PSOMAS

Information and Engineering Solutions

TO: Dave Wham

FROM: Matthew D. Cassel, PE
Richard King, PE

DATE: July 15, 2005

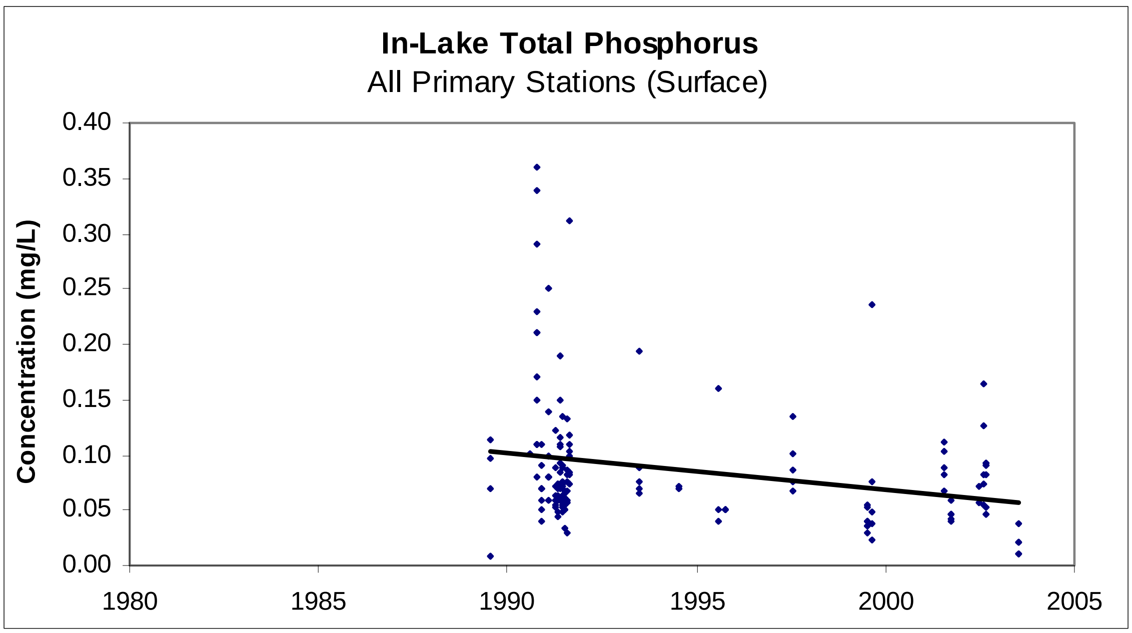
SUBJECT: Utah Lake TMDL Data Validation and Evaluation

1.0 EXECUTIVE SUMMARY

The Psomas team was selected by the Division of Water Quality to complete the Utah Lake TMDL. The TMDL process is detailed in §303(d) of the Clean Water Act (40 CFR 130.7) and Utah State Code (Utah Administrative Code R317-2). Utah Lake has been designated for the following beneficial uses: secondary recreational contact (2B), warm water fishery (3B), wild life and aquatic organisms in their food chain (3D), and agricultural uses including irrigations and stock watering (4). The lake is listed on Utah's 2000 303(d) list for exceedances of state criteria for total phosphorus which is a pollution indicator used to evaluate beneficial use 3B, and total dissolved solids impairing beneficial use 4.

Long-term trends of total phosphorus (TP) data show potential reductions in tributaries and primary station in-lake concentrations since 1990. A historic summary of data at primary lake stations are presented in Figure ES- 1. (See Table 4 for primary lake stations).

Figure ES- 1: Total Phosphorus Historical Data – All Primary Lake Stations



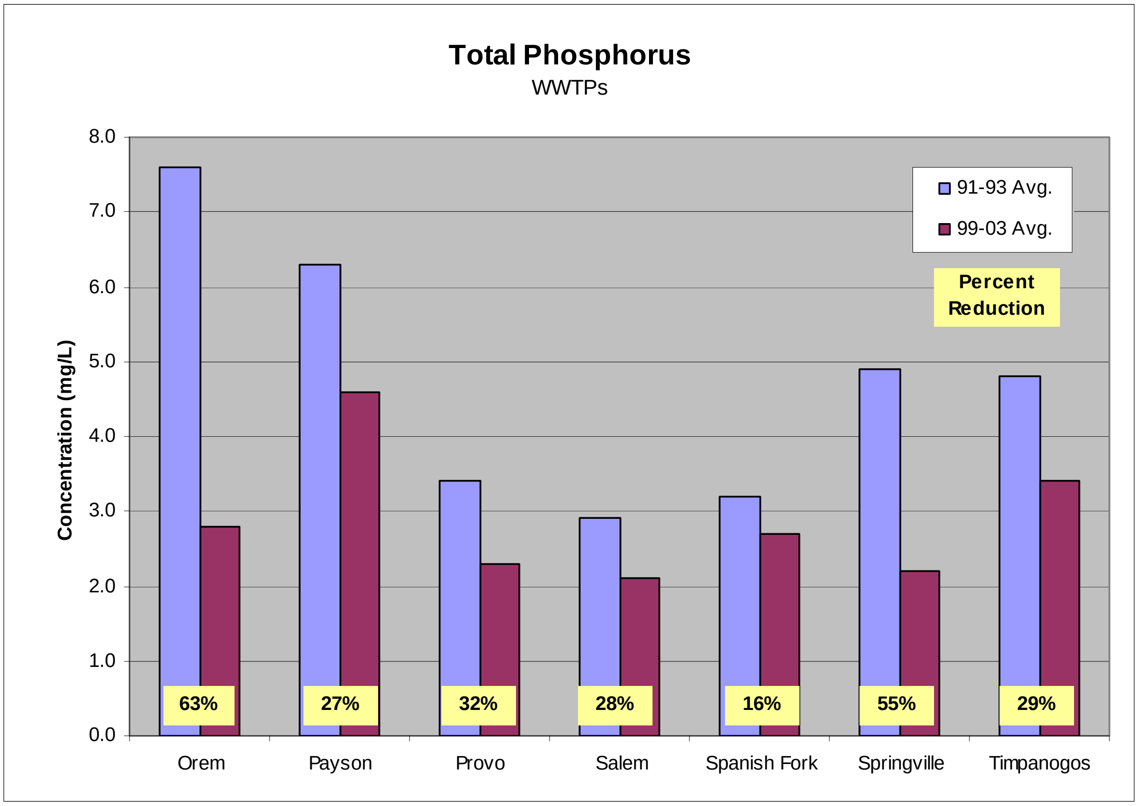
Average monthly TP concentrations for Provo River are below the TP pollution indicator value for warm water fisheries (0.025 mg/L for lakes). In-lake stations, Spanish Fork River, Hobble Creek, and Jordan River are typically above the pollution indicator values (0.025 mg/L for lakes, 0.05 mg/L for streams).

Since the early 1990s, the wastewater treatment plants have seen a reduction in effluent TP concentrations as shown in Figure ES- 2.

Phosphorus is a key nutrient in Utah Lake, necessary for the growth of plants and plankton. However, too many nutrients can promote the excessive growth, depleting oxygen, shading light needed for photosynthesis, and choking other aquatic life. This over fertilized condition is termed eutrophic. Higher concentrations of nutrients (phosphorus and nitrogen) typically result in increased production of algae. In Utah

Lake, however, algal populations are likely limited by the current suspended solids levels in the Lake. These suspended solids reduce light available to the algal populations.

Figure ES- 2: Average Monthly Total Phosphorus Concentrations – WWTPs



Long-term trends of total dissolved solids (TDS) concentrations show little or no change in in-lake or stream concentrations since 1980. The seasonality assessment of TDS data shows higher concentrations in December, February, and March, and lowest concentrations between May and August. An average of essentially all in-lake TDS data closely mimics concentrations in the single largest lake outlet, the Jordan River as shown in Figure ES- 3. The in-lake and outlet average TDS concentrations typically are below the TDS standard 1200 mg/L.

After exiting the lake, Jordan River TDS concentrations increase before reaching the Narrows and decrease again before reaching passing through Bluffdale as shown in Figure ES- 4. Flows in this section are greatly influenced by diversions at the Narrows and saline springs.

We recommend proceeding with the study and making any necessary assumptions to facilitate data analysis. We also recommend additional sampling as the study moves forward. Acquiring data for one or two years would not be expected to significantly change the current data set, however, many years of sampling would serve to confirm results, validate assumptions, and to provide additional data for future studies.

Figure ES- 3: Total Dissolved Solids Monthly Historical Data – Average In-Lake and Outflow

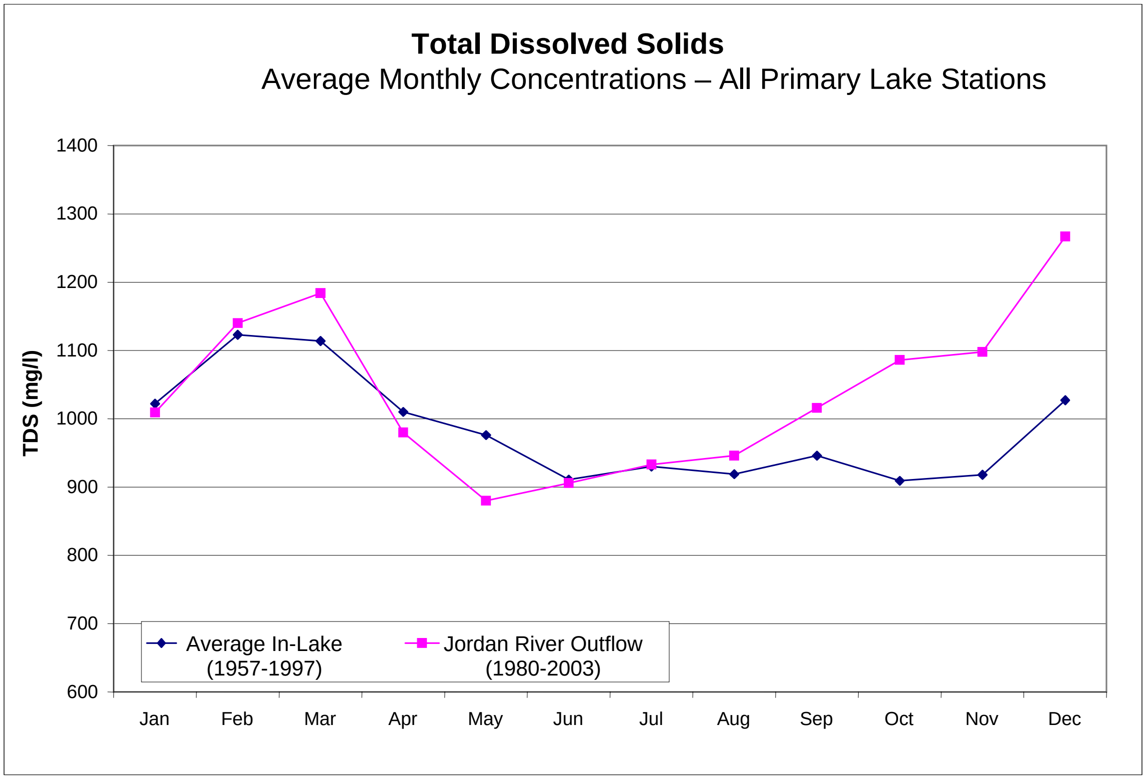
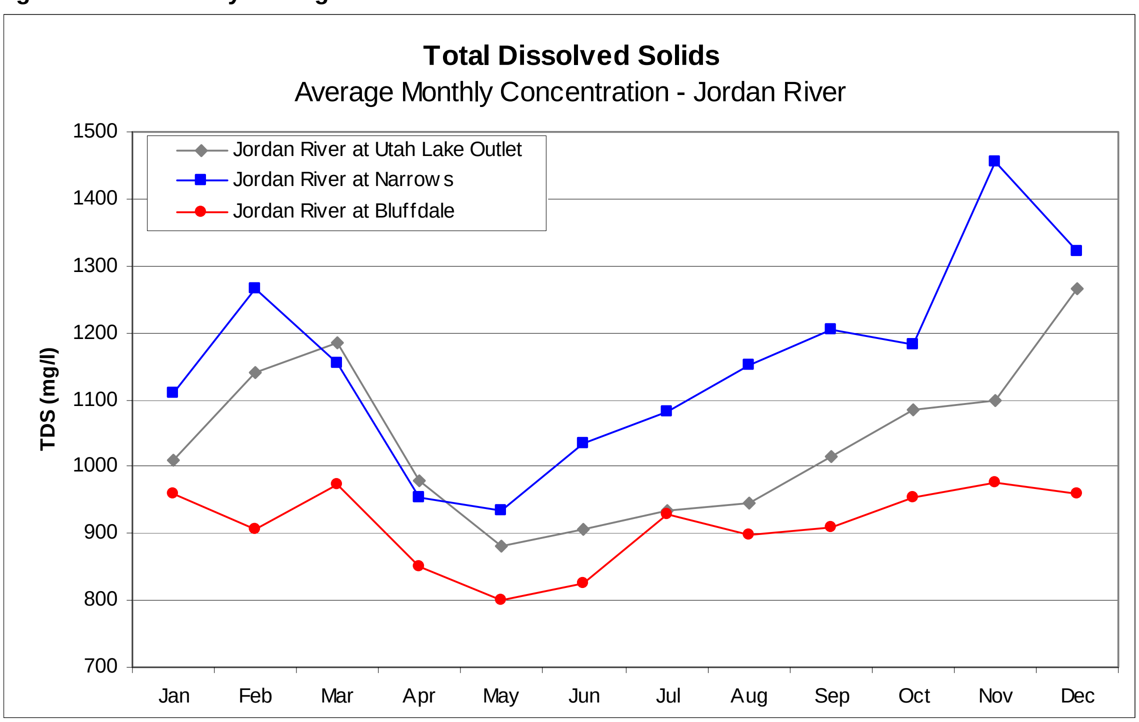


Figure ES- 4: Monthly Average Total Dissolved Solids Concentrations – Jordan River



2.0 INTRODUCTION

The Utah Lake TMDL is one of many currently planned or in progress in the state of Utah. The TMDL process is described in §303(d) of the Clean Water Act (40 CFR 130.7), the rules implementing §303(d), and Utah State Code (Utah Administrative Code R317-2).

The Psomas team was selected by the Utah Division of Water Quality (DWQ) to perform the TMDL analysis for the Utah Lake-Jordan River Watershed. This memorandum fulfills the requirements of Task 1 of this contract, described as "Compile, Evaluate and Validate Data".

A TMDL is the amount of an identified pollutant that a specific stream, lake, river or other water body can assimilate without causing the water body to exceed the water quality standards set to protect designated beneficial uses (e.g., fishing, domestic water supply, etc.). TMDLs are watershed-based plans for restoration of designated beneficial uses in water quality limited water bodies. These plans identify the causes of designated beneficial use impairment and estimate reductions in pollutant loads necessary to meet water quality standards and restore impaired designated beneficial uses within a specified time. Pollutant loads are the quantity of pollution contributed to a water body by a single source or by a group of sources. A TMDL can be best described as a watershed or basin-wide budget for pollutant loading and is established taking into account seasonal variations, natural and background loading, and a margin of safety.

The first step in the TMDL process is to gather the available data that will used to assess the impairment of the water body, aid in the identification of potential pollution sources, and provide the basis for recommendations. In the case of Utah Lake, data from sampling in the lake itself, as well as data from the lake inflows, are necessary. This memorandum evaluates and validates the data that have been obtained for use in this study. Additionally, a statistical analysis and seasonality assessment of these data are presented.

Utah Lake is listed on Utah's 2002 303(d) list for exceedances of state criteria for total phosphorus, which is a nutrient indicator, and total dissolved solids. This TMDL analysis will focus on these constituents, but will also consider other parameters when relevant such as dissolved oxygen and pH.

The warm water fishery beneficial use of the lake is identified as being possibly being impaired due to excess total phosphorus and the agricultural beneficial use is listed as impaired due to high concentrations of total dissolved solids. Utah Lake is a highly productive lake that experiences extensive algal blooms in the late summer and fall. Trophic state calculations identify the lake as being hypereutrophic. The Lake is also the receiving body for wastewater treatment plant effluent, several industrial discharges, stormwater discharges and nonpoint source runoff. Existing conditions are potentially being exacerbated by rapid growth and urban expansion within the watershed.

In addition to water quality data, flow data for the inflows and outflows of the lake were obtained. Flow data are necessary for determining pollutant loads as well as for establishing the water budget for the lake.

3.0 Water Quality Standards and Criteria

The TMDL process is detailed in §303(d) of the Clean Water Act (40 CFR 130.7) and Utah State Code (Utah Administrative Code R317-2). Water quality standards and criteria are defined for individual beneficial use designations.

