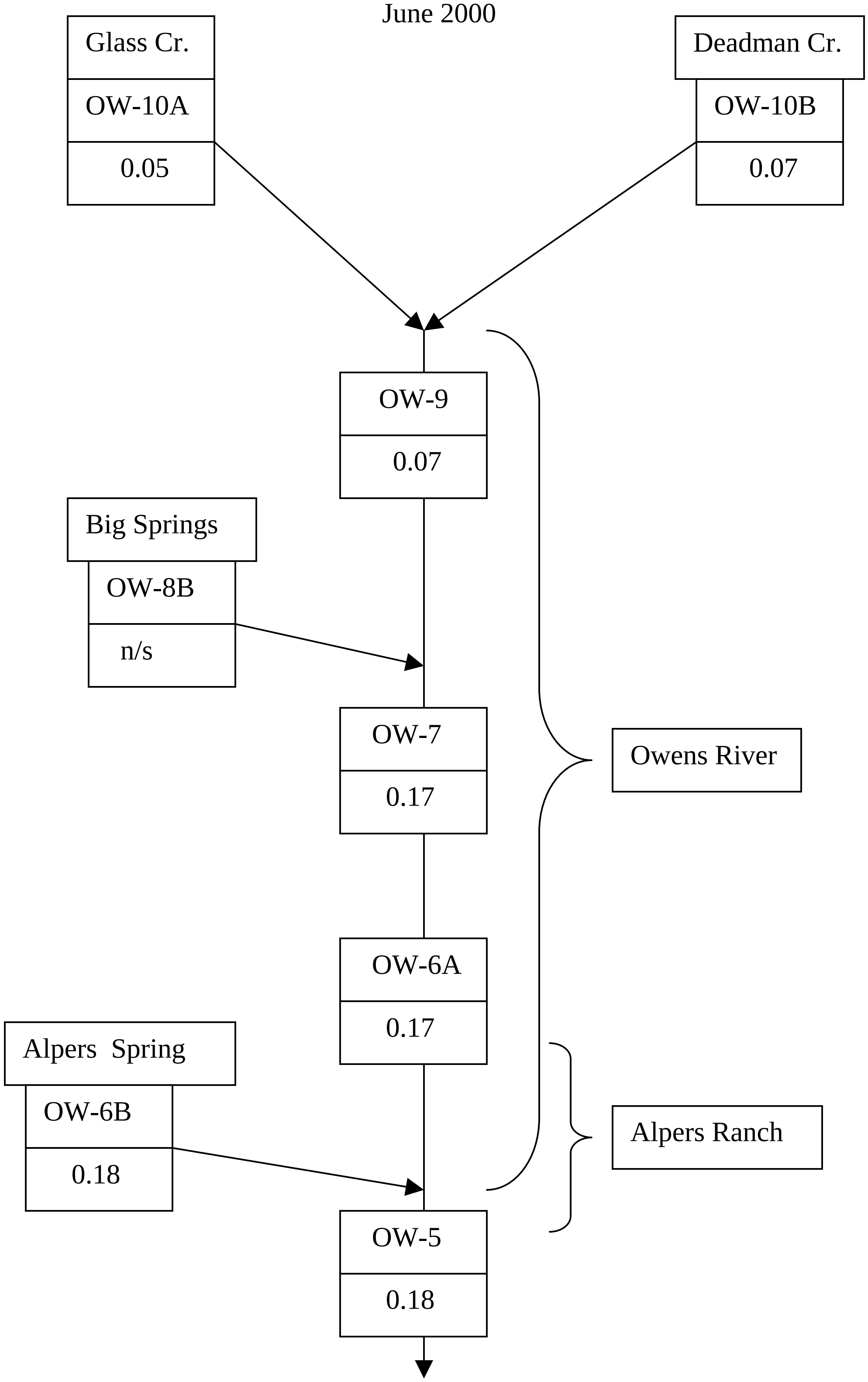
5 For highly manipulatable discharges, further restrictions apply.

6 All minima should be considered as instantaneous concentrations to be achieved at all times.

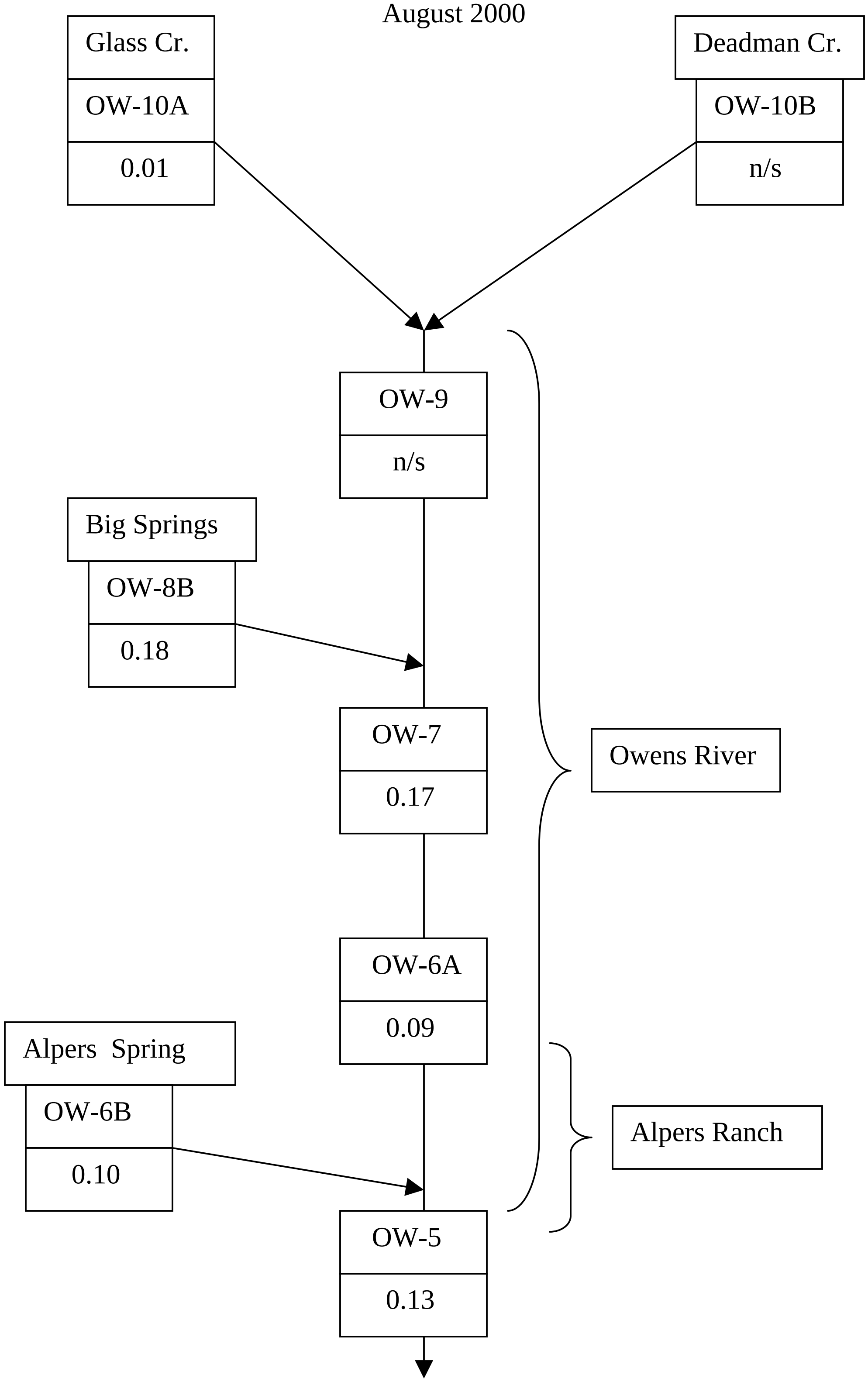
Appendix B

Total Phosphorous and Total Nitrogen Concentrations in the Upper Owens River Area

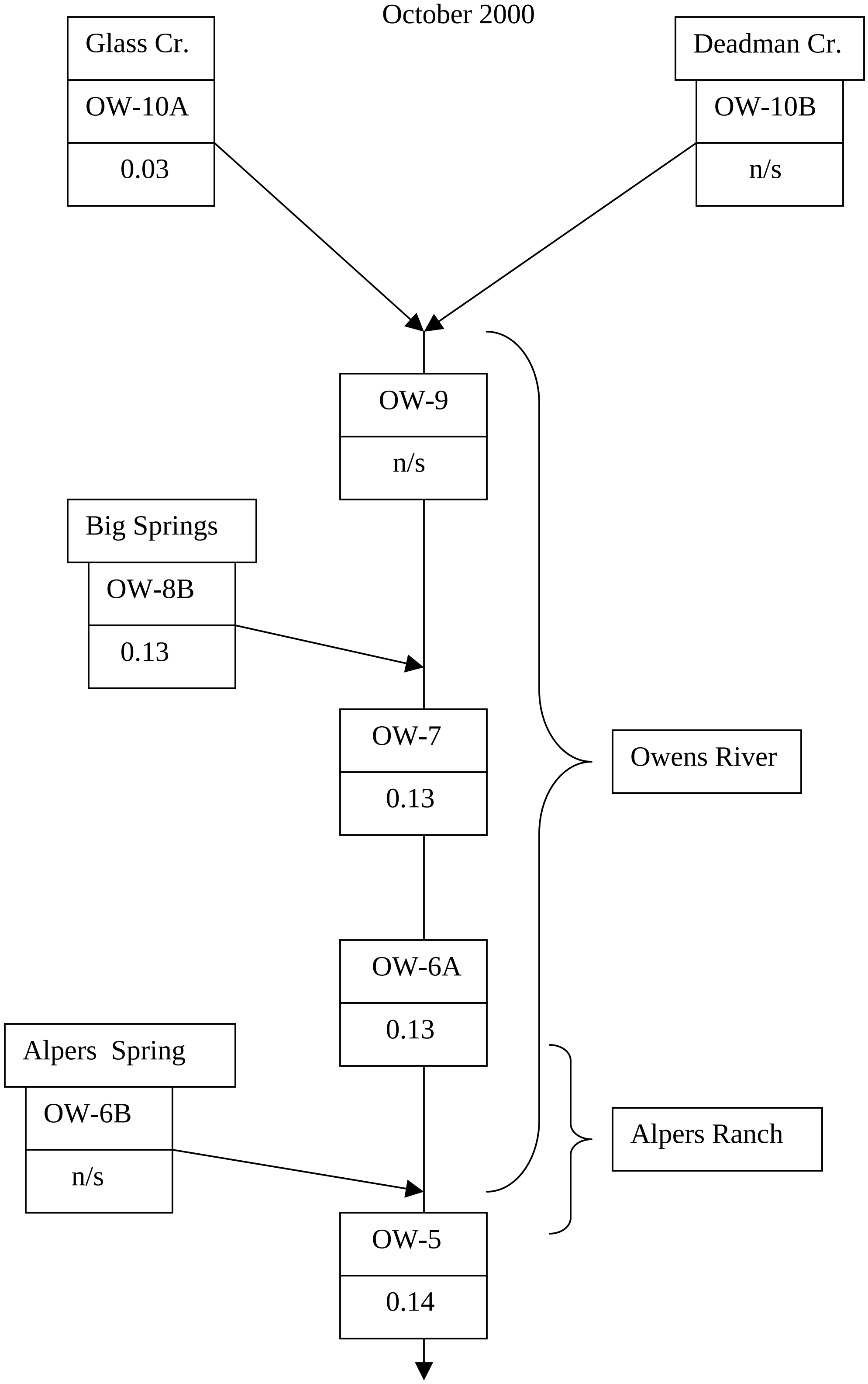
Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
June 2000