3.1 Beneficial Use Designations and Impairment

Utah Lake has been assigned the beneficial use designations listed in Table 1. It has been determined that concentrations of TDS in Utah Lake have exceeded water quality standards for the designated beneficial use of agriculture (4), including irrigation and stock watering. Also, TP concentrations in Utah Lake have exceeded pollution indicator values for the designated beneficial use of warm water fisheries (3B). As a result, the State of Utah's 2000 303(d) list identified Utah Lake as requiring a Total Maximum Daily Load Analysis (TMDL) focusing on the impairment parameters of TP and TDS.

Table 1: Utah Lake Beneficial Use Designations

Beneficial Use Designation	Description
2B	Protected for secondary contact recreation such as boating, wading, or similar uses.
3B	Protected for warm water species of game fish, including the necessary aquatic organisms in their food chain.
3D	Protected for other aquatic wildlife.
4	Protected for agricultural uses including irrigation of crops and stock watering.

3.2 Standards and Criteria

The water quality criteria identified by the State of Utah specific to Utah Lake are summarized as part of Utah State Code RS317-2. The water quality standards and pollution indicators for the designated impairment constituents (TDS and TP) and other relevant parameters (DTP, TSS, DO, and Temperature) are presented in Table 2.

Table 2: Water Quality Standards and Pollution Indicator Values

Constituent	2B	3B	3D	4
Total Phosphorus (mg/L)[a]	0.025 for Lakes[b] 0.05 for Streams[b]	0.025 for Lakes[b] 0.05 for Streams[b]	-	-
Dissolved Total Phosphorus (mg/L)[c]	0.025 for Lakes[b] 0.05 for Streams[b]	0.025 for Lakes[b] 0.05 for Streams[b]	-	-
Total Dissolved Solids (mg/L)[a]	-	-	-	1,200
Total Suspended Solids (mg/L)	-	-	-	-
Dissolved Oxygen (mg/L)	-			-
30 Day Average		5.5	5.0	
7-Day Average				
Early Life Stages		6.0		
All Life Stages		4.0		
1-Day Average			3.0	
Early Life Stages		5.0		
All Life Stages		3.0		
Water Temperature (Deg. C)	-	27	-	-

[a] Key Impairment Parameters
[b] Pollution Indicator
[c] Values derived from Total Phosphorus. No prescribed pollution indicator.

3.2.1 Spawning Habitat Needs

Adequate spawning habitat and spawning conditions are critical to the health and support of fish populations. Native and non-native fish species currently present in Utah Lake generally spawn between March and September. Temperature and habitat requirements vary as illustrated in Table 3. The majority of species prefer water temperatures below 20 ^{o} C to spawn, and many require adequate vegetative cover.

Table 3: Summary of Life History Characteristics of Native and Nonnative Fishes of Utah Lake

Species	Spawning Season	Spawning time	Spawning Temperature	Required Spawning Habitat	Required Nursery Habitat
June sucker	May-June	Night	11.6–17 ^{o} C (53–63 ^{o} F)	shallow riffles 0.3 to 0.8 m deep; water velocity about 0.6 ft/sec; mixture of coarse gravel and cobble	littoral habitat with cover
carp	March-April	Day and Night	18–22^{o} C (64–72^{o} F)	shallow lake margins, submerged vegetation	littoral habitat with cover
fathead minnow	mid May-mid August	Day	15–32^{o} C (59–90^{o} F)	build nest on the underside of submerged objects	guarded by the male
white bass	mid April-mid June	Day and Night	14–21^{o} C (58–69^{o} F)	rocky substrate, Lincoln Beach and tributaries including Provo River	littoral habitat with cover
yellow perch	mid March-mid April	Night	8–11^{o} C (46–52^{o} F)	submerged vegetation	larvae are pelagic
walleye	mid March-mid April	Night	4–10^{o} C (40–50^{o} F)	rocky substrate, Lincoln Beach and tributaries including Provo River	larvae and juveniles are pelagic
channel catfish	May-mid June	Night	21–24^{o} C (70–75^{o} F)	nest cavities or burrows	guarded by the male
black bullhead	June-August	Night	21–30^{o} C (70–86^{o} F)	sandy substrate, shallow backwaters or lake margin in 1-4 feet depth	young form large pelagic schools
black crappie	March-July	Day	15–20^{o} C (59–68^{o} F)	nest in or near shallow vegetated backwaters and littoral areas over soft mud, sand, or gravel	nest guarded by the male, fry are pelagic
large-mouth bass	June-July	Day	15–17^{o} C (59–62^{o} F)	nest in or near shallow vegetated backwaters and littoral areas over soft mud, sand, or gravel substrates	nest guarded by the male, juveniles form pelagic schools
small-mouth bass	June-July	Day	15–17^{o} C (59–62^{o} F)	nest in or near shallow vegetated backwaters and littoral areas over soft mud, sand, or gravel substrates near cover	nest guarded by male
bluegill	May-September	Day	20–28^{o} C (68–82^{o} F)	nest in or near shallow vegetated backwaters and littoral areas over firm sand or gravel substrates, often nest in colonies	nest guarded by the male, juveniles remain in littoral habitats

Species	Spawning Season	Spawning time	Spawning Temperature	Required Spawning Habitat	Required Nursery Habitat
green sunfish	May-September	Day	20–28^o C (68–82^o F)	nest in or near shallow vegetated backwaters and littoral areas over firm sand or gravel substrates	nest guarded by the male, juveniles remain in littoral habitats
mosquito-fish	May-September	Day	18–32^o+ C (65–90^o+ F)	warm shallow water with dense vegetation, livebearer	warm shallow water with dense vegetation
brown trout	mid September-November	Day	2–6^o C (36–43^o F)	builds redds in riffle areas of tributaries including the Provo River	backwaters and small side channels
rainbow trout	March-April	Day	12–13^o C (54–56^o F)	builds redds in riffle areas of tributaries including the Provo River	backwaters and small side channels

June suckers, as an endangered species, represent one of the most sensitive species in Utah Lake. June sucker spawn primarily in May and June at water temperatures between 12 and 17 ^{o} C. Spawning currently occurs only in the lower Provo River. Preferred spawning habitat includes shallow riffles (0.3–0.8 m deep), where water velocity is about 0.6 feet per second and substrate is a mixture of coarse gravel and cobble (Shirley 1982). Spawning typically occurs at night, and adults retreat to deep pools in the river during daytime. Average daily water temperatures measured during June sucker spawning have shown a gradual increase over the last two decades; ranging from 11.6 to 12.9 ^{o} C in the early 1980s, from 13 to 17 ^{o} C in the late 1980s and early 1990s, and from 12.8 to 18.4 ^{o} C in the early 2000s.

4.0 Previous Studies

A significant number of studies regarding Utah Lake have been completed. A summary of these reports are found in Appendix A. Topics of the studies include, but are not limited to, fisheries, algal characterizations, groundwater and water quality issues.

5.0 Data Gathering

This section describes what data was gathered, for what time period, and from where it was obtained. A discussion of data coverage and description of the data is included where appropriate.

5.1 Time Period

The time period of study for the Utah Lake TMDL Task 1 Memorandum is defined from 1980 to 2003. This range of data provides a historical look at the lake including periods of normal, above normal, and below normal precipitation conditions.

5.2 Parameters of Interest

Based on the designated impairments for the beneficial uses of Utah Lake, the primary parameters of interest are TP and TDS. All other parameters are studied to supplement understanding of the two key parameters.

Phosphorus is a key element needed for growth in organisms. Phosphorus stimulates necessary growth of plants and plankton, the basis for the aquatic food chain. However, high concentrations can promote the excessive growth of algae and other aquatic plants, which can cause oxygen depletion and even fish kills. This over fertilized condition is known as eutrophic. Utah Lake has been identified as a hypereutrophic water body by the State of Utah.

Nitrogen and nitrogen containing compounds are also plant nutrients. Some nitrogen containing compounds, such as ammonia, nitrites and nitrates, are toxic to fish and other organisms. Total nitrogen is frequently used as a pollution indicator.

TDS is a measure of the cations and anions in an aqueous sample. It tends to be more inorganic in composition, although dissolved organic molecules are included in TDS measurements. TDS is often used as an indication of salinity. The primary components of TDS include: Bicarbonate, Calcium, Chloride, Magnesium, Potassium, Sodium, and Sulfate. There is significantly more specific conductivity (SC) data for Utah Lake, the lake outflow, and the lake tributaries than there is TDS data. Therefore, the monthly SC data may be used in the future in order to estimate TDS conditions. Any correlation that is used will be documented and presented in future memorandums.

The composition of total suspended solids (TSS) includes a wide variety of materials ranging from sediment particles to plant and animal detritus and pollutants. High TSS can exert an oxygen demand. It also absorbs sun light, warming surface waters and shading aquatic plants. Industrial and agricultural uses can also be impacted, because the suspended solids may clog or scour pipes, machinery, and filters.

5.3 Flow Data

Flow data were obtained using the LKSIM model developed by Brigham Young University (LaVere Merritt and Wood Miller) in the 1970s and the Utah Division of Water Quality.

5.3.1 Brigham Young University

The flow data provided by LaVere Merritt and Wood Miller are averages based on actual and calculated historical flow data. They include average monthly values for 55 inflows and the Jordan River. Monthly data has been provided for the entirety of the study period. The average monthly flow values were generated previous to this study and were used as input to the LKSIM model for Utah Lake.

5.3.2 Utah DWQ

Stream flow rates recorded in the STORET database were estimated during each water quality sampling event. The methods used to estimate these flows have varying degrees of accuracy and are considered to be approximations of actual stream flow. Nevertheless, these estimates are valuable because they are recorded every time a water quality sample is taken.

5.4 Inorganic Data

All water quality data was obtained from the Utah Division of Water Quality (DWQ) through the EPA STORET system, a national database of water quality data. Data was gathered for the following parameters: Phosphorus, Nitrogen, Total Dissolved Solids, Bicarbonate, Calcium, Chloride, Magnesium, Potassium, Sodium, Sulfate, and Total

Suspended Solids. Water quality data from 1980 to 2003 were obtained from the STORET sites listed in Table 4.

Primary stations are indicated with an asterisk. All in-lake stations are considered primary, except those excluded from analysis (see Table 6). Stream stations that are located closest to Utah Lake are defined as primary. Primary stream stations are used to identify tributaries of interest. If a tributary is a potential concern, stations upstream of that primary station are examined further.

Table 4: Water Quality Sampling Stations

STORET	Description	Type	
491730	Utah Lake 300 Ft Offshore From Geneva Steel	Lake	
491731	Utah Lake 0.5 Mi W Of Geneva Discharge #15-A	Lake	*
491732	Utah Lake 0.5 Mi W Of Geneva Discharge #15-B (Duplicate)	Lake	
491733	Utah Lake 5mi N/NW Of Lincoln Beach/ 1 Mi Offshore	Lake	
491734	Utah Lake E Of Provo Boat Harbor/6 Mi N Of Lincoln Beach #08	Lake	*
491737	Utah Lake 4 Mi North Of Pelican Point 5 Mi West Of Geneva	Lake	*
491738	Utah Lake 0.5 Mi S Of American Fork Boat Harbor #14	Lake	
491739	Utah Lake 4 Mi West Of Provo Airport 4 Mi North Of Lincoln P	Lake	*
491740	Utah Lake 1.5 Mi NW Of Provo Boat Harbor #16	Lake	
491741	Utah Lake 1 Mi NE Of Pelican Point #10	Lake	
491742	Utah Lake 1 Mi Se Of Pelican Point #09	Lake	
491750	Utah Lake 3 Mi W/NW Of Lincoln Beach	Lake	*
491751	Utah Lake 4 Mi E Of Saratoga Springs #11	Lake	
491752	Utah Lake 2 Mi E Of Saratoga Springs #12	Lake	*
491762	Utah Lake Goshen Bay Midway Off Main Point On East Shore	Lake	*
491770	Utah Lake 2.5 Mi NE Of Lincoln Point #02	Lake	
491771	Utah Lake 1 Mi NE Of Lincoln Point #03	Lake	
491777	Utah Lake Provo Bay Outside Entrance To Provo Bay	Lake	*
499477	Drain North And Parallel To 4-73 Above Cnfl/ Jordan River	River/Stream	
499479	Jordan R At Utah L Outlet U121 Xing	River/Stream	*
499496	American Fk Ck 2.5mi S Of Am Fk City	River/Stream	*
499504	Timpanogos WWTP	Facility	
499512	Lindon Drain At Co Rd Xing Above Ut Lake	River/Stream	*
499515	Geneva Steel 004 WWTP	Facility	
499516	Geneva Steel 005 Coke Plant Biotp	Facility	
499520	US Steel Geneva	Facility	*
499522	D & I Steel Co Effluent 001	Facility	
499524	Unnamed Ck 3mi S Of Geneva Steel (Powell Slough To Utah L)	River/Stream	
499525	Orem WWTP	Facility	
499526	Powell Slough Above Orem WWTP	River/Stream	
499541	Payson WWTP	Facility	
499542	Beer Ck Above Payson WWTP At U115 Xing	River/Stream	
499544	Salem WWTP	Facility	
499545	Beer Ck Above Salem WWTP	River/Stream	
499546	Beer Ck (L-Fk) Above Salem WWTP	River/Stream	
499548	Payson City Power Plant Outfall	Facility	
499557	Ensign-Bickford Spanish Fork	Facility	
499558	Spanish Fork R Above Utah L (Lakeshore)	River/Stream	*
499597	Dry Ck 1mi N 0f Spanish Fk Airport	River/Stream	

STORET	Description	Type	
499600	Dry Ck @ Cr 77 Xing Above Utah Lake	River/Stream	*
499602	Spanish Fork WWTP	Facility	
499603	Dry Ck Above Spanish Fk WWTP	River/Stream	
499610	Hobble Ck At I-15 Bdg 3mi S Of Provo	River/Stream	*
499619	Spring Ck Uprr Xing 1.7mi Se Of Provo Golf Cse	River/Stream	
499622	Springville Fh 001 West Side Discharge	Facility	
499623	Springville Fh 002 West Side Raceway Cleaning Discharge	Facility	
499624	Springville Fh 003 East Side Discharge	Facility	
499628	Springville WWTP	Facility	
499631	Spring Ck Below Fish Hatcheries And Above Springville WWTP	River/Stream	
499641	Ironton Cnl Above Kuhnis Byproducts	River/Stream	
499642	Pacific States Waste Pond	Facility	
499643	Pacific States Cooling Tower Outfall 001 Formerly 003	Facility	
499645	Ironton Cnl Below Reilly T&C And Above Pacific States	River/Stream	
499646	Reilly Tar And Chemical	Facility	
499648	Ironton Cnl Above Reilly Tar & Chem & Below Fish Hatchery	River/Stream	
499649	W Springville Fh	Facility	
499650	E Springville Fh	Facility	
499651	Spring Ck At Dist. Box Above Springville Hatchery	River/Stream	
499653	Valtech Inc. Outfall	Facility	
499654	Mill Race Creek At I-15 Crossing (2 Mi S Provo Courthouse)	River/Stream	*
499656	Provo WWTP	Facility	
499657	Millrace Ck Above Provo WWTP	River/Stream	
499660	Provo City Power 001 (Above 500w Ditch)	Facility	
499661	Provo City Power 002 (Above Sewer Drain At E Manhole)	Facility	
499662	Provo City Power 003 (Above Millrace N Of Plant)	Facility	
499663	Mill Race Creek At Mouth	River/Stream	
499664	16th North Provo Storm Drain	River/Stream	
499665	8th North Provo Storm Drain	River/Stream	
499666	Provo Towne Center Mall Construction 001	Facility	
499668	Provo R. At Utah Lake Boat Harbor	River/Stream	
499669	Provo R At U114 Xing	River/Stream	*
499670	Provo River At 500 West	River/Stream	
499671	Duplicate Of 499669	River/Stream	
499674	Provo R. 600 Ft Below Up&L Hale Plant Effluent	River/Stream	
499678	Provo River At Murdock Diversion	River/Stream	
499680	Provo R At Rotary Park	River/Stream	
591760	Beer Creek Below Salem Pond Site #8	River/Stream	
591761	Salem Pond Above Dam Sp01	Lake	
591762	Salem Pond South End 02	Lake	
591975	Spring Ck At 400 North	River/Stream	
591976	Spring Ck Above Cnfl/ Beer Ck At 8400 S	River/Stream	
591982	Beer Ck At Arrowhead Road	River/Stream	
591984	Beer Ck At 4800 West And 8400 South	River/Stream	
591986	Beer Ck Above Utah Lake	River/Stream	*
591994	Spanish Fork R At 6800 South	River/Stream	
591997	Spanish Fork R At 5000 South	River/Stream	

* Primary Station

5.4.1.1 Data Coverage

The first step in data evaluation is determining the time periods and sampling stations where sufficient data are available and where significant gaps exist. Table 5 shows the entire time period of study, when data are available for selected stations. The extent of data reported at each STORET site varies considerably from one station to the next. Water quality data from Utah Lake was collected intermittently from 1980 to 2003. Overall the availability of data is good; however, several stations reported insufficient data to permit a statistical analysis.