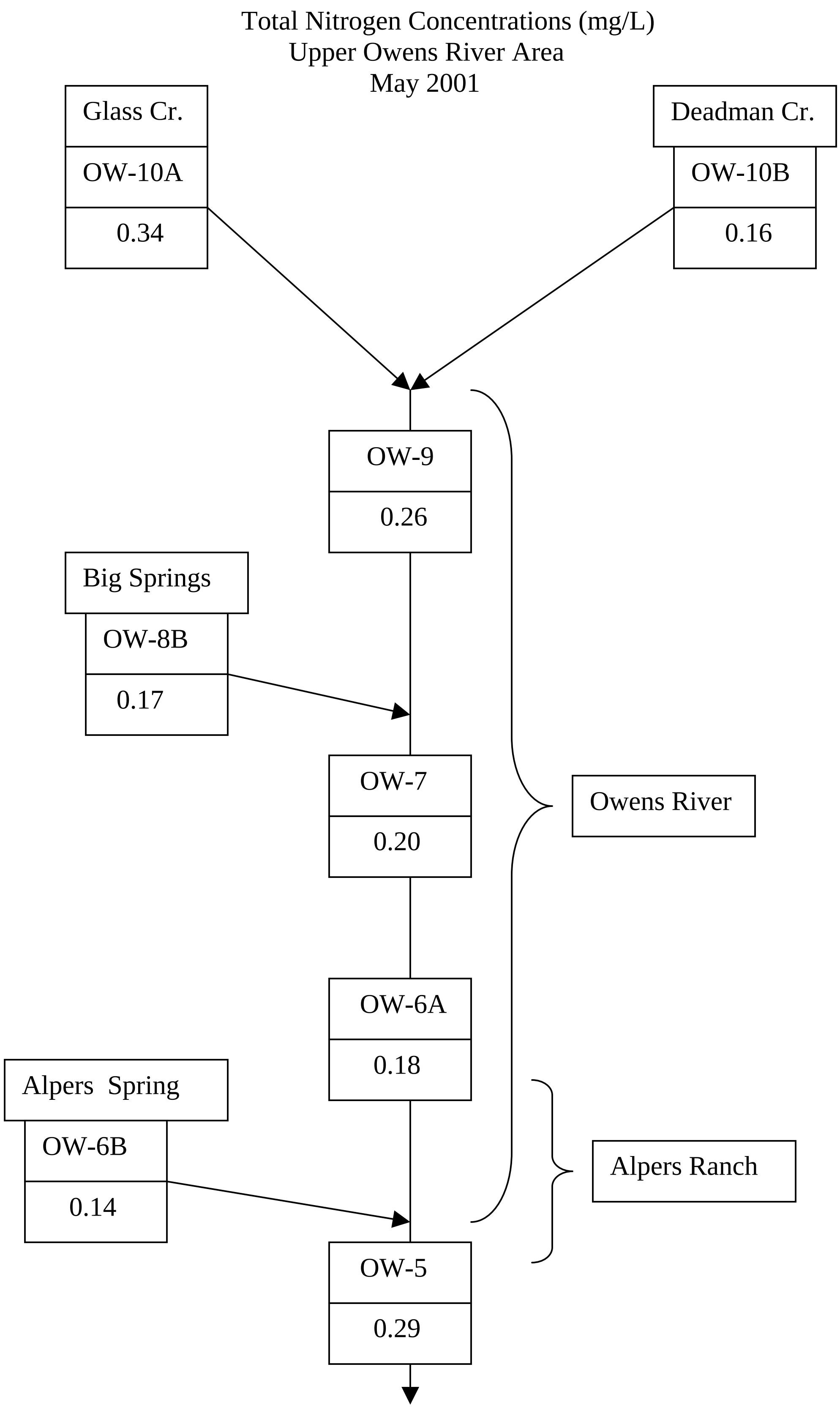


Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
August 2000

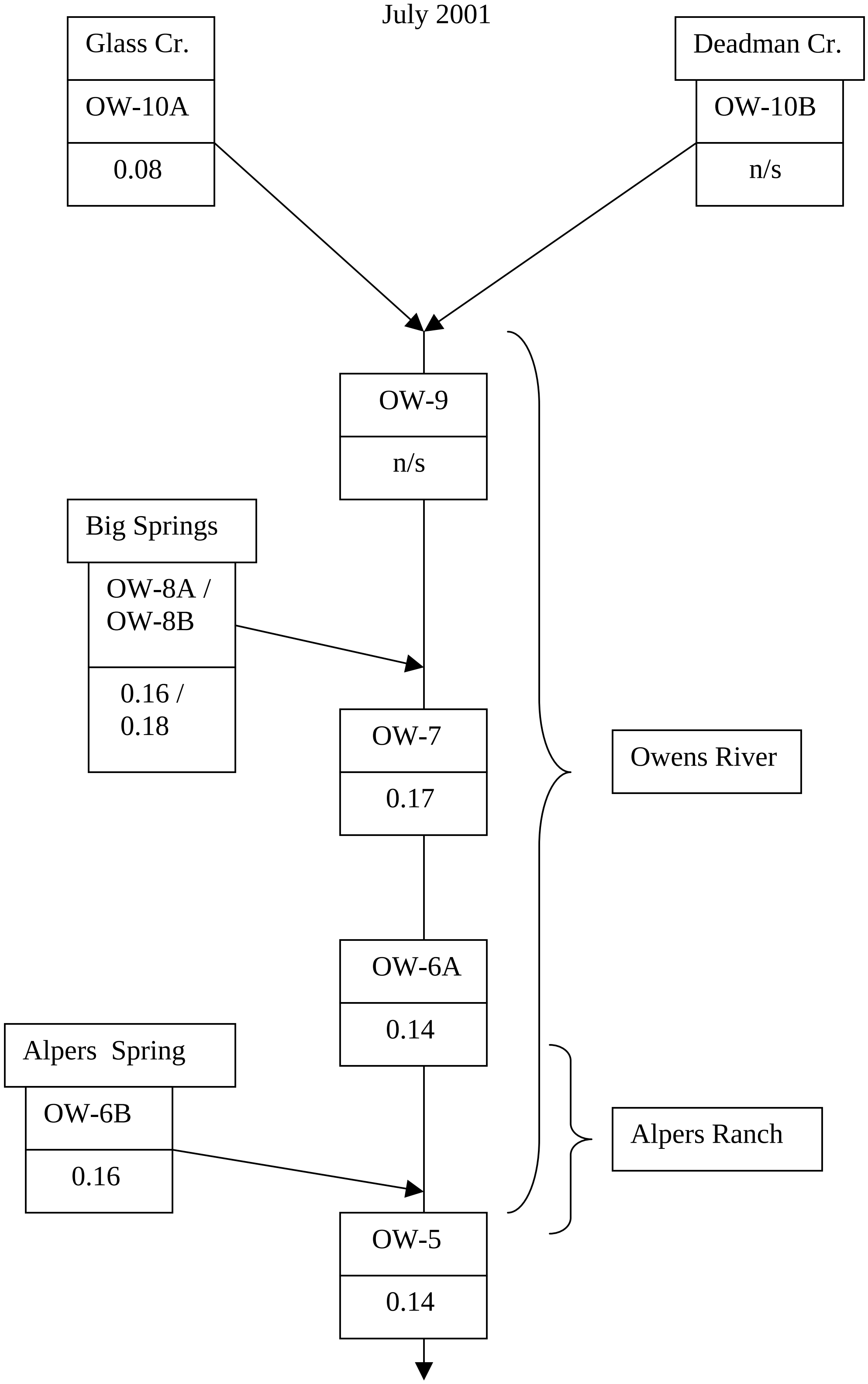


Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
October 2000

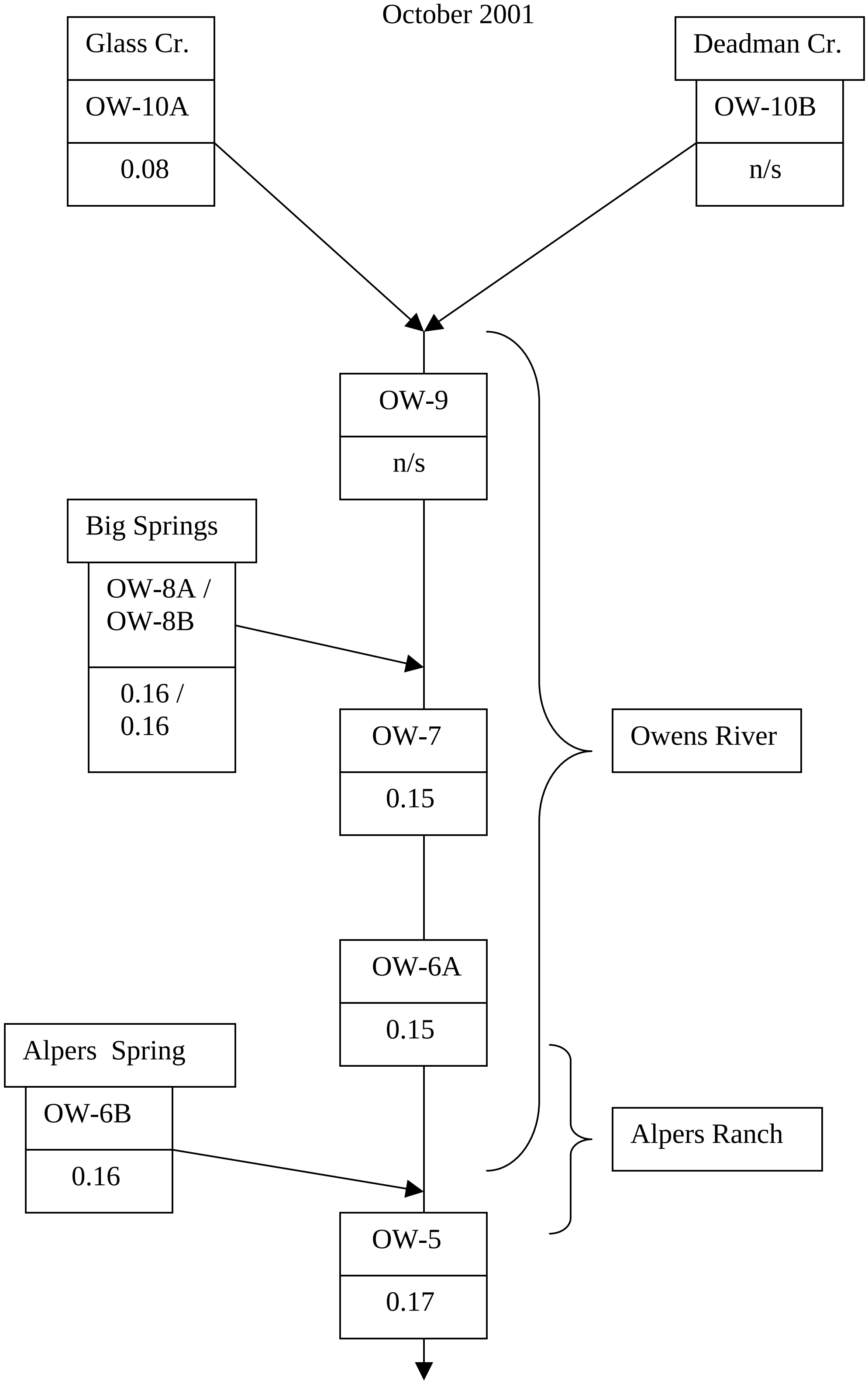



Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
May 2001
Glass Cr.
OW-10A
0.34
Deadman Cr.