Water quality data from facilities, such as wastewater treatment plants (WWTP), fish hatcheries (FH), and various utility and industrial facilities were also sporadic. In general, WWTPs appear to have collected data continuously since 1990. The Springville Fish Hatchery record of data was not as complete, ending after 1996. Many of the stations appear to have been temporary or only sampled while a particular facility was in operation, such as the Provo Towne Center Mall Construction 001.

The location of each STORET site listed in Table 5 is shown in the map provided in Appendix B. Stream station sampling was generally more consistent than it was at lake and point source locations. The major inflows and outflows, such as the Provo River and Jordan River, are well characterized and data are available for the entire period of interest.

Table 5: Water Quality Data Availability by Station

Station ID	Station Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
491731	UTAH LAKE 0.5 MI W OF GENEVA DISCHARGE #15-A											■	■		■	■	■		■		■		■	■	■
491734	UTAH LAKE E OF PROVO BOAT HARBOR/6 MI N OF LINCOLN BEACH #08											■	■			■	■								
491737	UTAH LAKE 4 MI NORTH OF PELICAN POINT 5 MI WEST OF GENEVA										■	■	■						■		■		■	■	■
491739	UTAH LAKE 4 MI WEST OF PROVO AIRPORT 4 MI NORTH OF LINCOLN P										■	■	■		■				■		■		■	■	■
491750	UTAH LAKE 3 MI WNW OF LINCOLN BEACH										■	■	■						■		■		■	■	■
491752	UTAH LAKE 2 MI E OF SARATOGA SPRINGS #12											■	■		■				■		■		■	■	■
491762	UTAH LAKE GOSHEN BAY MIDWAY OFF MAIN POINT ON EAST SHORE										■	■	■		■						■				
491777	UTAH LAKE PROVO BAY OUTSIDE ENTRANCE TO PROVO BAY											■	■		■		■				■				
499460	JORDAN R AT BLUFFDALE ROAD XING	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499472	JORDAN R AT NARROWS - PUMP STATION						■				■	■	■	■	■	■	■				■	■			
499479	JORDAN R AT UTAH L OUTLET U121 XING	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				■	■	■	■	■
499496	AMERICAN FK CK 2.5MI S OF AM FK CITY											■	■	■					■		■				
499504	TIMPANOGOS WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499512	LINDON DRAIN AT CO RD XING AB UTLAKE															■	■				■	■	■		
499520	US STEEL GENEVA	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499525	OREM WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499541	PAYSON WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499542	BEER CK AB PAYSON WWTP AT U115 XING				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499544	SALEM WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499545	BEER CK AB SALEM WWTP			■	■		■	■	■	■	■	■	■	■	■										
499548	PAYSON CITY POWER PLANT OUTFALL															■		■	■	■	■	■			
499558	SPANISH FORK R AB UTAH L (LAKESHORE)	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
499600	DRY CK @ CR 77 XING AB UTAH LAKE													■	■	■	■	■	■	■	■	■	■	■	■
499602	SPANISH FORK WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499603	DRY CK AB SPANISH FK WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499610	HOBBLE CK AT I-15 BDG 3MI S OF PROVO			■	■	■	■	■	■	■	■	■	■	■	■	■	■		■		■	■	■	■	
499622	SPRINGVILLE FH 001 WEST SIDE DISCHARGE																■	■	■	■	■	■	■	■	■
499624	SPRINGVILLE FH 003 EAST SIDE DISCHARGE																■	■	■	■	■	■	■	■	■
499628	SPRINGVILLE WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499631	SPRING CK BL FISH HATCHERIES AND AB SPRINGVILLE WWTP			■	■			■	■	■	■	■	■	■	■										
499643	PACIFIC STATES COOLING TOWER OUTFALL 001 FORMERLY 003							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499646	REILLY TAR AND CHEMICAL	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
499648	IRONTON CNL AB REILLY TAR & CHEM & BL FISH HATCHERY	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499649	W SPRINGVILLE FH	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
499651	SPRING CK AT DIST. BOX AB SPRINGVILLE HATCHERY	■	■	■	■	■	■	■	■	■	■	■	■	■	■										
499654	MILL RACE CREEK AT I-15 CROSSING (2 MI S PROVO COURTHOUSE)					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499656	PROVO WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499657	MILLRACE CK AB PROVO WWTP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
499669	PROVO R AT U114 XING	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
591760	BEER CREEK BL SALEM POND SITE #8		■	■							■	■		■							■	■			
591975	SPRING CK AT 400 NORTH																				■	■			
591976	SPRING CK AB CNFL/ BEER CK AT 8400 S													■		■	■				■	■			
591984	BEER CK AT 4800 WEST AND 8400 SOUTH				■									■	■	■	■	■	■	■	■	■	■	■	■
591986	BEER CK AB UTAH LAKE											■	■	■							■	■			

5.4.1.2 Stations Excluded From Analysis

Some stations within the boundaries of the Utah Lake-Jordan River Watershed were excluded from the analysis. Stations were evaluated based on geographic location and quantity of available data. Those stations downstream of the Utah Lake outlet or more than a mile upstream of the Utah Lake shoreline were excluded because of their location. Stations not sampled for TP or TSS, comprising less than three consecutive years of sampling data or with too few monthly data to perform a statistical analysis, were excluded because of insufficient data. A list of these STORET stations is presented in Table 6.

Table 6: Water Quality Sampling Stations Excluded from the Analysis

Station ID	Name	Type	Reason for Exclusion
491730	Utah Lake 300 Ft Offshore From Geneva Steel	Lake	Quantity
491732	Utah Lake 0.5 Mi W Of Geneva Discharge #15-B (Duplicate)	Lake	Quantity
491733	Utah Lake 5mi N/NW Of Lincoln Beach/ 1 Mi Offshore	Lake	Quantity
491738	Utah Lake 0.5 Mi S Of American Fork Boat Harbor #14	Lake	Quantity
491740	Utah Lake 1.5 Mi NW Of Provo Boat Harbor #16	Lake	Quantity
491741	Utah Lake 1 Mi NE Of Pelican Point #10	Lake	Quantity
491742	Utah Lake 1 Mi Se Of Pelican Point #09	Lake	Quantity
491751	Utah Lake 4 Mi E Of Saratoga Springs #11	Lake	Quantity
491770	Utah Lake 2.5 Mi NE Of Lincoln Point #02	Lake	Quantity
491771	Utah Lake 1 Mi NE Of Lincoln Point #03	Lake	Quantity
499477	Drain North And Parallel To 4-73 Ab Cnfl/ Jordan River	River/Stream	Location
499515	Geneva Steel 004 WWTP	Facility	Quantity
499516	Geneva Steel 005 Coke Plant Biotp	Facility	Quantity
499522	D & I Steel Co Effluent 001	Facility	Quantity
499524	Unnamed Ck 3mi S Of Geneva Steel (Powell Slough To Utah L)	River/Stream	Quantity
499526	Powell Slough Ab Orem WWTP	River/Stream	Quantity
499546	Beer Ck (L-Fk) Ab Salem WWTP	River/Stream	Quantity
499557	Ensign-Bickford Spanish Fork	Facility	Quantity
499597	Dry Ck 1mi N 0f Spanish Fk Airport	River/Stream	Quantity
499619	Spring Ck Uprr Xing 1.7mi Se Of Provo Golf Cse	River/Stream	Quantity
499623	Springville Fh 002 West Side Raceway Cleaning Discharge	Facility	Quantity
499641	Ironton Cnl Ab Kuhnis Byproducts	River/Stream	Quantity
499642	Pacific States Waste Pond	Facility	Quantity
499645	Ironton Cnl Bl Reilly T&C And Ab Pacific States	River/Stream	Quantity
499650	E Springville Fh	Facility	Quantity
499653	Valtech Inc. Outfall	Facility	Quantity
499660	Provo City Power 001 (Ab 500W Ditch)	Facility	Quantity
499661	Provo City Power 002 (Ab Sewer Drain At E Manhole)	Facility	Quantity
499662	Provo City Power 003 (Ab Millrace N Of Plant)	Facility	Quantity
499663	Mill Race Creek At Mouth	River/Stream	Quantity

Station ID	Name	Type	Reason for Exclusion
499664	16th North Provo Storm Drain	River/Stream	Quantity
499665	8th North Provo Storm Drain	River/Stream	Quantity
499666	Provo Towne Center Mall Construction 001	Facility	Quantity
499668	Provo R. At Utah Lake Boat Harbor	River/Stream	Quantity
499670	Provo River At 500 West	River/Stream	Quantity
499671	Duplicate Of 499669	River/Stream	Quantity
499674	Provo R. 600 Ft Bl Up&L Hale Plant Effluent	River/Stream	Quantity
499678	Provo River At Murdock Diversion	River/Stream	Location
499680	Provo R At Rotary Park	River/Stream	Location
591761	Salem Pond Ab Dam Sp01	Lake	Quantity
591762	Salem Pond South End 02	Lake	Quantity
591982	Beer Ck At Arrowhead Road	River/Stream	Quantity
591994	Spanish Fork R At 6800 South	River/Stream	Quantity
591997	Spanish Fork R At 5000 South	River/Stream	Quantity

5.5 Biological Data

All biological data were gathered through literature reviews of previous studies of Utah Lake. Chlorophyll A data were gathered from the STORET database.

5.6 Fishery Data

Climate data pertinent to the fishery in Utah Lake were obtained from the National Climatic Data Center (NCDC 1998). Water quality data were obtained from STORET. Fish population information is based on data collected using subsampling techniques including gill and trap nets, and trawling. Fish species and distribution information available to this effort is primarily from annual fish monitoring by UDWR, commercial harvest reports, and sport fishing reports. The data collected for these reports were gathered under a variety of conditions and sampling designs and may not be directly comparable. Gaps in available information regarding the warm water fishery in Utah Lake are evident. Accurate fish counts are not available based on total fish counts for Utah Lake. Continuous DO and temperature measurements were not available. Grab samples will be used to represent one day averages. Comprehensive fish population age class and distribution data are not available to this effort at this time. Previous subsample population estimates will be assumed representative of current populations.

6.0 Data Analysis Methodology

This section describes the methods used to perform a cursory review of the data, including the treatment of non-detect values and outliers. A brief summary of the analysis is presented where appropriate.

6.1 Flow

The average monthly flow values obtained from BYU were generated previous to this study based on actual and calculated historical flow data for the length of the study period.

Of all flows into Utah Lake, surface flow accounts for the majority (60.8%), followed by ground water inflows (23.7%) and precipitation (15.4%). When considering only the surface inflows, approximately half of the surface inflow is contributed by the Provo and Spanish Fork Rivers. Table 7 summarizes all inflows to Utah Lake based on flows from the LKSIM model.

Table 7: All Utah Lake Inflows

Flow Description	Acre-feet/Year	% Total Inflow
Streams	420,800	50.7
Provo River	*150,200*	*18.1*
Spanish Fork River	*99,700*	*12.0*
Beer Creek	*36,700*	*4.4*
Mill Race	*33,500*	*4.0*
Powell Slough	*24,900*	*3.0*
Hobble Creek	*19,800*	*2.4*
Other Streams	*56,000*	*11.1*
Groundwater/Springs	196,600	23.7
Precipitation	128,000	15.4
Other Surface Inflow	83,900	10.1
Total Inflow	**829,300**	

The Jordan River is the only major surface outflow from the lake and accounts for roughly 51% of the total outflow from Utah Lake.

6.2 Inorganic Data

Inorganic constituents including Stream Total Dissolved Solids (TDS), Specific Conductivity, both Total Phosphorus (TP) and Dissolved Total Phosphorus (DTP), Nitrogen, Bicarbonate, Calcium, Chloride, Magnesium, Sodium, Total Suspended Solids (TSS) and Sulfate. The data were analyzed to remove outliers and ensure data quality. The results of the statistical analysis are included in Appendix C.

6.2.1 Treatment of Non Detect Values

The water quality data used in this study contained a significant amount of values reported as being below the limits of detection.

For the purpose of analyzing these data, a numerical value must be assigned to samples reported as "non-detect". After consulting with DWQ, the decision was made to represent all non-detect sample values as being half of the detection limit. For example, "non-detect" TP samples were assigned a value of 0.01 mg/L, which is half of the detection limit of 0.02 mg/L.

6.2.2 Identification of Outliers

To more reliably calculate statistics for the water quality conditions, a preliminary effort was made to identify statistical outliers. An initial screening of the data identified data values that were either undefined or not physically possible. The criteria for removal (based on magnitude) are as follows:

- For Dissolved Oxygen, samples greater than 20 mg/L were removed.

- For pH at Stream stations, values less than 4 or greater than 11 mg/L were removed.
- For in-lake pH, values less than 3 or greater than 11 mg/L were removed.
- For pH at Point discharges, values less than 2 or greater than 12 mg/L were removed.

Monthly mean values and standard deviations were calculated for every parameter at each station. Data points which were more than three standard deviations away from their respective mean value were removed. Excluded data were documented and presented in this report (Appendix D).

6.2.3 Stream

An analysis of the stream station water quality data is presented in Appendix C. This analysis includes a descriptive statistical summary of the data and a count of the total number of exceedances for each station. A statistical summary of this data is shown in Table 8.

Table 8: Summary of Stream Water Quality Data

Station Number/Name	Constituent (Units)	Count	Exceedances Number	%	Minimum	Maximum	Mean	Standard Deviation
NATURAL RIVERS/STREAMS								
499460	**JORDAN R AT BLUFFDALE ROAD XING**							
	DO (mg/L)	219	**4**	**2**	4.1	15.8	9.7	2.2
	DTP (mg/L)	59	**13**	**22.0**	0.01	0.3	0.043	0.056
	TDS (mg/L)	184	**20**	**10.9**	118	1380	911.6	221.1
	Temp (°C)	230	0	0.0	0	24.7	12.3	6.7
	TP (mg/L)	175	**128**	**73.1**	0.01	0.29	0.091	0.061
	TSS (mg/L)	228	**135**	**59.2**	0	350	64.7	61.7
499472	**JORDAN R AT NARROWS - PUMP STATION**							
	DO (mg/L)	91	**5**	**5**	4.6	16.5	8.9	2.6
	DTP (mg/L)	55	**7**	**12.7**	0.01	0.146	0.031	0.029
	TDS (mg/L)	85	**38**	**44.7**	86	1562	1135.4	281.6
	Temp (°C)	90	0	0.0	0.7	45	12.3	8.1
	TP (mg/L)	83	**69**	**83.1**	0.025	0.413	0.108	0.065
	TSS (mg/L)	84	**61**	**72.6**	3	345	81.6	63.1
499479	**JORDAN R AT UTAH L OUTLET U121 XING**							
	DO (mg/L)	161	**4**	**2**	4	19.9	8.8	2.6
	DTP (mg/L)	53	**6**	**11.3**	0.01	0.391	0.034	0.059
	TDS (mg/L)	170	**50**	**29.4**	546	1910	1031.5	356.7
	Temp (°C)	171	0	0.0	0	28	12.4	7.8
	TP (mg/L)	164	**125**	**76.2**	0.01	0.66	0.121	0.113
	TSS (mg/L)	166	**98**	**59.0**	0	712	84.5	118.1
499496	**AMERICAN FK CK 2.5MI S OF AM FK CITY**							
	DO (mg/L)	10	0	0.0	7.2	9.8	8.2	0.8
	DTP (mg/L)	9	**1**	**11.1**	0.01	0.097	0.024	0.03
	TDS (mg/L)	9	0	0.0	180	440	357.3	80.4
	Temp (°C)	10	0	0.0	10.2	22.5	17.2	4.3
	TP (mg/L)	9	**1**	**11.1**	0.01	0.135	0.026	0.041
	TSS (mg/L)	10	**1**	**10.0**	0	398	43.4	124.7