OW-10B
0.16
OW-9
0.26
Big Springs
OW-8B
0.17
OW-7
0.20
Owens River
OW-6A
0.18
Alpers Spring
OW-6B
0.14
Alpers Ranch
OW-5
0.29

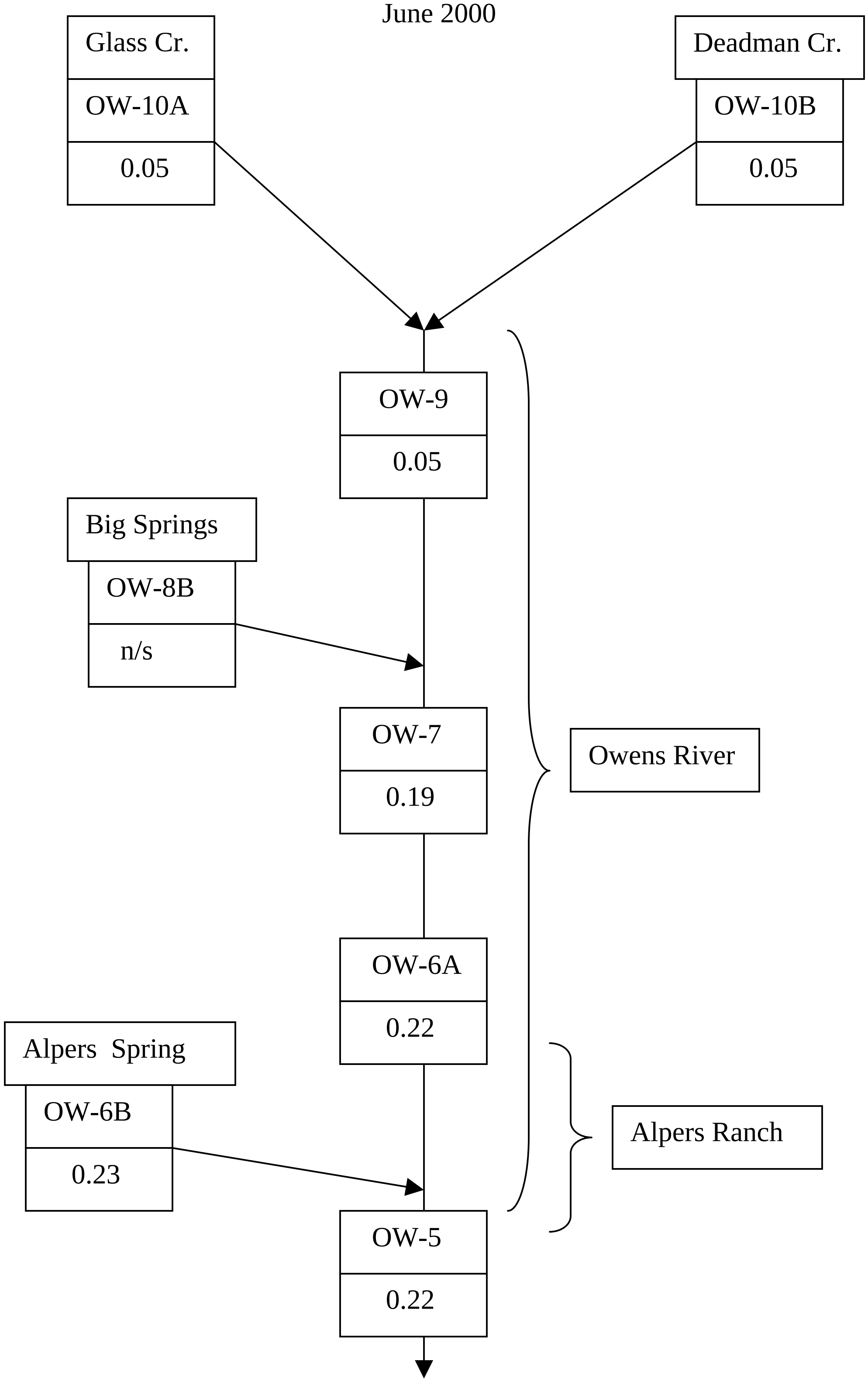
Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
July 2001



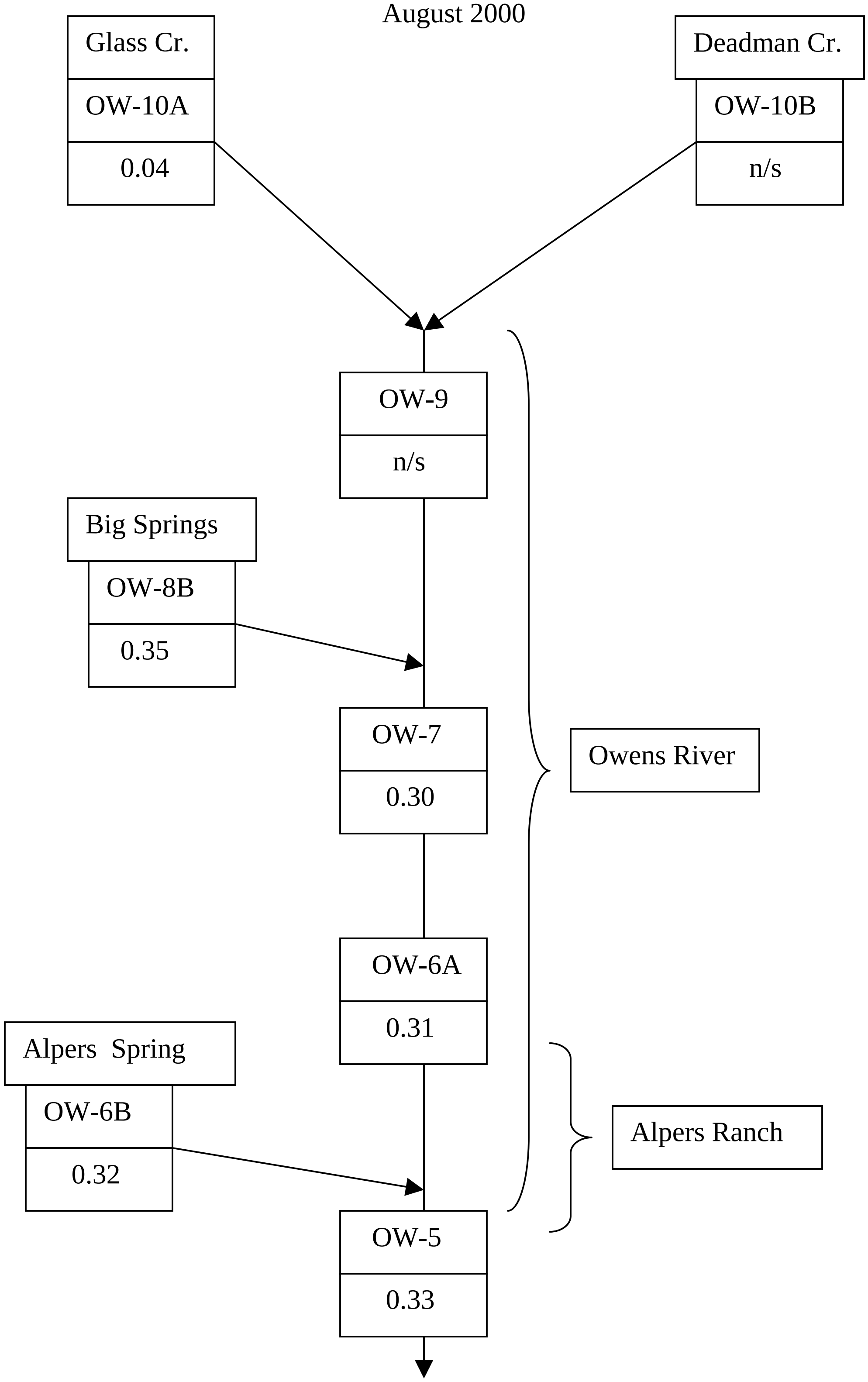
Total Nitrogen Concentrations (mg/L)
Upper Owens River Area
October 2001