Station Number/Name	Constituent (Units)	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
499558	**SPANISH FORK R AB UTAH L (LAKESHORE)**							
	DO (mg/L)	173	**12**	**7**	0.3	13.1	8.7	2.3
	DTP (mg/L)	64	**12**	**18.8**	0.01	0.136	0.033	0.028
	TDS (mg/L)	178	0	0.0	222	936	484.1	133.1
	Temp (°C)	175	0	0.0	0.1	25.7	10.8	6.6
	TP (mg/L)	165	**117**	**70.9**	0.009	1.5	0.141	0.2
499558 cont'd	TSS (mg/L)	171	**104**	**60.8**	0	1381	129	237
499600	**DRY CK @ CR 77 XING AB UTAH LAKE**							
	DO (mg/L)	43	**7**	**16**	3.3	11	7.4	1.9
	DTP (mg/L)	4	**1**	**25.0**	0.01	0.185	0.057	0.085
	TDS (mg/L)	1	0	0.0	344	344	344	
	Temp (°C)	43	0	0.0	3.6	22.7	12.7	5.1
	TP (mg/L)	4	**1**	**25.0**	0.019	0.185	0.069	0.078
	TSS (mg/L)	23	**11**	**47.8**	0	245	61.3	73.9
499610	**HOBBLE CK AT I-15 BDG 3MI S OF PROVO**							
	DO (mg/L)	128	**3**	**2**	4.7	14.1	8.8	1.5
	DTP (mg/L)	62	**4**	**6.5**	0.005	0.963	0.039	0.12
	TDS (mg/L)	128	0	0.0	172	612	304.9	75.2
	Temp (°C)	131	0	0.0	1.3	31.1	10.8	6.1
	TP (mg/L)	127	**47**	**37.0**	0.01	0.929	0.067	0.104
	TSS (mg/L)	124	**9**	**7.3**	0	188	15.9	28.6
499651	**SPRING CK AT DIST. BOX AB SPRINGVILLE HATCHERY**							
	DO (mg/L)	95	**15**	**16**	4.1	10.4	6.9	1.3
	DTP (mg/L)	16	0	0.0	0.01	0.045	0.028	0.01
	TDS (mg/L)	89	0	0.0	336	862	645.1	120.1
	Temp (°C)	99	0	0.0	11	18.5	14.7	1.8
	TP (mg/L)	93	**18**	**19.4**	0	0.45	0.04	0.052
	TSS (mg/L)	101	**1**	**1.0**	0	91	4	10.8
499654	**MILL RACE CREEK AT I-15 CROSSING (2 MI S PROVO COURTHOUSE)**							
	DO (mg/L)	133	**4**	**3**	0.4	12.4	8.4	1.7
	DTP (mg/L)	45	**45**	**100.0**	0.433	1.981	1.059	0.389
	TDS (mg/L)	91	0	0.0	448	736	570.7	56.4
	Temp (°C)	136	0	0.0	0.3	25.9	15.6	5.8
	TP (mg/L)	93	**92**	**98.9**	0.013	2.213	1.096	0.413
	TSS (mg/L)	111	**20**	**18.0**	0	528	30.1	49.8
499669	**PROVO R AT U114 XING**							
	DO (mg/L)	215	0	0.0	6.6	14.1	10	1.5
	DTP (mg/L)	87	**6**	**6.9**	0.01	0.141	0.022	0.019
	TDS (mg/L)	212	0	0.0	168	408	272.9	35.3
	Temp (°C)	219	0	0.0	0.5	22.6	9.7	5.5
	TP (mg/L)	203	**53**	**26.1**	0.009	3.511	0.056	0.245
	TSS (mg/L)	211	**3**	**1.4**	0	49	6.1	8
591975	**SPRING CK AT 400 NORTH**							
	DO (mg/L)	9	**1**	**11**	5.4	11	9.2	1.8
	DTP (mg/L)	9	**1**	**11.1**	0.01	0.74	0.097	0.241
	TDS (mg/L)	9	0	0.0	258	438	334.4	51.3
	Temp (°C)	9	0	0.0	4.4	22.2	11.9	6.6

Station Number/Name	Constituent (Units)	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
	TP (mg/L)	9	**4**	**44.4**	0.021	0.749	0.126	0.236
	TSS (mg/L)	9	**5**	**55.6**	14	78	36.3	21
591976	**SPRING CK AB CNFL/ BEER CK AT 8400 S**							
	DO (mg/L)	38	**2**	**5**	4.7	13	9.2	1.9
	DTP (mg/L)	37	**6**	**16.2**	0.01	0.158	0.035	0.033
	TDS (mg/L)	36	0	0.0	248	1116	469.5	189.6
591976 cont'd	Temp (°C)	38	0	0.0	0.3	27.2	10.4	6.1
	TP (mg/L)	38	**30**	**78.9**	0.01	1.612	0.138	0.258
	TSS (mg/L)	38	**30**	**78.9**	10	1160	102.9	184.1
591984	**BEER CK AT 4800 WEST AND 8400 SOUTH**							
	DO (mg/L)	74	**9**	**12**	1.9	14.3	8	2.2
	DTP (mg/L)	40	**38**	**95.0**	0.015	0.551	0.297	0.118
	TDS (mg/L)	37	**1**	**2.7**	604	1384	761.5	160.1
	Temp (°C)	74	0	0.0	0.7	28.6	13	6.7
	TP (mg/L)	40	**39**	**97.5**	0.01	0.753	0.392	0.167
	TSS (mg/L)	55	**31**	**56.4**	0	178	54.7	38.3
591986	**BEER CK AB UTAH LAKE**							
	DO (mg/L)	34	**3**	**9**	3	15	8.8	2.4
	DTP (mg/L)	34	**29**	**85.3**	0.01	0.496	0.197	0.141
	TDS (mg/L)	30	**9**	**30.0**	512	1564	904.8	340.3
	Temp (°C)	34	0	0.0	0	31.4	14.3	7.7
	TP (mg/L)	34	**33**	**97.1**	0.019	0.737	0.304	0.156
	TSS (mg/L)	34	**30**	**88.2**	23.6	468	94	80.6
DISCHARGES								
499504	**TIMPANOGOS WWTP**							
	DO (mg/L)	165	**93**	**56**	2.5	12.3	5.5	1.6
	DTP (mg/L)	18	**18**	**100.0**	2.71	6.744	3.88	1.034
	TDS (mg/L)	1	0	0.0	620	620	620	
	Temp (°C)	174	0	0.0	4.6	24.9	13.8	4.4
	TP (mg/L)	85	**85**	**100.0**	1.53	7.079	4.345	1.036
	TSS (mg/L)	166	**1**	**0.6**	0	43	4.1	5.7
499512	**LINDON DRAIN AT CO RD XING AB UTLAKE**							
	DO (mg/L)	35	0	0.0	6.8	13.4	9	1.3
	DTP (mg/L)	35	**3**	**8.6**	0.01	0.103	0.029	0.02
	TDS (mg/L)	35	0	0.0	352	718	521.3	77.7
	Temp (°C)	35	0	0.0	2.3	20.7	11.4	4.5
	TP (mg/L)	35	**29**	**82.9**	0.027	0.162	0.076	0.034
	TSS (mg/L)	35	**23**	**65.7**	0	179	48.8	31.5
499520	**US STEEL GENEVA**							
	DO (mg/L)	195	**77**	**39**	1	17.9	6.4	2.9
	DTP (mg/L)	8	**7**	**87.5**	0.026	1.561	0.396	0.501
	TDS (mg/L)	120	**33**	**27.5**	440	2046	898.7	369
	Temp (°C)	207	0	0.0	1.8	27.7	14.1	7.1
	TP (mg/L)	28	**23**	**82.1**	0.01	5.271	1.154	1.71
	TSS (mg/L)	154	**2**	**1.3**	0	47	4.4	7
499525	**OREM WWTP**							
	DO (mg/L)	174	**74**	**43**	2.7	10	5.6	1.1

Station Number/Name	Constituent (Units)	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
	DTP (mg/L)	18	**18**	**100.0**	0.196	9.835	4.841	2.822
	TDS (mg/L)	1	0	0.0	736	736	736	
	Temp (°C)	180	0	0.0	4.7	24.2	15.8	4.5
	TP (mg/L)	87	**87**	**100.0**	0.1	10.74	6.21	2.416
	TSS (mg/L)	169	**23**	**13.6**	0	97	16.9	16.7
499541	**PAYSON WWTP**							
	DO (mg/L)	163	**77**	**47**	1.3	9.1	5.6	1.3
	DTP (mg/L)	18	**18**	**100.0**	1.463	7.196	4.942	1.371
	TDS (mg/L)	0						
	Temp (°C)	169	0	0.0	5.7	24.7	14.1	4.5
	TP (mg/L)	83	**83**	**100.0**	1.24	10.74	5.341	1.701
	TSS (mg/L)	171	**5**	**2.9**	0	50	9.9	8.6
499542	**BEER CK AB PAYSON WWTP AT U115 XING**							
	DO (mg/L)	115	**4**	**3**	4.5	12.7	8	1.7
	DTP (mg/L)	15	**15**	**100.0**	0.122	0.445	0.253	0.097
	TDS (mg/L)	79	0	0.0	426	1098	655.4	134.5
	Temp (°C)	119	0	0.0	0.5	25.4	11.1	6.4
	TP (mg/L)	79	**78**	**98.7**	0.038	8.55	0.398	0.937
	TSS (mg/L)	98	**46**	**46.9**	0	130	37.4	25.9
499544	**SALEM WWTP**							
	DO (mg/L)	157	**46**	**29**	2	16.1	6.7	2.3
	DTP (mg/L)	19	**19**	**100.0**	0.983	3.716	2.138	0.731
	TDS (mg/L)	0						
	Temp (°C)	162	0	0.0	2	26.2	13.2	6.5
	TP (mg/L)	80	**80**	**100.0**	0.13	7.33	2.546	1.114
	TSS (mg/L)	160	**15**	**9.4**	0	68	18.7	13
499545	**BEER CK AB SALEM WWTP**							
	DO (mg/L)	62	**1**	**2**	5	15.5	9.6	2
	DTP (mg/L)	0						
	TDS (mg/L)	7	0	0.0	306	466	426.6	54.2
	Temp (°C)	64	0	0.0	1.9	24.5	12.9	5.7
	TP (mg/L)	62	**46**	**74.2**	0.01	4.98	0.214	0.704
	TSS (mg/L)	60	**14**	**23.3**	0	190	26.4	39.7
499548	**PAYSON CITY POWER PLANT OUTFALL**							
	DO (mg/L)	10	**2**	**20**	4.9	7.4	6.4	0.8
	DTP (mg/L)	0						
	TDS (mg/L)	10	**7**	**70.0**	610	1758	1197	411.3
	Temp (°C)	10	0	0.0	10.3	29.1	20.1	6.4
	TP (mg/L)	0						
	TSS (mg/L)	10	**1**	**10.0**	0	40.4	5.1	12.6
499602	**SPANISH FORK WWTP**							
	DO (mg/L)	164	**59**	**36**	2.5	8.4	5.8	1.3
	DTP (mg/L)	18	**18**	**100.0**	0.822	4.03	2.526	0.979
	TDS (mg/L)	0						
	Temp (°C)	169	0	0.0	6	25.8	14.1	4
	TP (mg/L)	86	**84**	**97.7**	0.01	4.82	2.66	1.072

Station Number/Name	Constituent (Units)	Count	Exceedances Number	%	Minimum	Maximum	Mean	Standard Deviation
	TSS (mg/L)	169	5	3.0	0	62	13.8	9.8
499603	DRY CK AB SPANISH FK WWTP							
	DO (mg/L)	130	1	1	5.2	12.6	8.6	1.4
	DTP (mg/L)	17	15	88.2	0.038	0.283	0.112	0.067
	TDS (mg/L)	89	0	0.0	436	902	588.5	91.7
	Temp (°C)	136	0	0.0	0.5	25.4	10.5	5.6
499603 cont'd	TP (mg/L)	94	93	98.9	0.01	0.56	0.21	0.091
	TSS (mg/L)	115	106	92.2	0	1092	93.8	103.2
499622	SPRINGVILLE FH 001 WEST SIDE DISCHARGE							
	DO (mg/L)	104	4	4	4.8	8.4	6.9	0.6
	DTP (mg/L)	5	0	0.0	0.01	0.027	0.019	0.008
	TDS (mg/L)	0						
	Temp (°C)	105	0	0.0	10.5	23	14.9	2
	TP (mg/L)	7	0	0.0	0.01	0.049	0.031	0.014
	TSS (mg/L)	107	0	0.0	0	6.4	0.2	1.1
499624	SPRINGVILLE FH 003 EAST SIDE DISCHARGE							
	DO (mg/L)	99	2	2	4.4	20	7.1	1.4
	DTP (mg/L)	4	1	25.0	0.01	0.077	0.03	0.032
	TDS (mg/L)	0						
	Temp (°C)	100	0	0.0	10.9	22.9	14.8	1.7
	TP (mg/L)	6	1	16.7	0.01	0.106	0.035	0.036
	TSS (mg/L)	102	0	0.0	0	23.6	1.2	3.6
499628	SPRINGVILLE WWTP							
	DO (mg/L)	168	9	5	3.7	9.6	7	1
	DTP (mg/L)	18	18	100.0	1.13	5.252	2.952	1.539
	TDS (mg/L)	0						
	Temp (°C)	174	0	0.0	1.9	25.5	14.9	4.1
	TP (mg/L)	85	85	100.0	0.1	5.797	2.75	1.361
	TSS (mg/L)	172	4	2.3	0	42	13.8	9.4
499631	SPRING CK BL FISH HATCHERIES AND AB SPRINGVILLE WWTP							
	DO (mg/L)	56	2	4	3.1	9.3	7	1.1
	DTP (mg/L)	0						
	TDS (mg/L)	6	0	0.0	348	878	505	223
	Temp (°C)	58	0	0.0	6	19.3	14.9	2.3
	TP (mg/L)	58	45	77.6	0.01	0.48	0.105	0.082
	TSS (mg/L)	57	1	1.8	0	73	3.6	9.9
499643	PACIFIC STATES COOLING TOWER OUTFALL 001 FORMERLY 003							
	DO (mg/L)	117	38	32	3.2	9.9	6	1.2
	DTP (mg/L)	10	10	100.0	0.414	2.205	0.951	0.504
	TDS (mg/L)	0						
	Temp (°C)	119	0	0.0	11.5	39.6	30.7	5.4
	TP (mg/L)	15	14	93.3	0.03	3.04	0.988	0.726
	TSS (mg/L)	115	8	7.0	0	96	12.4	15.2
499646	REILLY TAR AND CHEMICAL							
	DO (mg/L)	154	31	20	1.1	15.2	7.1	2.1
	DTP (mg/L)	10	3	30.0	0.024	0.06	0.041	0.011
	TDS (mg/L)	1	0	0.0	562	562	562	

Station Number/Name	Constituent (Units)	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
	Temp (°C)	159	0	0.0	8.3	27.4	18.2	4.1
	TP (mg/L)	30	**13**	**43.3**	0.01	0.2	0.059	0.041
	TSS (mg/L)	114	**2**	**1.8**	0	67	2.7	8.9
499648	**IRONTON CNL AB REILLY TAR & CHEM & BL FISH HATCHERY**							
	DO (mg/L)	129	**4**	**3**	3.7	11.1	7.7	1.1
	DTP (mg/L)	17	**8**	**47.1**	0.023	0.077	0.048	0.019
499648 cont'd	TDS (mg/L)	88	0	0.0	656	1040	829.9	95.7
	Temp (°C)	134	0	0.0	3.3	20.6	14.8	2.8
	TP (mg/L)	92	**45**	**48.9**	0.006	0.26	0.071	0.053
	TSS (mg/L)	94	**2**	**2.1**	0	63	6.4	9.5
499649	**W SPRINGVILLE FH**							
	DO (mg/L)	197	**16**	**8**	3.7	10.8	6.9	1
	DTP (mg/L)	10	**5**	**50.0**	0.028	0.091	0.058	0.021
	TDS (mg/L)	2	0	0.0	616	760	688	101.8
	Temp (°C)	207	0	0.0	11.1	19.6	14.8	1.7
	TP (mg/L)	22	**12**	**54.5**	0.01	0.25	0.072	0.058
	TSS (mg/L)	212	0	0.0	0	30	2.8	4.6
499656	**PROVO WWTP**							
	DO (mg/L)	168	**3**	**2**	5.2	9.2	7.6	0.9
	DTP (mg/L)	18	**18**	**100.0**	0.361	6.232	2.851	1.201
	TDS (mg/L)	0						
	Temp (°C)	172	0	0.0	6.7	22.9	16	3.5
	TP (mg/L)	85	**85**	**100.0**	0.13	5.48	3.178	0.964
	TSS (mg/L)	170	**3**	**1.8**	0	92	2.1	9
499657	**MILLRACE CK AB PROVO WWTP**							
	DO (mg/L)	140	**6**	**4**	3.6	13.8	8.6	1.6
	DTP (mg/L)	17	**10**	**58.8**	0.022	0.415	0.09	0.092
	TDS (mg/L)	91	0	0.0	108	640	349.1	62.4
	Temp (°C)	144	0	0.0	4	22.4	13.1	4.5
	TP (mg/L)	98	**83**	**84.7**	0.01	1.76	0.144	0.204
	TSS (mg/L)	123	**12**	**9.8**	0	159	13.4	20.8
591760	**BEER CREEK BL SALEM POND SITE #8**							
	DO (mg/L)	28	**3**	**11**	3.9	15.8	9.7	3
	DTP (mg/L)	21	**2**	**9.5**	0.01	0.506	0.05	0.122
	TDS (mg/L)	35	0	0.0	264	514	424.2	42
	Temp (°C)	28	0	0.0	7.9	23.4	14.6	4.4
	TP (mg/L)	29	**6**	**20.7**	0.01	0.5	0.059	0.121
	TSS (mg/L)	29	**5**	**17.2**	0	108	16.8	27.2

6.2.4 Lake

An analysis of the lake station water quality data is presented in Appendix C. In addition to the individual sample values, this analysis includes the minimum, maximum, mean, standard deviation, and number of exceedances for selected constituents. A statistical summary of this data is shown in Table 9.

Table 9: Summary of Lake Water Quality Data

Station Number(Depth) /Name	Constituent	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
491731(Surface)	**UTAH LAKE 0.5 MI W OF GENEVA DISCHARGE #15-A**							
	DO (mg/L)	25	0	0	6.2	14.3	9.5	2
	DTP (mg/L)	25	**15**	**60**	0.01	0.16	0.036	0.032
	TDS (mg/L)	14	**3**	**21**	418	1214	895.7	224.1
491731(Surface)	Temp (°C)	25	0	0	0.7	26.7	20	6.8
Cont'd	TP (mg/L)	23	**22**	**96**	0.01	0.25	0.081	0.048
	TSS (mg/L)	21	**13**	**62**	0	233	53	49
491731(Bottom)	**UTAH LAKE 0.5 MI W OF GENEVA DISCHARGE #15-A**							
	DO (mg/L)	22	**4**	**18**	1.9	11	6.9	2.1
	DTP (mg/L)	20	**11**	**55**	0.01	0.084	0.029	0.018
	TDS (mg/L)	0						
	Temp (°C)	22	0	0	7.1	25.7	19.2	5.3
	TP (mg/L)	18	**17**	**94**	0.01	0.193	0.101	0.047
	TSS (mg/L)	6	**6**	**100**	57	227	105.8	60.8
491734(Surface)	**UTAH LAKE E OF PROVO BOAT HARBOR/6 MI N OF LINCOLN BEACH #08**							
	DO (mg/L)	15	**1**	**7**	0.8	12.1	7.9	2.6
	DTP (mg/L)	17	**13**	**76**	0.01	0.068	0.035	0.016
	TDS (mg/L)	2	**1**	**50**	1062	1292	1177	162.6
	Temp (°C)	16	0	0	0.4	24.3	16.5	7
	TP (mg/L)	15	**15**	**100**	0.048	0.36	0.091	0.08
	TSS (mg/L)	11	**9**	**82**	23	133	67.8	34.5
491734(Bottom)	**UTAH LAKE E OF PROVO BOAT HARBOR/6 MI N OF LINCOLN BEACH #08**							
	DO (mg/L)	2	0	0	7.7	9.4	8.6	1.2
	DTP (mg/L)	2	0	0	0.01	0.02	0.015	0.007
	TDS (mg/L)	0						
	Temp (°C)	2	0	0	15.7	21.9	18.8	4.4
	TP (mg/L)	2	**2**	**100**	0.04	0.05	0.045	0.007
	TSS (mg/L)	0						
491737(Surface)	**UTAH LAKE 4 MI NORTH OF PELICAN POINT 5 MI WEST OF GENEVA**							
	DO (mg/L)	22	0	0	6.1	12.1	8.3	1.5
	DTP (mg/L)	22	**13**	**59**	0.01	0.08	0.034	0.021
	TDS (mg/L)	3	**2**	**67**	1080	1238	1176.7	84.7
	Temp (°C)	24	0	0	0.4	24.7	19	6.4
	TP (mg/L)	21	**20**	**95**	0.01	0.126	0.078	0.03
	TSS (mg/L)	17	**13**	**76**	0	174	70.4	49.1
491737(Bottom)	**UTAH LAKE 4 MI NORTH OF PELICAN POINT 5 MI WEST OF GENEVA**							
	DO (mg/L)	18	**1**	**6**	5.5	8.6	6.8	0.9
	DTP (mg/L)	15	**7**	**47**	0.01	0.06	0.025	0.013
	TDS (mg/L)	1	0	0	1084	1084	1084	
	Temp (°C)	18	0	0	10.3	24.4	19.7	4.2
	TP (mg/L)	15	**14**	**93**	0.01	0.114	0.077	0.029
	TSS (mg/L)	5	**4**	**80**	15	173	98.8	57.5
491739(Surface)	**UTAH LAKE 4 MI WEST OF PROVO AIRPORT 4 MI NORTH OF LINCOLN P**							
	DO (mg/L)	24	0	0	6.1	9.9	7.9	1
	DTP (mg/L)	25	**13**	**52**	0.01	0.056	0.025	0.013

Station Number(Depth) /Name	Constituent	Count	Exceedances Number	Exceedances %	Minimum	Maximum	Mean	Standard Deviation
	TDS (mg/L)	3	2	67	1056	1262	1185.3	112.6
	Temp (°C)	26	0	0	0.6	28.5	19.2	6.4
	TP (mg/L)	22	21	95	0.022	0.21	0.072	0.048
	TSS (mg/L)	21	9	43	0	76	34.2	21.6
491739(Bottom)	**UTAH LAKE 4 MI WEST OF PROVO AIRPORT 4 MI NORTH OF LINCOLN P**							
	DO (mg/L)	11	1	9	4.4	7.1	6.3	0.7
	DTP (mg/L)	8	2	25	0.01	0.06	0.022	0.018
	TDS (mg/L)	1	0	0	1070	1070	1070	
	Temp (°C)	11	0	0	17.3	24.6	21	2
	TP (mg/L)	7	7	100	0.027	0.083	0.058	0.02
	TSS (mg/L)	2	2	100	60	102	81	29.7
491750(Surface)	**UTAH LAKE 3 MI WNW OF LINCOLN BEACH**							
	DO (mg/L)	23	0	0	6.4	12.8	8.4	1.5
	DTP (mg/L)	22	9	41	0.01	0.091	0.028	0.019
	TDS (mg/L)	3	1	33	838	1246	1048	204.3
	Temp (°C)	24	0	0	1	27.6	18.9	6.9
	TP (mg/L)	21	18	86	0.008	0.34	0.08	0.07
	TSS (mg/L)	19	10	53	0	124	46.4	36
491750(Bottom)	**UTAH LAKE 3 MI WNW OF LINCOLN BEACH**							
	DO (mg/L)	13	2	15	4.6	9.8	6.9	1.5
	DTP (mg/L)	10	5	50	0.01	0.061	0.029	0.021
	TDS (mg/L)	1	0	0	1064	1064	1064	
	Temp (°C)	13	0	0	6.4	24.5	19	5.4
	TP (mg/L)	10	9	90	0.021	0.659	0.155	0.206
	TSS (mg/L)	3	2	67	24	190	90.7	87.7
491752(Surface)	**UTAH LAKE 2 MI E OF SARATOGA SPRINGS #12**							
	DO (mg/L)	22	1	5	4.8	13.5	8.3	1.8
	DTP (mg/L)	23	12	52	0.01	0.069	0.026	0.014
	TDS (mg/L)	2	2	100	1202	1262	1232	42.4
	Temp (°C)	23	0	0	0.6	26.2	19.2	6.8
	TP (mg/L)	20	20	100	0.037	0.235	0.087	0.045
	TSS (mg/L)	19	13	68	0	120	59.7	41.9
491752(Bottom)	**UTAH LAKE 2 MI E OF SARATOGA SPRINGS #12**							
	DO (mg/L)	9	0	0	6.1	7.7	6.8	0.6
	DTP (mg/L)	7	2	29	0.01	0.059	0.021	0.02
	TDS (mg/L)	0						
	Temp (°C)	9	0	0	18.1	25.2	21.2	2.3
	TP (mg/L)	7	6	86	0.021	0.127	0.08	0.034
	TSS (mg/L)	0						
491762(Surface)	**UTAH LAKE GOSHEN BAY MIDWAY OFF MAIN POINT ON EAST SHORE**							
	DO (mg/L)	14	0	0	6.5	9.9	7.9	1
	DTP (mg/L)	14	9	64	0.01	0.116	0.036	0.028
	TDS (mg/L)	3	1	33	716	1330	1068.7	317
	Temp (°C)	15	0	0	2	27.8	17.1	7.4
	TP (mg/L)	13	13	100	0.036	0.312	0.119	0.089

Station Number(Depth) /Name	Constituent	Count	Exceedances Number	%	Minimum	Maximum	Mean	Standard Deviation
	TSS (mg/L)	10	9	90	25.2	254	119.4	75
491762(Bottom)	**UTAH LAKE GOSHEN BAY MIDWAY OFF MAIN POINT ON EAST SHORE**							
	DO (mg/L)	7	1	14	5.4	8.2	6.9	1
	DTP (mg/L)	7	1	14	0.019	0.035	0.023	0.006
	TDS (mg/L)	0						
491762(Bottom)	Temp (°C)	7	0	0	10.2	23.7	17.4	5.5
Cont'd	TP (mg/L)	7	7	100	0.04	0.23	0.119	0.078
	TSS (mg/L)	2	2	100	285	305	295	14.1
491777(Surface)	**UTAH LAKE PROVO BAY OUTSIDE ENTRANCE TO PROVO BAY**							
	DO (mg/L)	17	1	6	5.3	13.6	8.3	2.1
	DTP (mg/L)	17	11	65	0.012	0.09	0.043	0.025
	TDS (mg/L)	2	1	50	682	1214	948	376.2
	Temp (°C)	18	0	0	0.6	27.4	17.2	7.1
	TP (mg/L)	15	15	100	0.05	0.23	0.108	0.055
	TSS (mg/L)	12	8	67	6	166	84.1	57.8
491777(Bottom)	**UTAH LAKE PROVO BAY OUTSIDE ENTRANCE TO PROVO BAY**							
	DO (mg/L)	15	1	7	3.7	10.3	7.1	1.7
	DTP (mg/L)	14	7	50	0.01	0.59	0.07	0.15
	TDS (mg/L)	1	0	0	1084	1084	1084	
	Temp (°C)	15	0	0	6.4	23.5	16.7	5.4
	TP (mg/L)	15	15	100	0.06	0.7	0.174	0.154
	TSS (mg/L)	7	7	100	40	188	116	50.4

6.3 Biological

Chlorophyll A data were analyzed using the same methodology as the inorganic data. All other biological data used in this study were analyzed as a part of previous studies.

6.4 Fishery

Accurate population surveys based on total fish counts are not available for Utah Lake. The population information presented here is based on data collected using subsampling techniques (gill and trap nets, and trawling), normalized to represent the populations in the lake as a whole. The subsampling techniques available exhibit some inherent bias towards certain species and age classes. The information presented should therefore be interpreted as a general characterization of relative populations, not a quantitative evaluation of absolute fish numbers.

Catch rates (number of fish per hour) of the more common fish species in gill nets (1958-1993) and trap nets (1995-2000) in Utah Lake (see Figure 1 to Figure 3) show a predominance of carp and white bass, which account for the majority of the biomass and numbers of fish present in Utah Lake. Carp numbers were greatest in 1958 to 1959 and have declined through 2000. Catch rates of white bass are observed to vary substantially on an annual basis, with peak populations occurring between 1982 and 1985.

Channel catfish are the third most abundant species captured between 1958 and 1989, but catch rates dropped dramatically between 1989 and 2000. Black bullhead catch rates ranked fourth in the late 1950s, experienced a substantial drop through the 1980s and early 1990s, but have rebounded in 1995 to 2000 to occupy the position of third most abundant species (20.2%) in the lake (Figure 3). Population estimates based on averaged data (1995 to 2000) show carp at 36.2% of the total population, white bass at 21.6% and black bullhead at 20.2%.

Figure 1: Average catch rates for the more common fish species in Utah Lake, 1958 through 2000

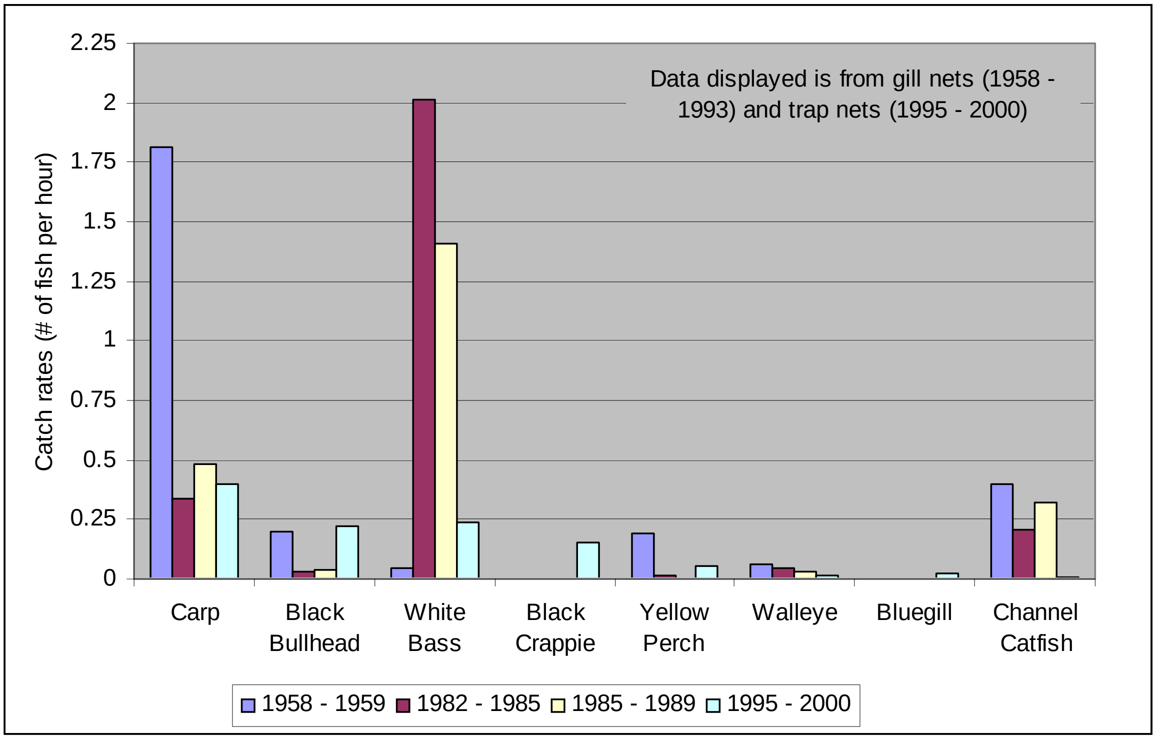


Figure 2: Average catch rates for the more common fish species in Utah Lake, 1995 through 2000

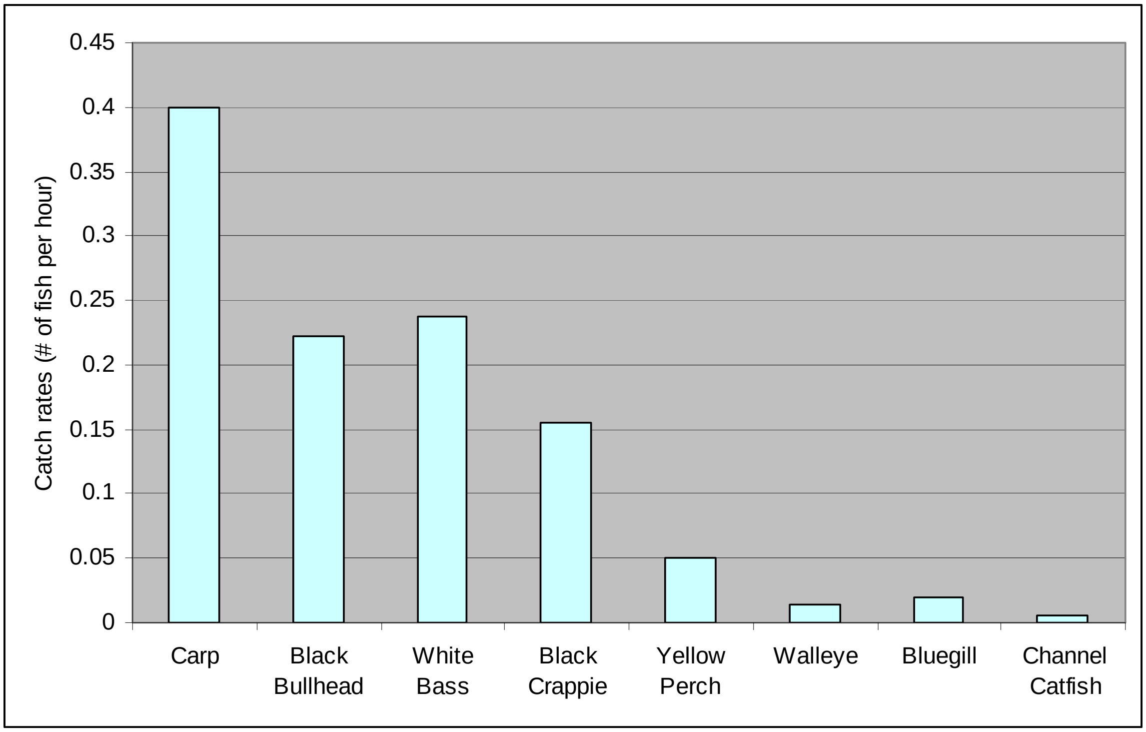


Figure 3: Relative percent population based on average catch rates using trap nets in Utah Lake, 1995 through 2000