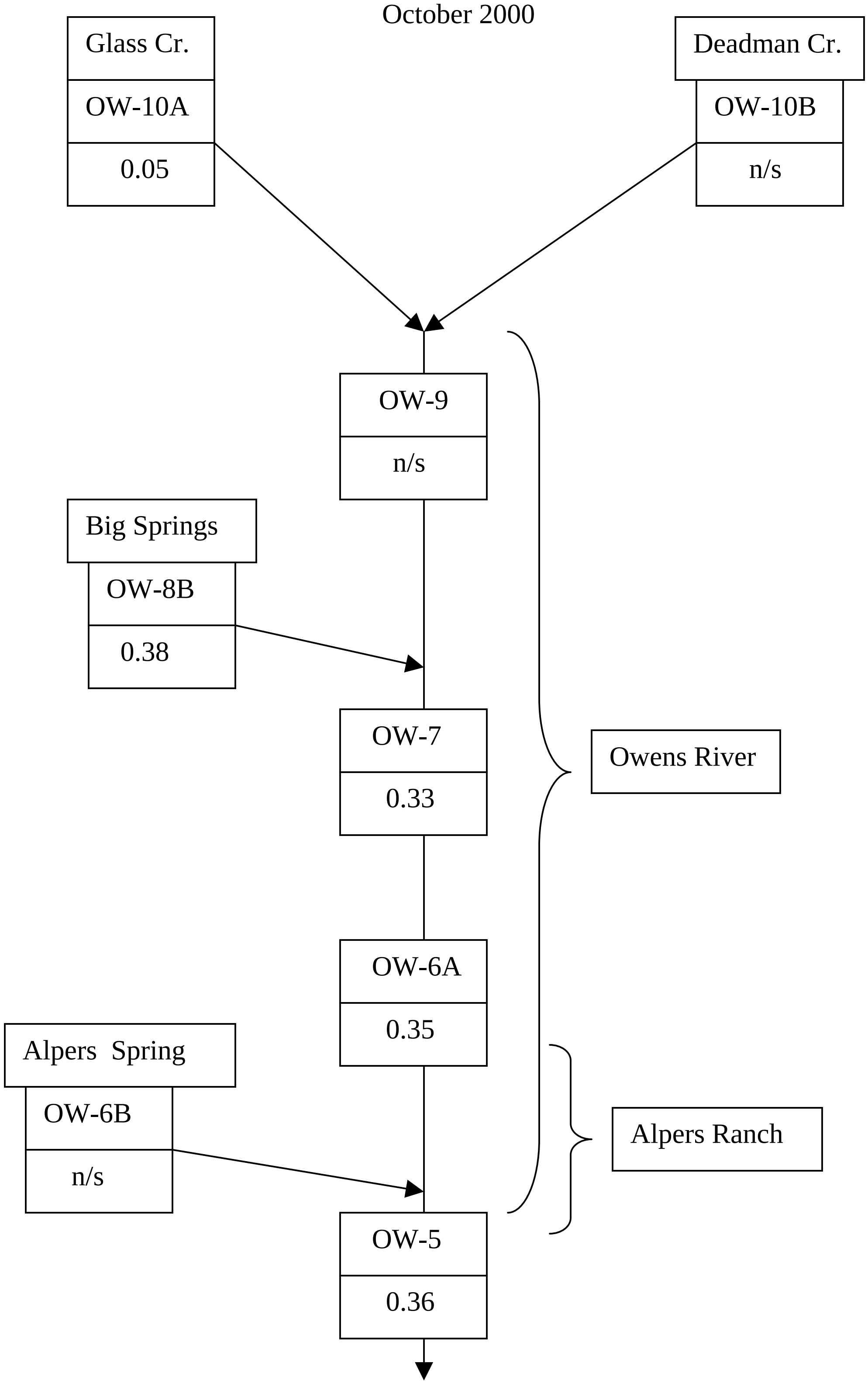
Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
June 2000



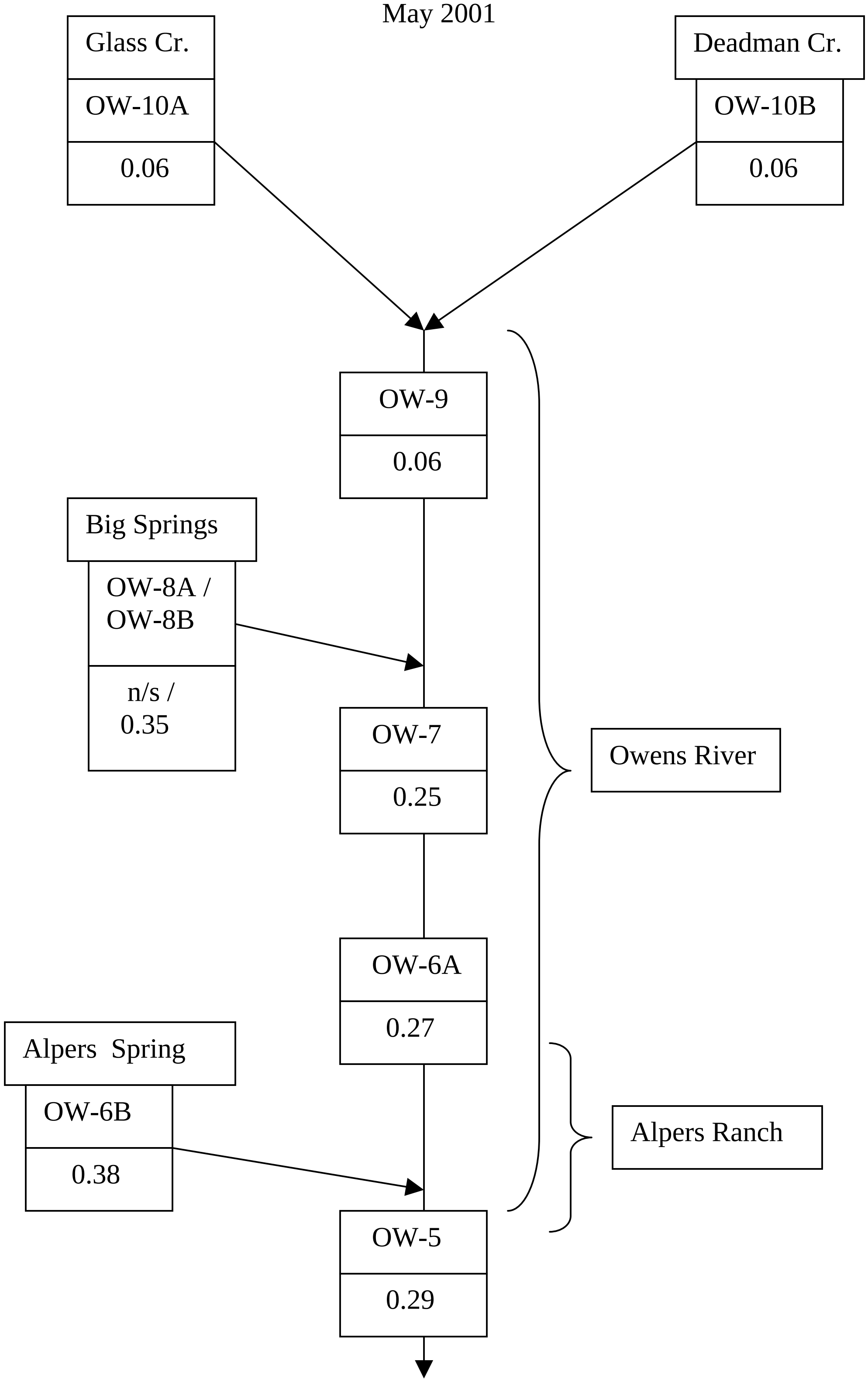
Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
August 2000



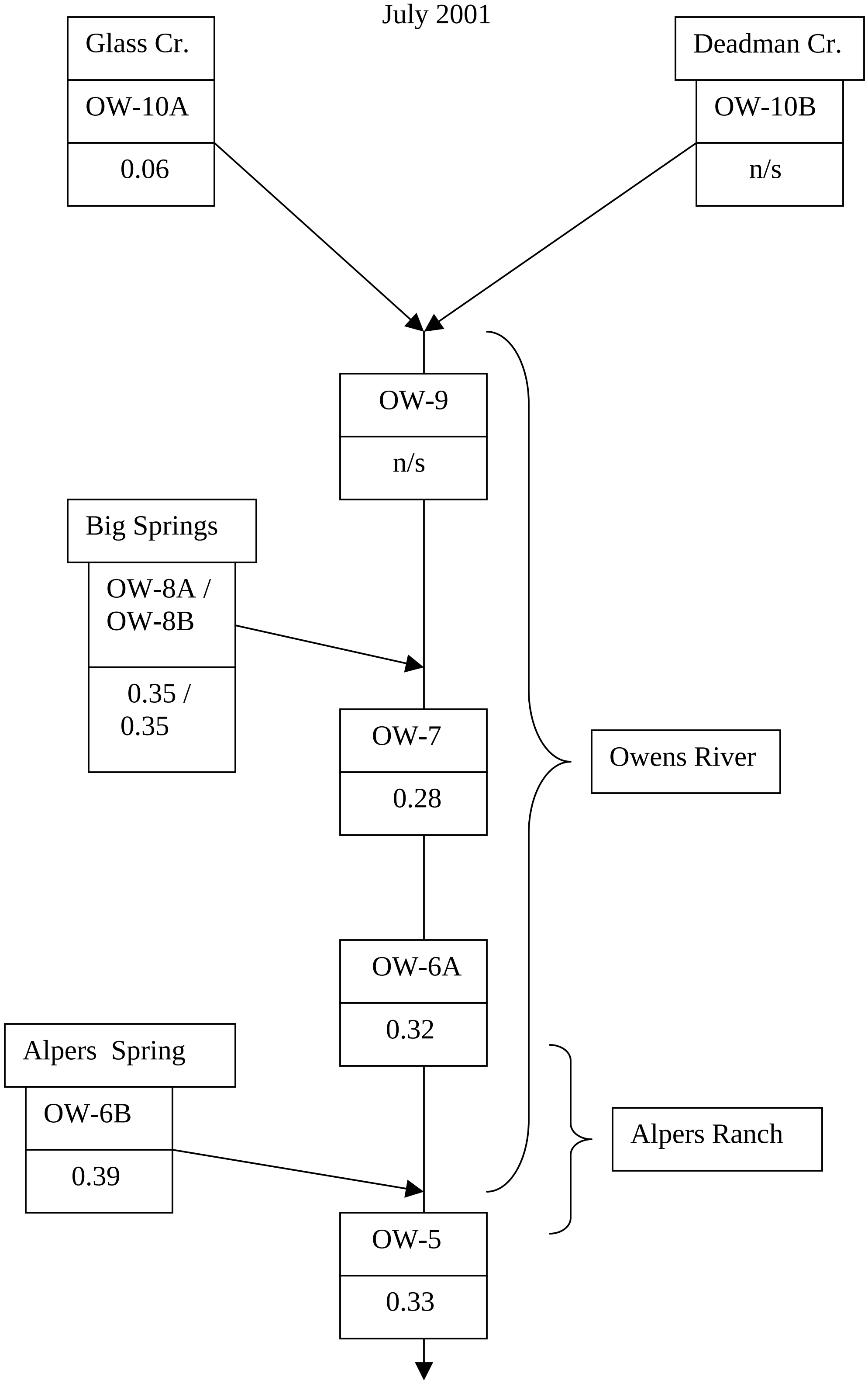
Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
October 2000