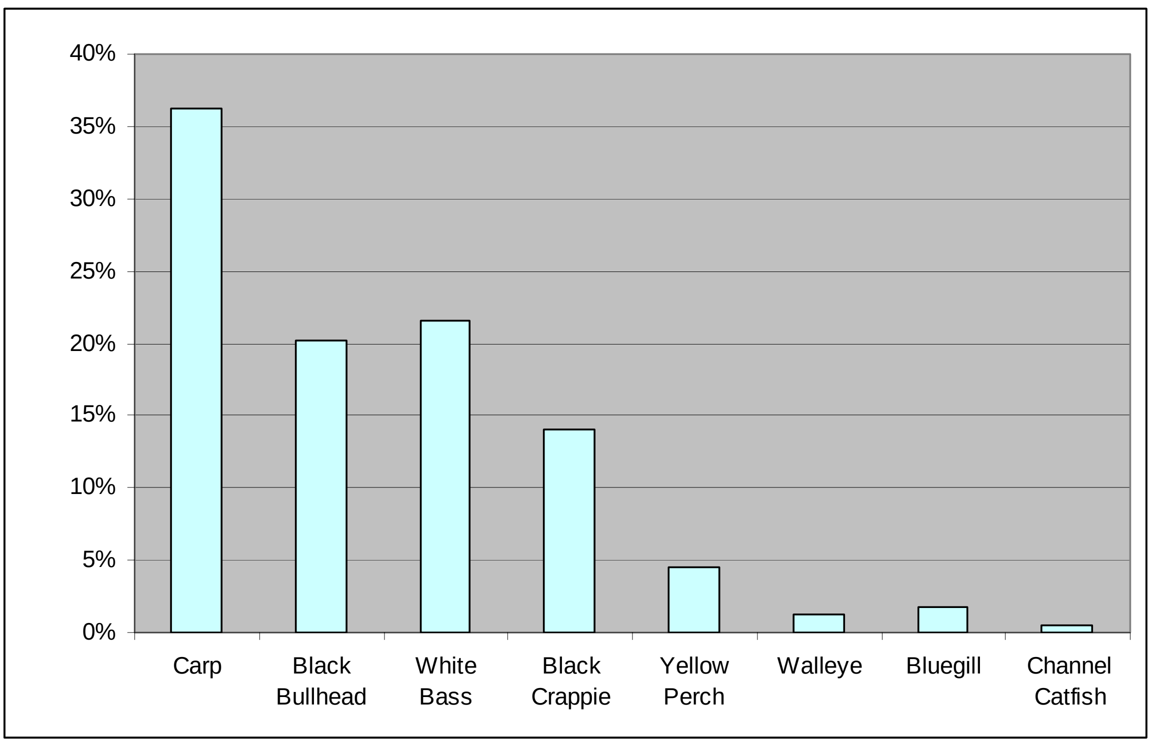
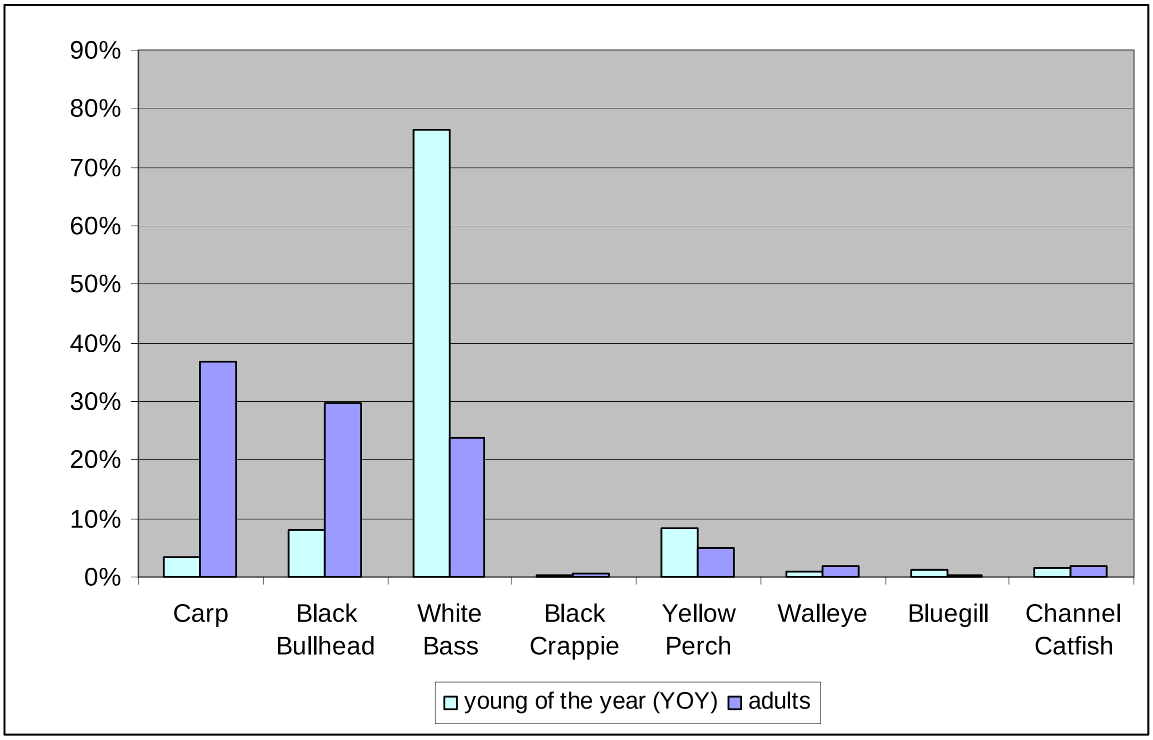


Figure 4 shows relative percent of young-of-the-year versus adult fish in Utah Lake. Average trawl rates for young-of-the-year and adult fish species in Utah Lake also identify the predominance of carp, white bass, and black bullhead, although the trawling gear utilized selectively emphasizes the capture of young-of-the-year white bass and adult carp. Adult carp captured using this technique represent 36.7% of the population, adult white bass represent 23.8% of the population and black bullhead represent 29.8% of the population as averaged from 1995 to 1999.

Figure 4: Relative Percent Population Based on Average Trawl Rates for Common Young-of-the-Year and Adult Fish Species in Utah Lake, 1995 through 2000



7.0 SEASONALITY AND TREND ASSESSMENT

This section provides a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends and seasonality. If any trends are used in the future, further evaluation will be completed.

7.1 FLOW

Figure 5 shows the seasonal variation of discharge into Utah Lake from the 2 major tributaries, namely the Provo and Spanish Fork Rivers. The figure also shows seasonal variations of discharge out of Utah Lake in the Jordan River at the outlet and also down stream at the Narrows.

These monthly values are based on measured and/or correlated flows for at least 20 years. The 2 inflow-rivers have higher discharges in the spring and drop off significantly in the summer, which reflect the seasonal pattern of the majority of the inflow streams. The controlled outflow peaks slightly later in the early summer.

Figure 6 shows the monthly total inflow to Utah Lake. The graph closely resembles the variation of the main tributary inflows.

Figure 5: Average Monthly Discharge – Significant Tributaries

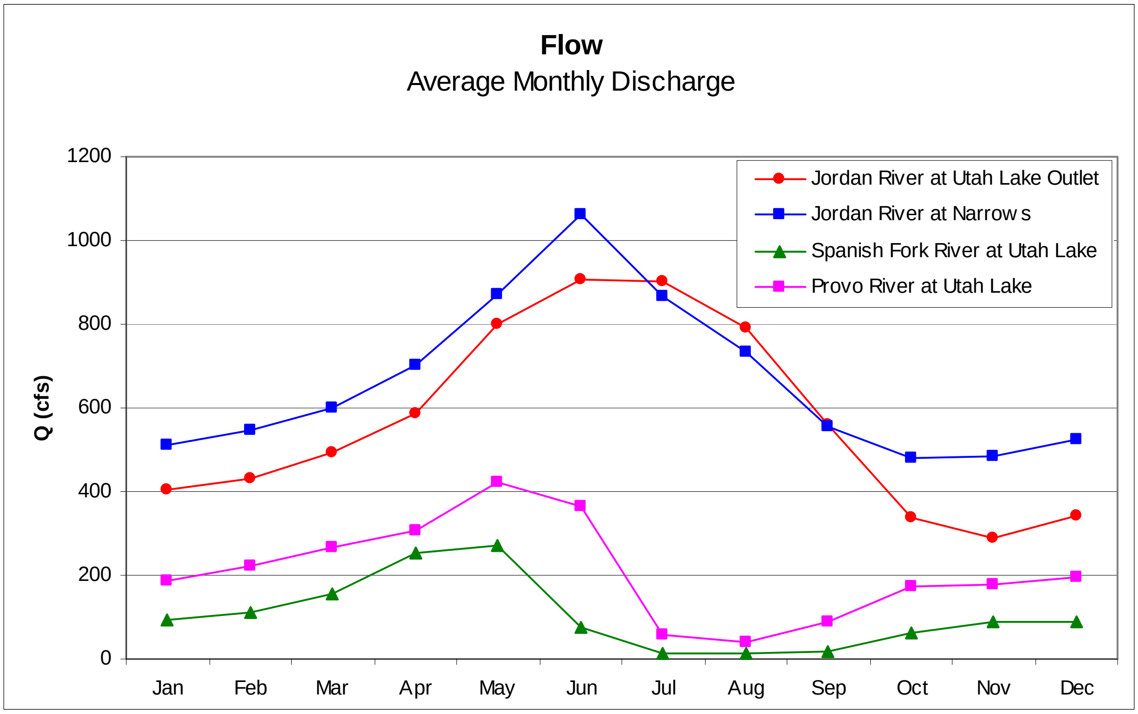
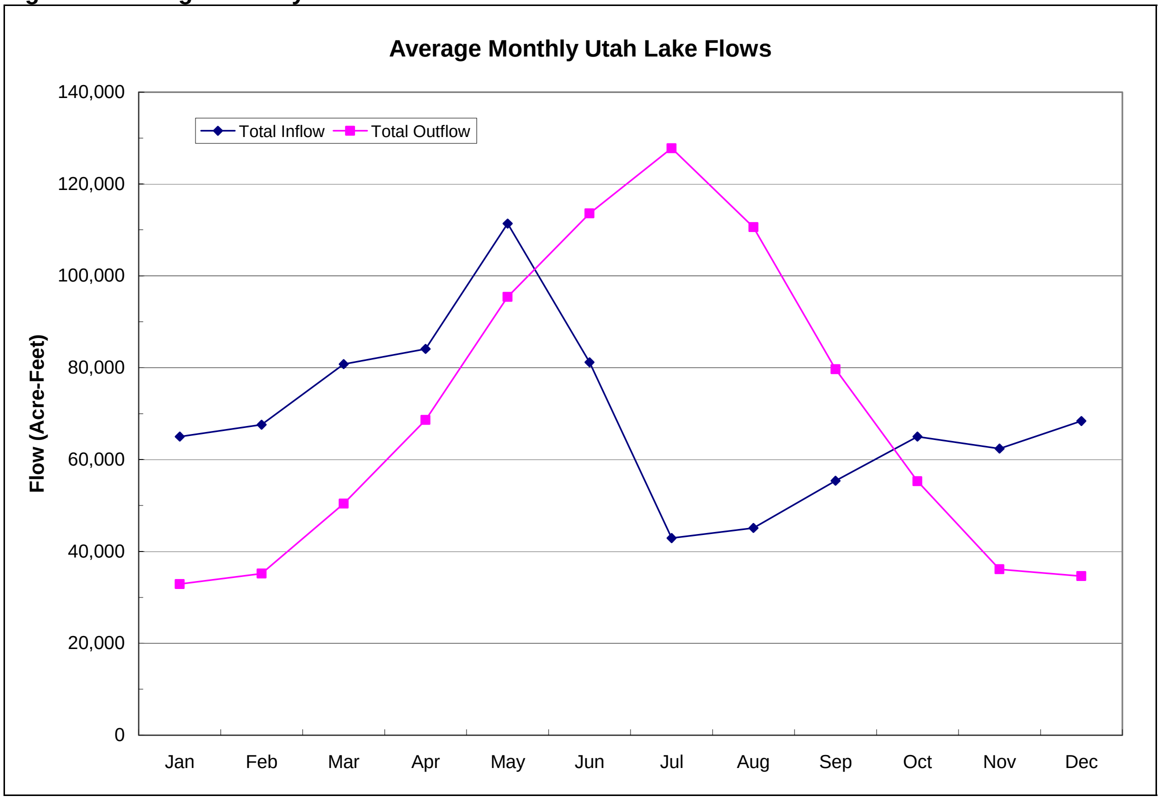


Figure 6: Average Monthly Utah Lake Flows



7.2 Inorganic Data

The parameters included in the inorganic data seasonality discussion include: Stream Total Dissolved Solids (TDS), Specific Conductivity, both Total Phosphorus (TP) and Dissolved Total Phosphorus (DTP), Nitrogen, Bicarbonate, Calcium, Chloride, Magnesium, Sodium, Total Suspended Solids (TSS) and Sulfate. The parameters are given for key Utah Lake tributaries, including WWTPs, for Utah Lake outflows, and for the lake itself. The data presented are generally monthly values averaged from at least 5 measurements. The results of the seasonality assessment analysis are included as Appendix E.

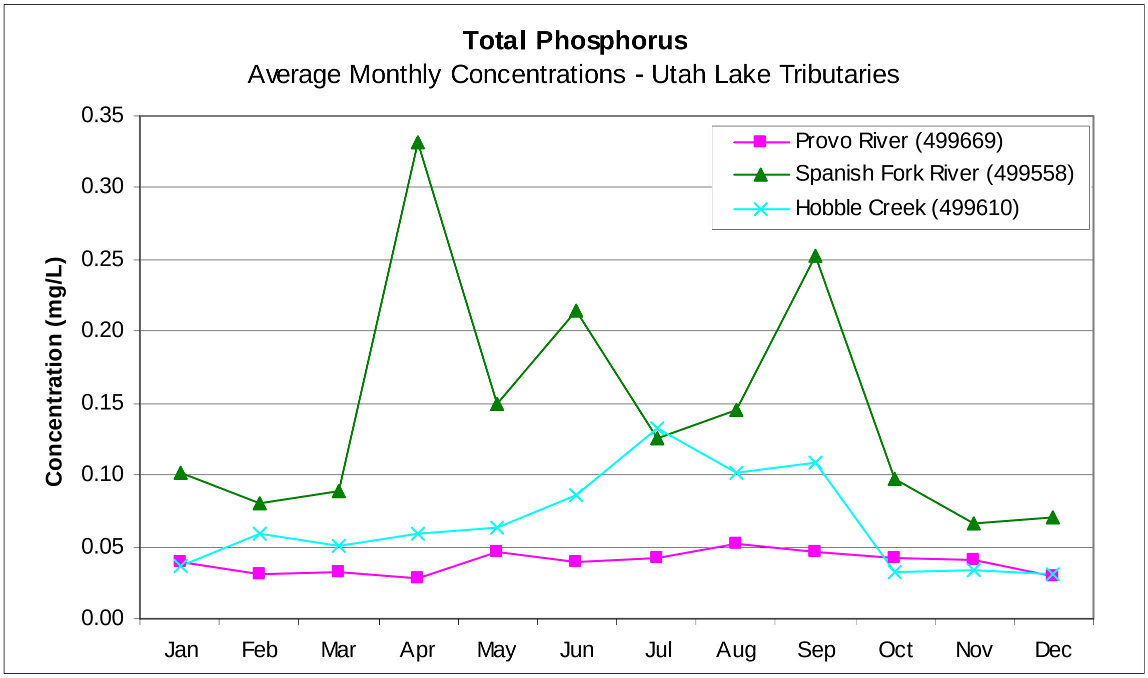
7.2.1 Total Phosphorus

The seasonality of phosphorus is typically influenced by changes in temperature and precipitation. This may be caused by increased sediment in runoff during spring and summer.

7.2.1.1 Significant Inflows

Figure 7 shows the average monthly concentration of total phosphorus in the three most significant inflows into Utah Lake; the Provo River, the Spanish Fork River, and Hobble Creek.

Figure 7: Total Phosphorus Average Concentrations – Significant Inflows



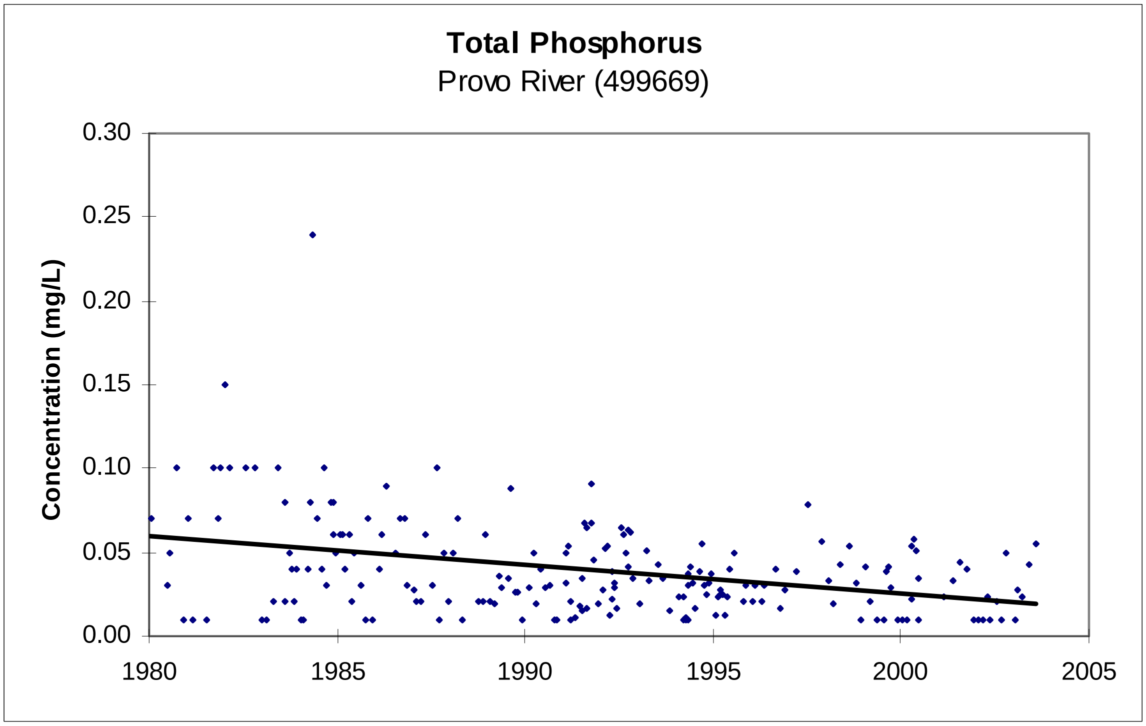
Seasonal changes in the concentration of total phosphorus range from slight in the Provo River, to strong in the Spanish Fork River. In the Spanish Fork River, average monthly concentrations of TP are greatest from April to September, with an average concentration above 0.30 mg/L and peak values occurring in April. In Hobble Creek, the average monthly concentration of TP peaks in July and remains elevated above 0.01 mg/L through September. Concentrations of TP in the Provo River remain relatively constant at approximately 0.04 mg/L throughout the year. During the spring and summer months the average concentration of TP approaches the pollution indicator of 0.05 mg/L for streams.

<u>Provo River</u>

The Provo River, which is the largest inflow to Utah Lake, rarely exceeds the pollution indicator value for TP in streams. Figure 8 shows the historical profile of TP in the Provo River at STORET station 499669.

TP in the Provo River has decreased steadily over the past two decades, from an average concentration of nearly 0.08 mg/L to approximately 0.04 mg/L. The most rapid decrease took place from 1985 to the early 1990’s. Since 1995 the average annual concentration has been relatively constant.

Figure 8: Total Phosphorus Historical Data – Provo River



Spanish Fork River

The Spanish Fork River has the highest average monthly total phosphorus concentration of all of the major inflows to Utah Lake. It is the second largest inflow to Utah Lake, contributing nearly 15% of the total flow.

A historical summary of TP in the Spanish Fork River (STORET station 499558) is shown in Figure 9. Since 1981 the average concentration of TP has decreased from approximately 0.3 mg/L to nearly 0.1 mg/L. TP levels appear to have increased in 1983 and, to a lesser extent, from 1996 to 1997.

Hobble Creek

Hobble Creek is the smallest of the major inflows to Utah Lake, accounting for about 4% of the total flow. Figure 10 shows historical TP data at this location (STORET station 499610).

The historical profile of Hobble Creek is not as complete as it is for the Provo River or Spanish Fork River. Average concentrations have decreased from around 0.16 mg/L in 1983 - 84 to approximately 0.08 mg/L. In 1992 TP concentrations spiked. A gap in sampling occurs from 1996 to 1999.

WWTPs

WWTPs were not sampled sufficiently to assess any seasonal variation in total phosphorus concentration, although no variation would be expected. Sampling for total phosphorus typically occurred at all seven WWTPs in from 1991 to 1993 and from 1999 to 2003. No samples have been recorded between 1993 and 1999. Figure 11 shows average concentrations for these two periods at each treatment plant.

WWTP effluent TP levels have decreased at all seven Utah County facilities. At the Orem and Springville treatment plants, the 1999 to 2003 average concentrations are less than half what they were a decade earlier. Significant reductions are also observed at the Provo, Payson, Salem and Timpanogos WWTPs.

Figure 9: Total Phosphorus Historical Data – Spanish Fork River

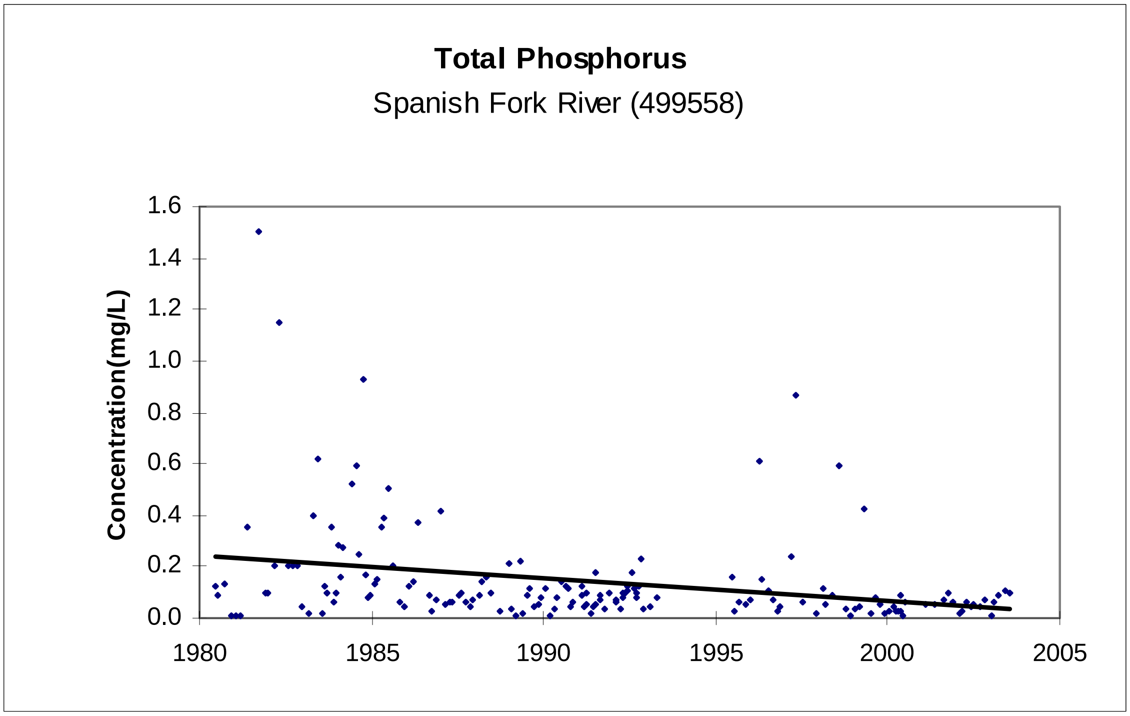


Figure 10: Total Phosphorus Historical Data – Hobble Creek

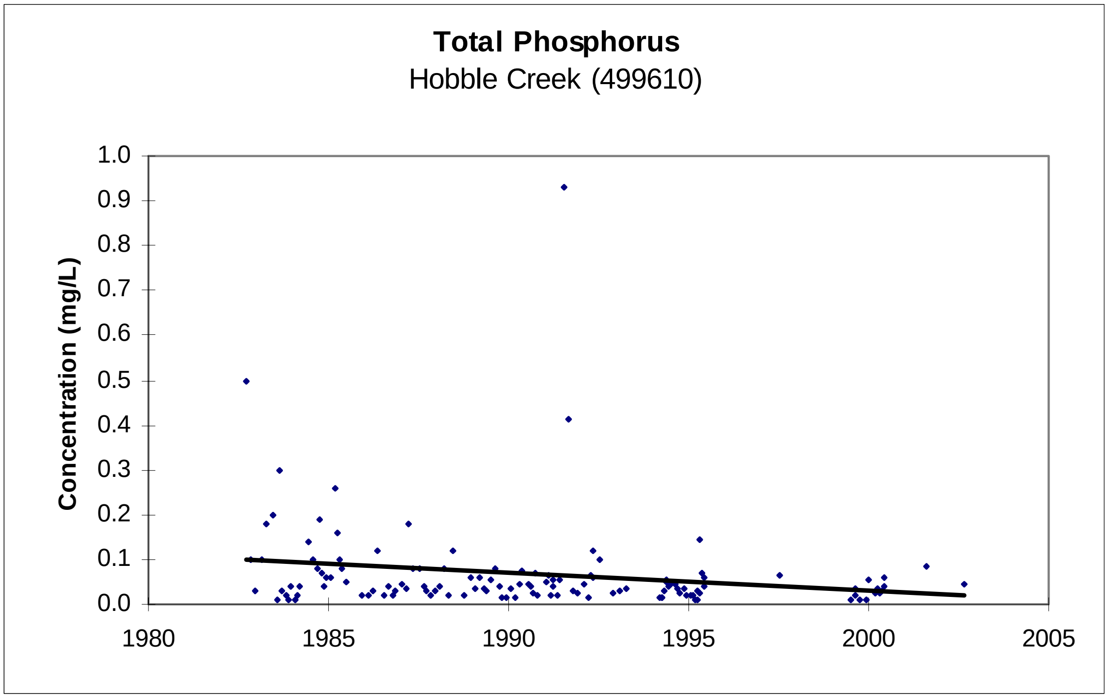
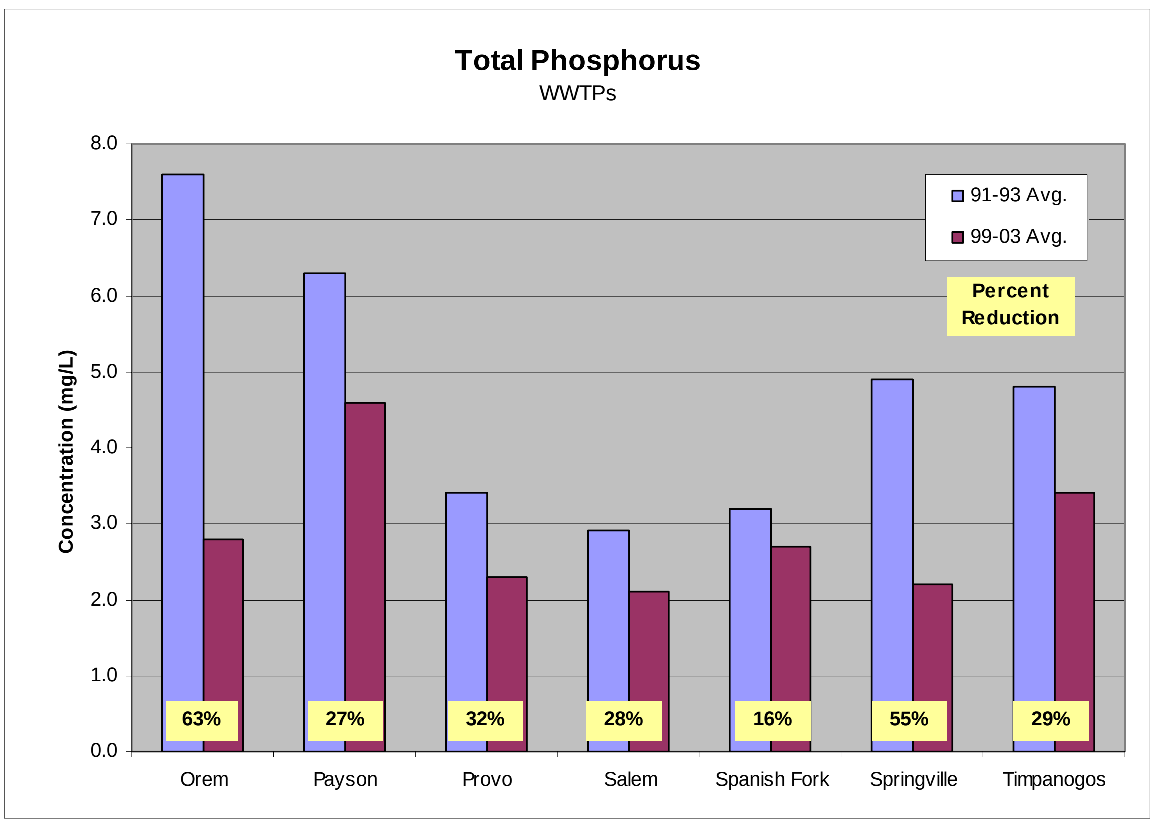


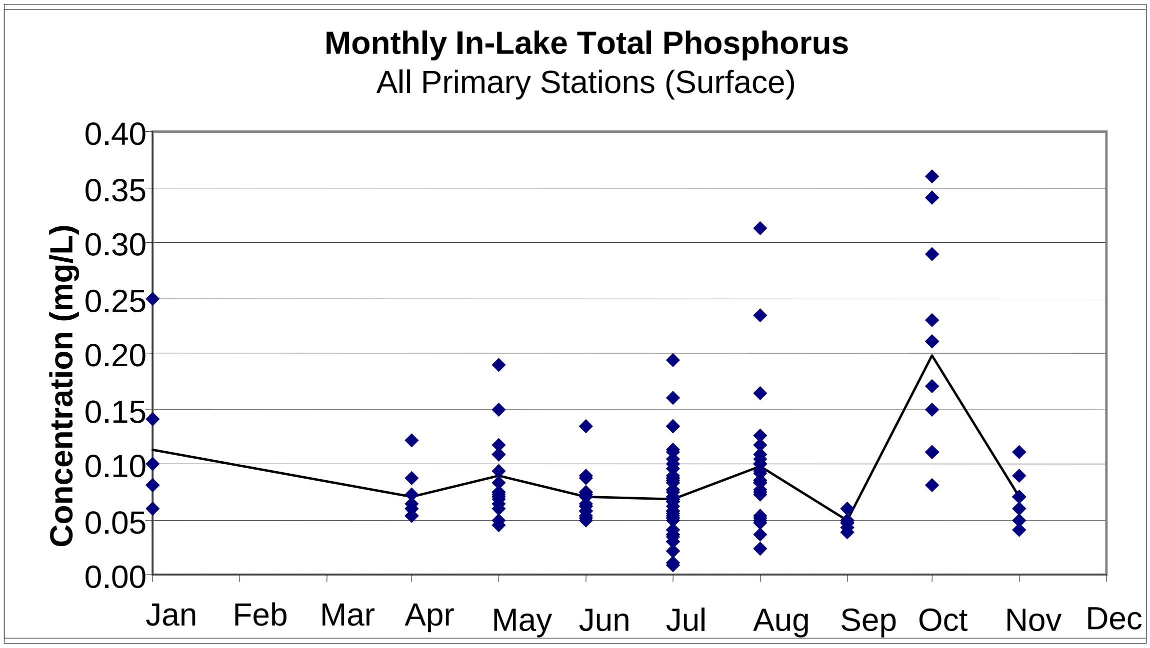
Figure 11: Total Phosphorus Average Concentrations – WWTPs



7.2.1.2 In-Lake

Utah Lake receives water from several significant inflows. The relatively shallow depth of Utah Lake allows wind and turbulence to stir up bottom sediments and re-suspend phosphorus and other materials. As a result, TP is consistently high in the lake. Unfortunately, Utah Lake has not been sampled consistently at all stations for all months. July and August are typically well characterized, but data for the other months, particularly December, February, and March, are few or non-existent. In order to accrue enough data to facilitate a statistical analysis and determine seasonal trends the data from all primary lake stations were combined. All available monthly in-lake surface TP values for the primary lake stations during the period of study are presented in Figure 12. (See Table 4 for primary lake stations).

Figure 12: Total Phosphorus Monthly Historical Data – All Primary Lake Stations



Total phosphorus increases from July through October; although September values are consistently low. A spike in the concentration of TP occurs in January. However, because of the lack of data during the winter months it is unclear if this is part of a trend. Seasonal factors, such as temperature and precipitation, are only a few of several variables that potentially contribute to the changes in monthly TP. Fluctuations in lake surface elevation, wind events, and human activity around the lake also contribute to variations in TP levels.