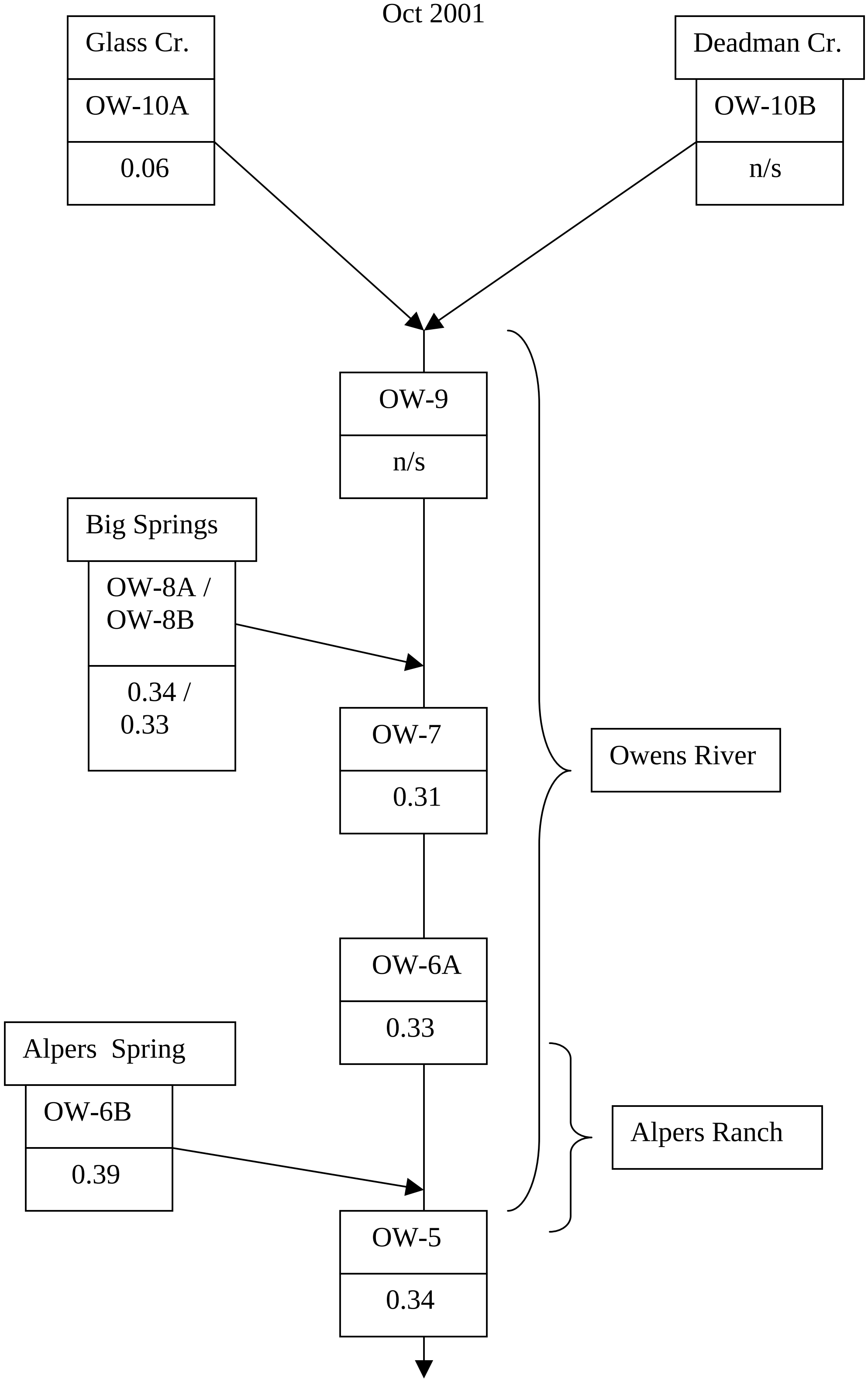
Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
May 2001



Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
July 2001



Total Phosphorous Concentrations (mg/L)
Upper Owens River Area
Oct 2001



Appendix C

Figures 4.1 and 4.3 from Jellison and Dawson (2003)

Fig. 4.1

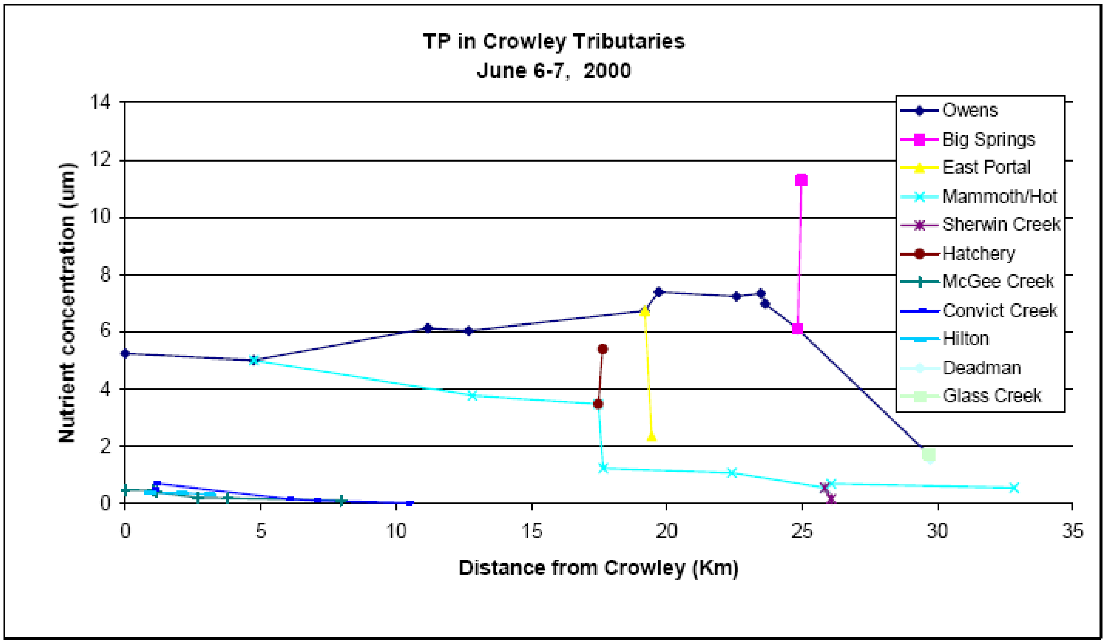
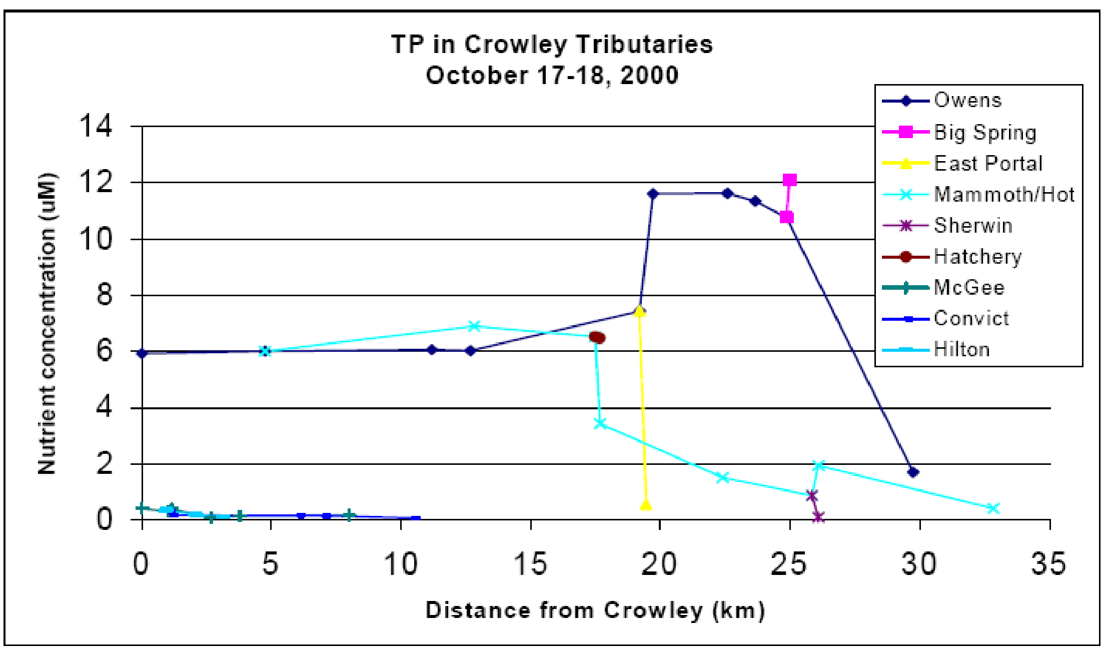

TP in Crowley Tributaries
June 6-7, 2000
Nutrient concentration (um)
Distance from Crowley (Km)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
Owens
Big Springs
East Portal
Mammoth/Hot
Sherwin Creek
Hatchery
McGee Creek
Convict Creek
Hilton
Deadman
Glass Creek

Fig. 4.3


TP in Crowley Tributaries
October 17-18, 2000
Nutrient concentration (uM)
Distance from Crowley (km)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
Owens
Big Spring
East Portal
Mammoth/Hot
Sherwin
Hatchery
McGee
Convict
Hilton

Appendix D

Summary of Dissolved Oxygen Data

APPENDIX D
Summary of Dissolved Oxygenation Concentrations in Crowley Lake
Crowley Lake, Mono County
Results in milligrams per liter (mg/L)

Date	Station	DEPTH (meters)																														Average of All Depths
		-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14.9	15	16	17	18	19	20	21	21.5	21.75	22	23	24	25	
5/31/2000	W		9.1	9.4	9.5	9.1	8.6	8.1	7.6	7.2																						**8.6**
5/31/2000	S		10.2	9.7	9.5	9.5	9.6	9.5	9.2	9.5	8.7	8.4	8.1	7.2	7.0	6.5	5.9		5.8	5.8	5.8	5.6	5.6	5.4	5.4			5.4	5.4			**7.4**
5/31/2000	N		7.4	7.6	7.6	7.5	7.4	7.3	5.3	5.3																						**6.9**
5/31/2000	M		8.4	8.6	8.4	8.3	8.1	8.1	8.3	8.3	8.2	6.8	5.8	5.7	5.2	4.7	4.3		3.2													**6.9**
5/31/2000	E		9.0	9.2	9.2	9.1	8.7	8.7	8.5	8.7	7.9	6.4	6.1	5.6	5.0	4.8	4.7		4.7	4.5	4.4	3.8	3.6									**6.6**
Average By Depth			**8.8**	**8.9**	**8.8**	**8.7**	**8.5**	**8.3**	**7.8**	**7.8**	**8.3**	**7.2**	**6.7**	**6.2**	**5.7**	**5.3**	**5.0**		**4.6**	**5.2**	**5.1**	**4.7**	**4.6**	**5.4**	**5.4**			**5.4**	**5.4**			**7.3**
6/9/2000	S		7.9	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.1	4.4	4.0	3.5		2.9	2.6	2.4	2.3	2.2	2.2								**5.6**
6/21/2000	S		9.6	10.4	10.2	10.2	9.0	8.4	7.6	7.2	6.4	5.7	4.9	4.4	3.8	3.1	2.4		2.3	1.9	1.4	0.5	0.5	0.3	0.1			0.1				**4.8**
7/5/2000	S	7.1	8.7	8.3	7.5	7.3	7.1	6.8	6.6	6.1	6.2	6.4	5.8	5.3	4.1	3.5	2.7		2.0	0.5	0.3	0.1	0.1	0.1	0.1							**4.3**
8/2/2000	S		7.5	7.6	7.6	7.6	7.5	7.1	3.7	2.7	0.4	0.3	0.2	0.2	0.2	0.2	0.2		0.1	0.1	0.1	0.1										**2.8**
8/14/2000	W	4.3	7.4	7.0	6.9	6.8	6.8	6.8																								**7.0**
8/14/2000	N	5.4	6.2	6.1	6.4	6.4	4.8																									**6.0**
8/14/2000	M	4.7	7.2	6.9	7.1	7.0	6.9	6.2	5.6	5.5	5.4	4.5	3.7	3.3																		**5.8**
8/14/2000	E	6.0	6.8	6.7	6.4	6.3	6.1	5.6	5.2	4.9	3.5	3.0	2.6	0.9	0.8	0.6	0.1		0.1													**3.7**
8/14/2000	S	6.5	7.4	7.2	7.0	7.0	6.8	6.4	5.6	5.6	4.6	2.5	2.0	1.0	0.2	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1								**3.1**
Average By Depth		**5.4**	**7.0**	**6.8**	**6.8**	**6.7**	**6.3**	**6.3**	**5.5**	**5.3**	**4.5**	**3.3**	**2.8**	**1.7**	**0.5**	**0.4**	**0.1**		**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**								**5.1**
11/8/2000	S	11.4	10.5	10.5	10.5	10.5	10.5	10.0	10.0	10.0	10.4	10.4	10.2	10.0	10.0	10.0	10.0		10.0	10.0	10.0	10.0	10.0	10.0	9.9			9.9				**10.1**
11/8/2000	E		8.4	8.4	8.3	8.2	8.1	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.3	8.3	8.3		8.3													**8.2**
Average By Depth		**11.4**	**9.4**	**9.4**	**9.4**	**9.3**	**9.3**	**9.1**	**9.1**	**9.1**	**9.3**	**9.3**	**9.2**	**9.1**	**9.2**	**9.2**	**9.2**		**9.2**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**9.9**			**9.9**				**9.2**
4/17/2001	M	12.7	9.7	9.4	8.9	8.7	8.4	8.2	8.1	8.0	7.7	7.6	7.4	7.2	7.1	7.0	6.7		6.6	5.2												**7.8**
4/17/2001	W	8.5	7.6	7.7	7.7	7.7	7.7	7.7	7.8	7.7	7.3																					**7.7**
4/17/2001	N	11.3	7.7	7.7	7.5	7.4	7.4	7.4	7.4	7.2	6.4																					**7.3**
Average By Depth		**10.8**	**8.3**	**8.3**	**8.0**	**7.9**	**7.8**	**7.8**	**7.8**	**7.6**	**7.1**	**7.6**	**7.4**	**7.2**	**7.1**	**7.0**	**6.7**		**6.6**	**5.2**												**7.6**
5/9/2001	W	9.3	10.7	10.8	11.2	11.3	11.1	10.9	10.3																							**10.9**
5/9/2001	S		11.0	10.8	10.8	10.8	10.3	9.3	9.2	8.9	8.9	8.6	8.5	8.4	8.3	8.2	8.2		8.1	7.6	7.0	7.0	6.9	6.8	6.8			6.5	6.4			**8.5**
Average By Depth		**9.3**	**10.8**	**10.8**	**11.0**	**11.1**	**10.7**	**10.1**	**9.8**	**8.9**	**8.9**	**8.6**	**8.5**	**8.4**	**8.3**	**8.2**	**8.2**		**8.1**	**7.6**	**7.0**	**7.0**	**6.9**	**6.8**	**6.8**			**6.5**	**6.4**			**9.7**
5/23/2001	W		8.9	8.9	8.9	9.0	8.8	8.9																								**8.9**
5/23/2001	S		8.5	8.7	8.4	8.4	8.2	7.8	7.2	6.2	5.8	5.8	5.4	5.1	4.5	3.8	3.7		3.7	3.6	3.5	3.2	3.1	2.5	2.3			2.1	1.9	1.5	1.4	**4.9**
Average By Depth			**8.7**	**8.8**	**8.6**	**8.7**	**8.5**	**8.3**	**7.2**	**6.2**	**5.8**	**5.8**	**5.4**	**5.1**	**4.5**	**3.8**	**3.7**		**3.7**	**3.6**	**3.5**	**3.2**	**3.1**	**2.5**	**2.3**			**2.1**	**1.9**	**1.5**	**1.4**	**6.9**
6/6/2001	W		9.3	8.7	8.5	8.2	7.8	7.6	7.6	7.3	7.1	6.9																				**7.9**
6/6/2001	S		9.0	8.8	8.8	8.8	8.6	8.4	8.2	8.1	8.0	7.3	6.8	5.5	2.9	2.6	2.1		1.9	1.3	1.1	1.0	1.0	0.7	0.6			0.5				**4.9**
Average By Depth			**9.2**	**8.8**	**8.7**	**8.5**	**8.2**	**8.0**	**7.9**	**7.7**	**7.5**	**7.1**	**6.8**	**5.5**	**2.9**	**2.6**	**2.1**		**1.9**	**1.3**	**1.1**	**1.0**	**1.0**	**0.7**	**0.6**			**0.5**				**6.4**
6/20/2001	S		9.6	9.9	9.6	9.1	8.7	7.7	7.1	6.8	6.1	6.0	5.8	5.5	4.7	4.2	3.7		2.8	2.1	1.4	0.9	0.4	0.2								**5.3**
7/3/2001	W		10.7	10.5	10.1	9.7	9.7	9.4	7.5	6.8																						**9.3**
7/3/2001	S		14.2	11.1	9.4	9.3	7.8	7.4	7.3	6.9	6.8	6.3	6.0	5.4	4.8	4.8	3.6		2.9	2.3	2.2	2.1	1.8	1.7	1.7							**5.7**
Average By Depth			**12.4**	**10.8**	**9.8**	**9.5**	**8.8**	**8.4**	**7.4**	**6.9**	**6.8**	**6.3**	**6.0**	**5.4**	**4.8**	**4.8**	**3.6**		**2.9**	**2.3**	**2.2**	**2.1**	**1.8**	**1.7**	**1.7**							**7.5**
7/17/2001	W		9.4	9.4	8.5	8.4	8.4	8.4	8.4	7.6	7.1																					**8.4**
7/17/2001	S	8.7	10.8	10.6	10.2	10.0	10.0	9.3	8.4	7.4	6.2	6.1	5.4	5.2	4.9	2.3	1.5		0.4	0.2	0.2	0.2	0.1	0.1	0.1							**5.0**
Average By Depth		**8.7**	**10.1**	**10.0**	**9.3**	**9.2**	**9.2**	**8.8**	**8.4**	**7.5**	**6.6**	**6.1**	**5.4**	**5.2**	**4.9**	**2.3**	**1.5**		**0.4**	**0.2**	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**							**6.7**
8/1/2001	W		8.3	8.4	8.2	8.2	7.5	6.8	5.1																							**7.5**

APPENDIX D
Summary of Dissolved Oxygenation Concentrations in Crowley Lake
Crowley Lake, Mono County
Results in milligrams per liter (mg/L)

		DEPTH (meters)																														
Date	**Station**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**14.9**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**21.5**	**21.75**	**22**	**23**	**24**	**25**	**Average of All Depths**
8/1/2001	S		8.3	8.5	8.7	8.3	8.3	8.2	8.1	5.6	5.1	4.6	2.1	1.8	1.2	0.2	0.1		0.1	0.1	0.1	0.1	0.1	0.1								**3.8**
Average By Depth			**8.3**	**8.4**	**8.4**	**8.3**	**7.9**	**7.5**	**6.6**	**5.6**	**5.1**	**4.6**	**2.1**	**1.8**	**1.2**	**0.2**	**0.1**		**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**								**5.6**
8/15/2001	W		6.9	7.1	6.8	6.8	6.5	6.4																								**6.8**
8/15/2001	N		6.5	6.4	6.2	6.1	6.1	4.2																								**5.9**
8/15/2001	M		6.7	6.7	6.5	6.4	6.3	6.2	6.1	6.1	6.0	0.9	0.3	0.3	0.3	0.3																**4.2**
8/15/2001	E		6.7	6.7	6.6	6.5	6.3	6.1	5.1	4.2	3.2	2.5	1.5	1.7	0.4	0.4	0.4		0.4	0.4												**3.5**
8/15/2001	S		7.1	7.0	6.9	6.8	6.8	6.8	6.7	6.7	5.3	4.4	3.6	2.8	0.5	0.3	0.3		0.3	0.3	0.3	0.3	0.3	0.3	0.3			0.3	0.3			**3.1**
Average By Depth			**6.8**	**6.8**	**6.6**	**6.5**	**6.4**	**5.9**	**6.0**	**5.7**	**4.8**	**2.6**	**1.8**	**1.6**	**0.4**	**0.3**	**0.4**		**0.4**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**			**0.3**	**0.3**			**4.7**
8/29/2001	W		5.9	6.0	5.8	5.6	5.1	3.9																								**5.4**
8/29/2001	S		6.2	6.2	6.3	5.9	5.0	4.8	4.1	3.7	3.1	2.5	1.4	0.9	0.2	0.1	0.1							0.1								**3.2**
Average By Depth			**6.0**	**6.1**	**6.1**	**5.8**	**5.0**	**4.4**	**4.1**	**3.7**	**3.1**	**2.5**	**1.4**	**0.9**	**0.2**	**0.1**	**0.1**							**0.1**								**4.3**
9/12/2001	W		5.6	5.6	5.5	5.2	5.0	5.1																								**5.3**
9/12/2001	S		4.9	4.8	4.7	4.7	4.6	4.5	4.5	4.5	4.5	4.4	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.5	4.5	4.5	4.5	4.5							**4.5**
Average By Depth			**5.3**	**5.2**	**5.1**	**4.9**	**4.8**	**4.8**	**4.5**	**4.5**	**4.5**	**4.4**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**		**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**							**4.9**
9/26/2001	W	8.8	7.2	7.2	7.1	6.4	6.3	5.9	5.7																							**6.5**
9/26/2001	S		6.1	6.1	6.0	6.0	6.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0		5.9	5.9	5.9	5.8										**6.0**
Average By Depth			**6.6**	**6.6**	**6.5**	**6.2**	**6.2**	**6.0**	**5.8**	**6.1**	**6.1**	**6.1**	**6.1**	**6.1**	**6.1**	**6.0**	**6.0**		**5.9**	**5.9**	**5.9**	**5.8**										**6.3**
10/10/2001	W		8.0	7.7	7.3	7.2	7.2	7.2																								**7.4**
10/10/2001	S		7.6	7.3	7.3	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.8	6.8	6.8	6.7		6.7	6.8	6.7	6.7	6.7	6.7	6.9							**6.9**
Average By Depth			**7.8**	**7.5**	**7.3**	**7.1**	**7.1**	**7.1**	**6.9**	**6.9**	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**	**6.7**		**6.7**	**6.8**	**6.7**	**6.7**	**6.7**	**6.7**	**6.9**							**7.2**
10/24/2001	W		7.4		7.0	6.9	6.9	6.8																								**7.0**
10/24/2001	S		7.1	7.1	6.8	6.7	6.6	6.6	6.6	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.6		6.6	6.6	6.6	6.6	6.6									**6.7**
Average By Depth			**7.3**	**7.1**	**6.9**	**6.8**	**6.8**	**6.7**	**6.6**	**6.7**	**6.7**	**6.7**	**6.7**	**6.7**	**6.7**	**6.7**	**6.6**		**6.6**	**6.6**	**6.6**	**6.6**	**6.6**									**6.8**
11/7/2001	N		6.8	6.8	6.8	6.8	6.7	6.7																								**6.8**
11/7/2001	W		6.9	6.9	6.9	6.7	6.7	6.7	6.5																							**6.8**
11/7/2001	M		6.7	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.2	6.2	6.2																	**6.3**
11/7/2001	E		6.6	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.2	6.2	6.1	6.1	5.7		5.7													**6.2**
11/7/2001	S		6.2	6.1	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8		5.8	5.8	5.8	5.9	5.8	5.7	5.7			5.7				**5.8**
Average By Depth			**6.6**	**6.5**	**6.5**	**6.4**	**6.4**	**6.4**	**6.2**	**6.1**	**6.1**	**6.1**	**6.1**	**6.1**	**6.0**	**6.0**	**5.8**		**5.8**	**5.8**	**5.8**	**5.9**	**5.8**	**5.7**	**5.7**			**5.7**				**6.4**
4/3/2002	W		11.0	11.1	10.8	10.8	10.8	10.8	10.8	10.6																						**10.8**
4/3/2002	M		10.9	10.9	11.0	10.9	11.0	11.0	11.0	11.2	10.8	10.8	10.4	10.1	9.8	9.5	9.3															**10.6**
4/3/2002	E		10.2	10.3	10.5	10.6	10.5	10.4	10.3	10.3	10.3	10.3	10.1	9.9	9.8	9.7	9.5		9.3	9.1	8.9											**10.0**
4/3/2002	S		9.9	10.0	10.0	10.1	10.4	10.8	10.4	10.4	10.3	10.3	10.1	10.1	10.0	9.9	9.8		9.8	9.8	9.7	9.6	9.6	9.5	9.5			9.5				**10.0**
4/3/2002	N		9.4	9.5	9.6	9.8	10.2	9.6	9.2																							**9.6**
Average By Depth			**10.3**	**10.4**	**10.4**	**10.4**	**10.6**	**10.5**	**10.3**	**10.6**	**10.5**	**10.5**	**10.2**	**10.0**	**9.9**	**9.7**	**9.5**		**9.6**	**9.5**	**9.3**	**9.6**	**9.6**	**9.5**	**9.5**			**9.5**				**10.2**
6/19/2002	E				8.3				8.3			8.2																				**8.3**
6/19/2002	E		8.0	8.2		8.3	8.3	8.3		8.3	8.2		8.1	8.1	5.2		3.1		2.7		1.9											**6.7**
6/19/2002	S		8.4	8.6	5.6	8.6	8.7	8.6	8.6	8.5	8.5	8.6	8.5	6.1	3.4	3.0	2.7		2.3	2.0	1.5	1.4	1.3	1.3								**5.5**
6/19/2002	E															3.8				2.5												**3.1**
6/19/2002	S																								0.9							**0.9**
Average By Depth			**8.2**	**8.4**	**7.0**	**8.5**	**8.5**	**8.5**	**8.5**	**8.4**	**8.3**	**8.4**	**8.3**	**7.1**	**4.3**	**3.4**	**2.9**		**2.5**	**2.3**	**1.7**	**1.4**	**1.3**	**1.3**	**0.9**							**4.9**
7/1/2002	E				12.5			8.1				6.0			3.8				1.6													**6.4**
7/1/2002	E		12.5	13.1		10.9	9.2		7.7	7.1	6.3		5.7	4.9		2.6	2.0			0.9	0.2											**6.4**
7/1/2002	S			12.0	11.4	10.3	9.9	8.7	7.6	7.5	6.5	5.9	5.2	4.2	3.9	3.6	3.1		1.6	0.9	0.7	0.3	0.2	0.2	0.2			0.2	0.2	0.2		**4.4**
Average By Depth			**12.5**	**12.6**	**11.9**	**10.6**	**9.5**	**8.4**	**7.6**	**7.3**	**6.4**	**6.0**	**5.4**	**4.5**	**3.9**	**3.1**	**2.5**		**1.6**	**0.9**	**0.4**	**0.3**	**0.2**	**0.2**	**0.2**			**0.2**	**0.2**	**0.2**		**5.7**

APPENDIX D
Summary of Dissolved Oxygenation Concentrations in Crowley Lake
Crowley Lake, Mono County
Results in milligrams per liter (mg/L)

Date	Station	DEPTH (meters)																														Average of All Depths
		-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14.9	15	16	17	18	19	20	21	21.5	21.75	22	23	24	25	
7/16/2002	E				9.1	8.9			6.7			3.2			0.2				0.2													**4.7**
7/16/2002	E		8.8	9.2			8.6	8.2		5.7	5.3		0.3	0.2		0.2	0.2			0.2	0.2											**3.9**
7/16/2002	S		8.8	9.2	8.6	8.2	8.1	7.3	8.2	7.0	5.8	5.3	5.2	2.3	0.5	0.3	0.3		0.3	0.3	0.3	0.2	0.2	0.2	0.2			0.2	0.2	0.2		**3.5**
Average By Depth			**8.8**	**9.2**	**8.9**	**8.5**	**8.4**	**7.8**	**7.4**	**6.3**	**5.6**	**4.3**	**2.7**	**1.2**	**0.4**	**0.3**	**0.3**		**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**			**0.2**	**0.2**	**0.2**		**4.0**
7/29/2002	E		9.1		8.7	8.0	5.2		3.6	4.5		1.1	1.1		0.2	0.2			0.2	0.2												**3.5**
7/29/2002	E			9.1				4.3			2.1			0.4			0.2															**3.2**
7/29/2002	S		8.4	8.3	8.4	8.0	7.9	7.8	7.2	3.7	3.0	2.5	2.4	1.6	0.3	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2			0.2	0.2			**3.0**
Average By Depth			**8.8**	**8.7**	**8.5**	**8.0**	**6.5**	**6.1**	**5.4**	**4.1**	**2.5**	**1.8**	**1.8**	**1.0**	**0.3**	**0.2**	**0.2**		**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**			**0.2**	**0.2**			**3.2**
8/13/2002	E			9.5			9.4			5.2			1.2																			**6.3**
8/13/2002	S		8.6	8.8	8.8	8.6	8.1	7.1	5.2	4.3	0.9	0.2	0.2																			**5.5**
8/13/2002	E		9.2		9.6	9.6		9.1	7.6		2.3	1.4		0.6	0.3	0.2																**5.0**
Average By Depth			**8.9**	**9.2**	**9.2**	**9.1**	**8.8**	**8.1**	**6.4**	**4.8**	**1.6**	**0.8**	**0.7**	**0.6**	**0.3**	**0.2**																**5.6**
8/29/2002	S			5.5	5.3		4.6	4.2			4.3	5.0		4.9	4.9		5.2		5.2		5.0	5.0		5.0	5.0	5.0						**4.9**
8/29/2002	E		6.9	6.7			6.1	5.6		4.7	4.5		3.7	3.2		2.9	3.1															**4.7**
8/29/2002	S		5.5			5.0			4.4	4.5			4.9			5.2				5.2			5.0				2.2					**4.7**
8/29/2002	E				6.5	6.2			5.3			4.3			1.5			2.2														**4.3**
Average By Depth			**6.2**	**6.1**	**5.9**	**5.6**	**5.3**	**4.9**	**4.9**	**4.6**	**4.4**	**4.7**	**4.3**	**4.1**	**3.2**	**4.0**	**4.1**	**2.2**	**5.2**	**5.2**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**2.2**					**4.7**
9/10/2002	S																								6.5							**6.5**
9/10/2002	S		6.9	6.9	6.8	6.3	6.2	6.1	6.1	6.2	6.1	6.1	6.1	6.1	6.3	6.4	6.4		6.5	6.5	6.5	6.4	6.4	6.5				6.4				**6.4**
9/10/2002	E		7.4			6.8			6.7			5.9				4.4																**6.2**
9/10/2002	E			7.4	7.2		6.7	6.7		6.6	6.4		5.6	5.4	5.0		3.7															**6.1**
Average By Depth			**7.2**	**7.2**	**7.0**	**6.6**	**6.4**	**6.4**	**6.4**	**6.4**	**6.3**	**6.0**	**5.8**	**5.8**	**5.7**	**5.4**	**5.1**		**6.5**	**6.5**	**6.5**	**6.4**	**6.4**	**6.5**	**6.5**			**6.4**				**6.3**
9/24/2002	E		8.5			7.6			7.1	6.6			6.7			5.3																**7.0**
9/24/2002	S		10.0	9.8	9.0	8.8	8.4	8.4	8.4	8.5	8.5	7.1	6.5	6.4	5.6	5.5	5.3		5.2	5.2	5.2	5.2	4.5	2.2								**6.8**
9/24/2002	E			8.8	7.9		7.3	7.2			6.5	6.8		6.6	6.2		4.5		1.4													**6.3**
9/24/2002	S																								1.1							**1.1**
Average By Depth			**9.3**	**9.3**	**8.5**	**8.2**	**7.8**	**7.8**	**7.7**	**7.5**	**7.5**	**7.0**	**6.6**	**6.5**	**5.9**	**5.4**	**4.9**		**3.3**	**5.2**	**5.2**	**5.2**	**4.5**	**2.2**	**1.1**							**5.3**

Appendix E

Summary of Ammonia Data

APPENDIX E
Summary of In-Lake and Outlet Ammonia Data
Crowley Lake, Mono County

Date	Station	Depth (meters)[1]	Measured Total Ammonia: $NH_4^+ + NH_3^0$ (uM)[2]	Measured Total Ammonia: $NH_4^+ + NH_3^0$ (mg/L)[3]	Temperature (Celsius)	pH	pKa[4]	f[5]	Calculated Unionized Ammonia (NH_3^0) (mg/L)	Calculated Ammonium (NH_4^+) (mg/L)	FT: 1-hour Average NH_3[6]	FT: 4-day Average, NH_3[7]	FPH[8]	Ratio[9]	1-hr maximum NH_3^0 (calculated) (mg/L)[10]	4-day maximum NH_3^0 (calculated) (mg/L)[11]	1- hour criteria met?[12]	4-day criteria met?[12]
IN-LAKE SAMPLES																		
5/31/2000	S	5	0.24	0.004	16.50	8.90	9.515	0.195	0.001	0.003	1.274	1.413	1	13.500	0.2042	0.042	TRUE	TRUE
5/31/2000	S	20	12.07	0.217	12.20	8.20	9.657	0.034	0.007	0.210	1.714	1.714	1	13.500	0.1517	0.035	TRUE	TRUE
5/31/2000	S	10	4.78	0.086	13.80	8.60	9.604	0.090	0.008	0.078	1.535	1.535	1	13.500	0.1694	0.039	TRUE	TRUE
5/31/2000	S	15	11.24	0.202	12.30	8.30	9.654	0.042	0.009	0.194	1.702	1.702	1	13.500	0.1527	0.035	TRUE	TRUE
11/8/2000	S	5	0.56	0.010	7.90	9.00	9.803	0.136	0.001	0.009	2.307	2.307	1	13.500	0.1127	0.026	TRUE	TRUE
11/8/2000	S	20	0.65	0.012	7.40	9.00	9.821	0.131	0.002	0.010	2.388	2.388	1	13.500	0.1089	0.025	TRUE	TRUE
11/8/2000	S	15	0.65	0.012	7.50	9.00	9.817	0.132	0.002	0.010	2.371	2.371	1	13.500	0.1096	0.025	TRUE	TRUE
11/7/2001	S	10	3.17	0.057	10.80	9.00	9.704	0.165	0.009	0.048	1.888	1.888	1	13.500	0.1377	0.031	TRUE	TRUE
11/7/2001	S	15	3.42	0.062	10.70	9.00	9.708	0.164	0.010	0.051	1.901	1.901	1	13.500	0.1368	0.031	TRUE	TRUE
11/7/2001	S	5	3.42	0.062	10.80	9.00	9.704	0.165	0.010	0.051	1.888	1.888	1	13.500	0.1377	0.031	TRUE	TRUE
5/31/2000	E	5	0.17	0.003	16.20	8.80	9.525	0.159	0.000	0.003	1.300	1.413	1	13.500	0.2000	0.042	TRUE	TRUE
5/31/2000	E	10	4.47	0.080	13.30	8.50	9.620	0.070	0.006	0.075	1.589	1.589	1	13.500	0.1637	0.037	TRUE	TRUE
5/31/2000	E	15	7.77	0.140	12.60	8.30	9.644	0.043	0.006	0.134	1.667	1.667	1	13.500	0.1559	0.036	TRUE	TRUE
8/15/2001	**E**	**15**	**31.39**	**0.565**	**18.80**	**8.80**	**9.441**	**0.186**	**0.105**	**0.460**	**1.086**	**1.413**	**1**	**13.500**	**0.2393**	**0.042**	**TRUE**	**FALSE**
4/3/2002	E	5	0.26	0.005	6.40	8.80	9.856	0.081	0.000	0.004	2.559	2.559	1	13.500	0.1016	0.023	TRUE	TRUE
4/3/2002	E	10	0.93	0.017	5.60	8.70	9.884	0.061	0.001	0.016	2.704	2.704	1	13.500	0.0962	0.022	TRUE	TRUE
4/3/2002	E	15	3.31	0.060	5.10	8.60	9.901	0.048	0.003	0.057	2.799	2.799	1	13.500	0.0929	0.021	TRUE	TRUE
5/31/2000	N	5	1.31	0.024	15.30	8.70	9.554	0.123	0.003	0.021	1.384	1.413	1	13.500	0.1879	0.042	TRUE	TRUE
11/7/2001	N	5	2.56	0.046	10.20	9.00	9.725	0.159	0.007	0.039	1.968	1.968	1	13.500	0.1321	0.030	TRUE	TRUE
4/3/2002	N	5	0.10	0.002	6.60	8.70	9.849	0.066	0.000	0.002	2.523	2.523	1	13.500	0.1030	0.023	TRUE	TRUE
5/31/2000	W	5	0.21	0.004	15.60	8.90	9.544	0.185	0.001	0.003	1.355	1.413	1	13.500	0.1919	0.042	TRUE	TRUE
4/3/2002	W	5	0.13	0.002	7.30	8.80	9.824	0.086	0.000	0.002	2.404	2.404	1	13.500	0.1081	0.025	TRUE	TRUE
OUTLET SAMPLES																		
5/24/2000	OUT	-1	5.92	0.107	12.90	8.20	9.634	0.036	0.004	0.103	1.633	1.633	1	13.500	0.1592	0.036	TRUE	TRUE
6/7/2000	OUT	-1	12.22	0.220	14.10	8.20	9.594	0.039	0.009	0.211	1.503	1.503	1	13.500	0.1730	0.039	TRUE	TRUE
6/21/2000	OUT	-1	15.30	0.275	17.00	7.90	9.499	0.025	0.007	0.269	1.230	1.413	1.053	13.500	0.2007	0.040	TRUE	TRUE
7/19/2000	**OUT**	**-1**	**18.28**	**0.329**	**18.90**	**8.70**	**9.438**	**0.155**	**0.051**	**0.278**	**1.079**	**1.413**	**1**	**13.500**	**0.2410**	**0.042**	**TRUE**	**FALSE**
8/16/2000	**OUT**	**-1**	**37.55**	**0.676**	**21.10**	**8.80**	**9.368**	**0.213**	**0.144**	**0.532**	**1**	**1.413**	**1**	**13.500**	**0.2600**	**0.042**	**TRUE**	**FALSE**
8/30/2000	**OUT**	**-1**	**21.28**	**0.383**	**19.80**	**9.00**	**9.409**	**0.281**	**0.107**	**0.276**	**1.014**	**1.413**	**1**	**13.500**	**0.2564**	**0.042**	**TRUE**	**FALSE**
11/22/2000	OUT	-1	1.16	0.021	4.20	9.00	9.933	0.104	0.002	0.019	2.979	2.979	1	13.500	0.0873	0.020	TRUE	TRUE
12/20/2000	OUT	-1	5.39	0.097	5.50	8.80	9.887	0.076	0.007	0.090	2.723	2.723	1	13.500	0.0955	0.022	TRUE	TRUE
5/9/2001	OUT	-1	9.00	0.162	7.60	8.40	9.814	0.037	0.006	0.156	2.355	2.355	1	13.500	0.1104	0.025	TRUE	TRUE
5/23/2001	OUT	-1	16.05	0.289	14.10	8.20	9.594	0.039	0.011	0.278	1.503	1.503	1	13.500	0.1730	0.039	TRUE	TRUE
8/15/2001	**OUT**	**-1**	**48.59**	**0.875**	**19.00**	**8.60**	**9.434**	**0.128**	**0.112**	**0.763**	**1.072**	**1.413**	**1**	**13.500**	**0.2426**	**0.042**	**TRUE**	**FALSE**
8/29/2001	**OUT**	**-1**	**33.03**	**0.595**	**19.10**	**8.90**	**9.431**	**0.227**	**0.135**	**0.459**	**1.064**	**1.413**	**1**	**13.500**	**0.2443**	**0.042**	**TRUE**	**FALSE**
9/12/2001	**OUT**	**-1**	**11.08**	**0.199**	**17.90**	**9.00**	**9.470**	**0.253**	**0.050**	**0.149**	**1.156**	**1.413**	**1**	**13.500**	**0.2249**	**0.042**	**TRUE**	**FALSE**
11/7/2001	OUT	-1	5.63	0.101	11.30	9.00	9.687	0.170	0.017	0.084	1.824	1.824	1	13.500	0.1426	0.032	TRUE	TRUE

APPENDIX E
Summary of In-Lake and Outlet Ammonia Data
Crowley Lake, Mono County

12/5/2001	OUT	-1	7.93	0.143	5.40	8.90	9.891	0.093	0.013	0.130	2.742	2.742	1	13.500	0.0948	0.022	TRUE	TRUE
2/13/2002	OUT	-1	29.28	0.527	5.50	7.90	9.887	0.010	0.005	0.522	2.723	2.723	1.053	13.500	0.0907	0.021	TRUE	TRUE

Notes

1. A negative 1 (-1) typically indicates a "grab" stream water sample, but, in this case, indicates the sample was taken from the dam discharge.

2. uM = micromoles per liter

3. mg/L = milligrams per liter

4. pKa is the negative log of the equilibrim constant for the reaction NH_4 <--> $NH_3^0 + H^+$, and is calculated by pKa = 0.0901821 + [2729.92 / (T + 273.15)]

5. f is the fraction of unionizied ammonia to total ammonia species.

6. FT = 1.000 for temperatures from 20 to 30 degrees Celsius, and FT = $10^{(0.03(20\text{-}T)}$ for temperatures from 0 to 20 degrees Celsius

7. FT = $10^{(0.03(20\text{-}15)}$ (which equals 1.413) for temperatures from 15 to 30 degrees celsius, and FT= $10^{(0.03(20\text{-}T)}$ for temperatures from 0 to 15 degrees Celsius

8. FPH = [1 + $10^{(7.4\text{-pH})]}$ / 1.25 for pH from 6.5 to 8.0, and FPH = 1 for pH from 8.0 to 9.0

9. Ratio = 20.25 x ($10^{(7.7\text{-pH})}$) / (1+$10^{(7.4\text{-pH})}$) for pH from 6.5 to 7.7, and Ratio = 13.5 for pH from 7.7 to 9.0.

10. 1h-NH3 = 0.52 / (FT x FPH x 2)

11. 4day-NH3 = 0.80 / (FT x FPH x Ratio)

12. True indicates the data meet the criteria; false indicates the data exceed the criteria.

13. Bold indicates the sample exceeds either the 1-hour or 4-day unionized ammonia criteria.