A historical profile of TP in Utah Lake (surface) is presented in Figure 13. Historically, TP levels in Utah Lake have been relatively high. Values above 0.1 mg/L, twice the state water quality pollution indicator value, are not uncommon. Infrequent sampling since 1991 prevents detailed assessment of long-term in-lake TP trends; however conditions appear to improve.

7.2.1.3 Outflow

The Jordan River is the only major outflow from Utah Lake. The river, which extends from Utah Lake to the Great Salt Lake, is protected for domestic purposes, recreation, wildlife, and agriculture. Several monitoring stations along the entire length of the river have provided a profusion of water quality data. Figure 14 shows the average monthly concentration of TP in the Jordan River at Bluffdale Road (499460), Narrows (499472), and Utah Lake Outlet (499479). Station 499479 is the farthest upstream, followed by 499472 and 499460 respectively.

Average monthly concentrations of TP exceed the state pollution indicator value of 0.05 mg/L at each location for every month except December at the Utah Lake outlet. A strong seasonal trend is observed as TP levels increase rapidly in the summer and then plummet in the fall. Concentrations of TP tend to decrease as the distance downstream increases, particularly during the spring and summer months of April through September. The apparent reduction in TP concentrations may be attributed to removal (settling, uptake, etc.) or dilution from stream inputs.

Figure 13: Total Phosphorus Historical Data – All Primary Lake Stations

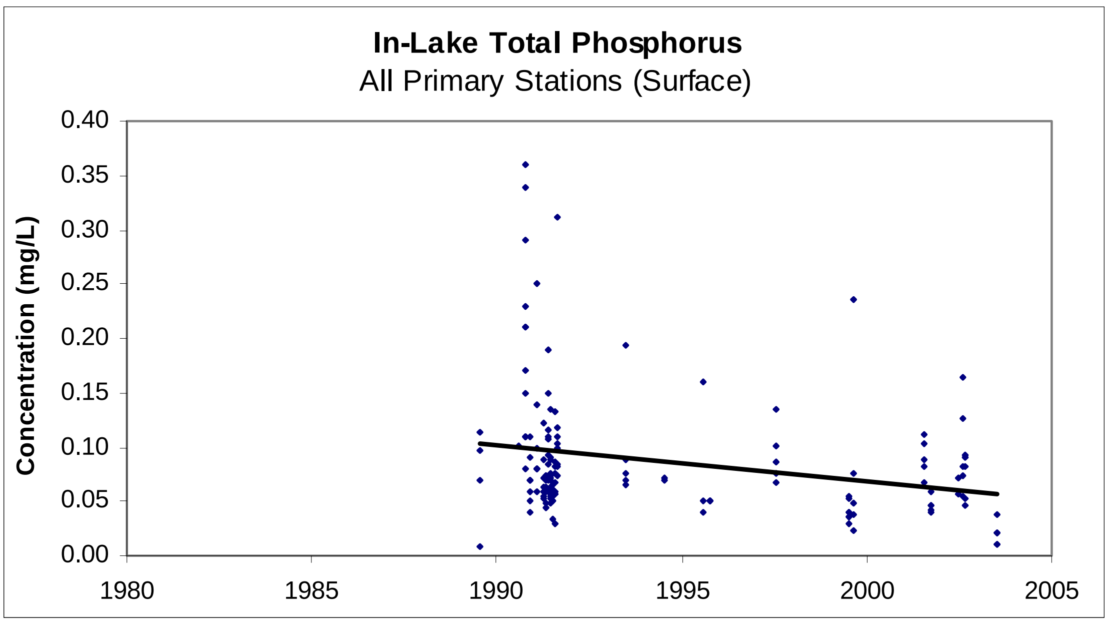
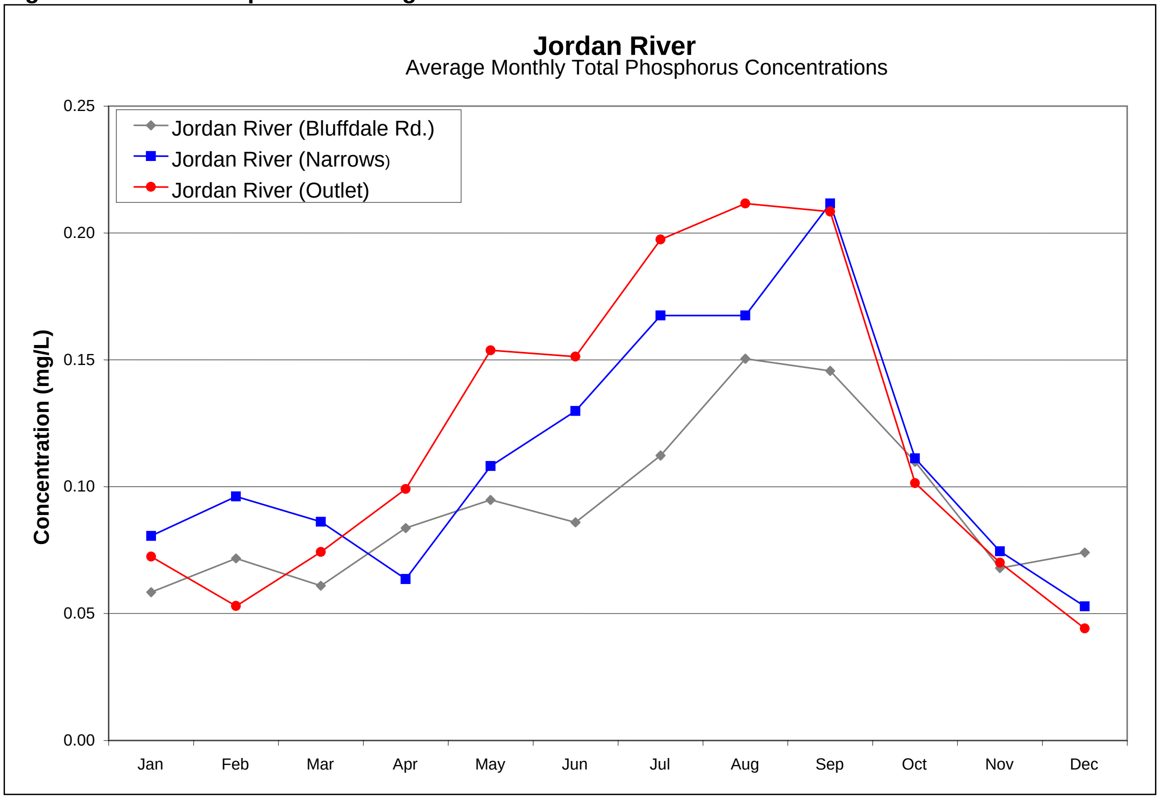


Figure 14: Total Phosphorus Average Concentrations – Jordan River



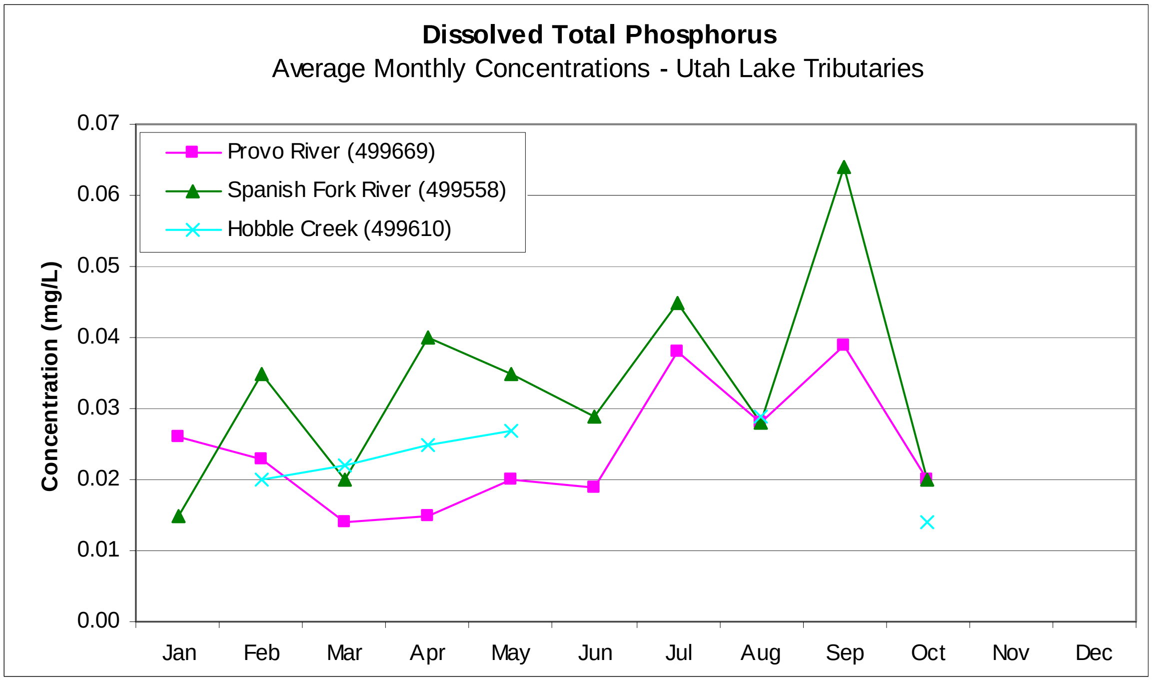
7.2.2 Dissolved Total Phosphorus

Dissolved total phosphorus (DTP) is defined as both the soluble and insoluble phosphorus portions having a diameter smaller than 0.7 µm. Since it excludes large suspended particles, it is generally a more accurate estimate of the bio-available fraction of phosphorus in an aqueous system. Sources of DTP are similar to TP and include sediment loading from streams and reservoirs, chemical/biological processes, and human activities. However, the relative contribution from each source is different from that of TP. DTP is only weakly affected by seasonal changes.

7.2.2.1 Significant Inflows

Figure 15 shows the average monthly concentration of dissolved total phosphorus in the three most significant inflows into Utah Lake; the Provo River, the Spanish Fork River, and Hobble Creek.

Figure 15: Dissolved Total Phosphorus Average Concentrations – Significant Inflows

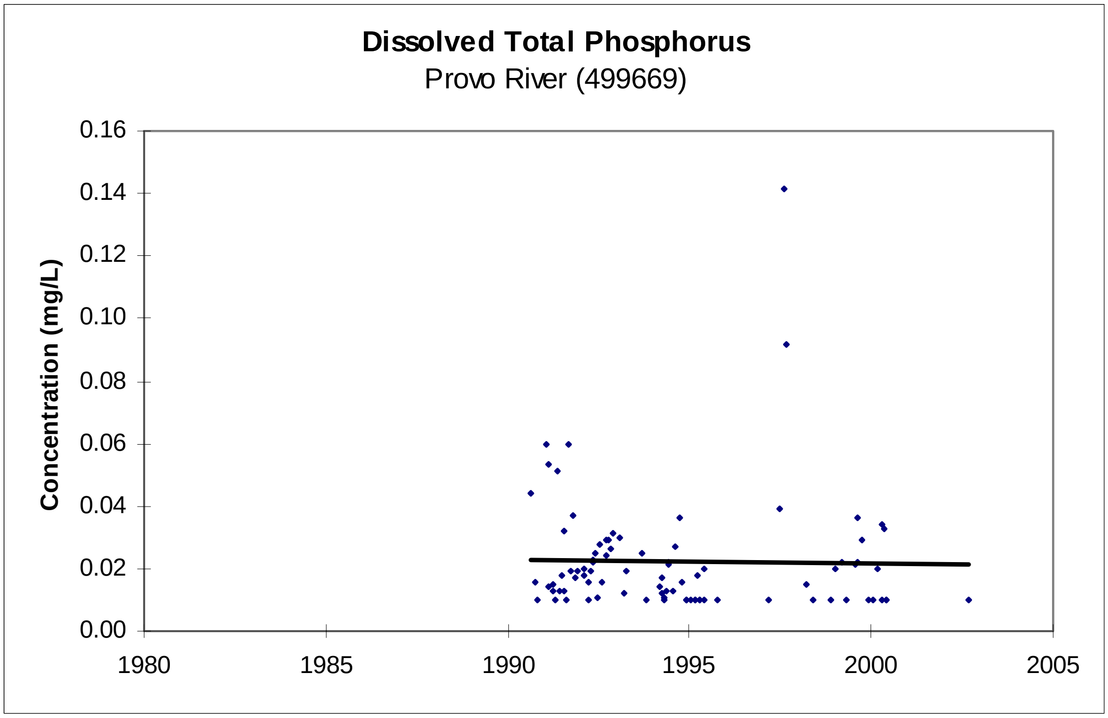


Data for the months of November and December are not available at the following stations: Provo River (499669), Spanish Fork River (499558), and Hobble Creek (499610). Although concentrations of DTP are slightly higher during the summer months, no clear seasonal trend can be determined from the data presented in Figure 15. DTP levels in the Spanish Fork River tend to be higher than the other major inflows, and exceed the state pollution indicator values in September by more than 0.01 mg/L. High concentrations in late summer may be a result of anoxic conditions in Strawberry Reservoir. The DTP concentrations in Provo River are higher in January and July through September. This seasonality trend is directly related to anoxic conditions upstream in Deer Creek Reservoir. The limited data available for Hobble Creek shows a gradual increase in spring time concentrations.

Provo River

Historical DTP data for the Provo River are presented in Figure 16. A very slight decrease in the concentration of DTP may be observed since data collection began in 1991. However, it is unclear if this is any indication of a long term trend. Relatively higher DTP concentrations occur in 1997.

Figure 16: Dissolved Total Phosphorus Historical Data – Provo River



<u>Spanish Fork River</u>

A historical profile of DTP data in the Spanish Fork River, station 499558, is presented in Figure 17. DTP concentrations in the Spanish Fork River have become increasingly scattered since data collection began in the early 1990's. This trend is opposite of what was observed with TP.

<u>Hobble Creek</u>

Figure 18 shows historical TP data at Hobble Creek (STORET station 499610). No significant changes in the concentration of DTP have occurred since sampling began at Hobble Creek in 1991.

Figure 17: Dissolved Total Phosphorus Historical Data – Spanish Fork River

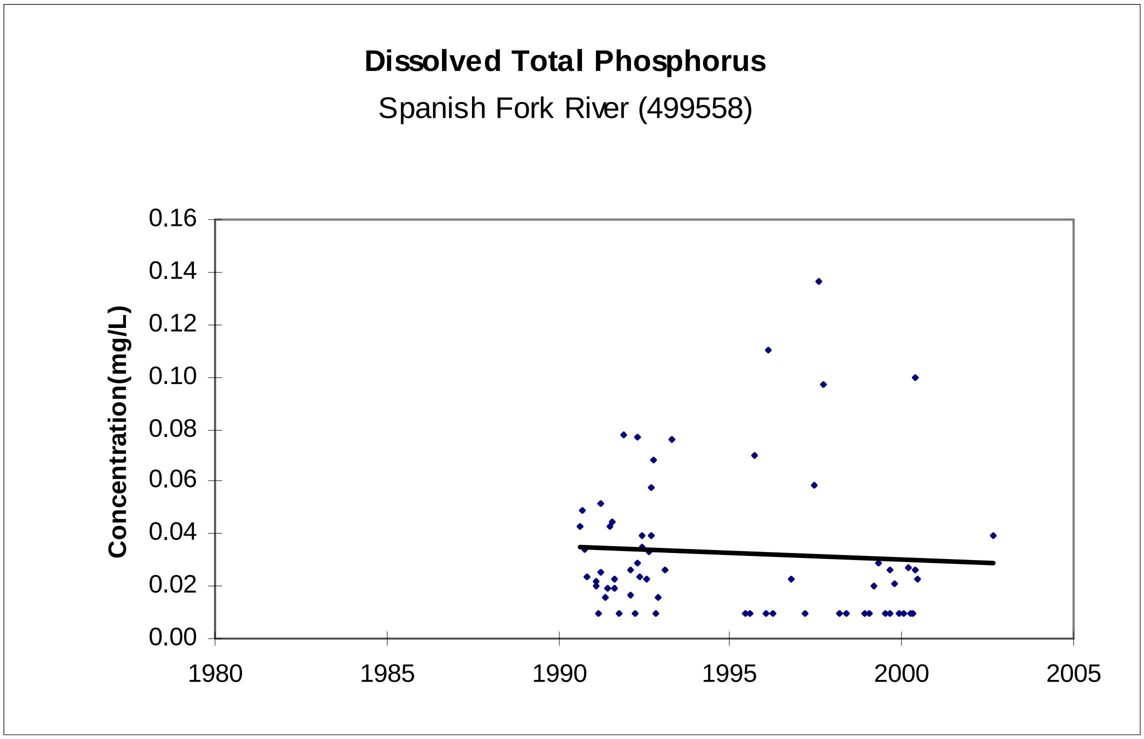
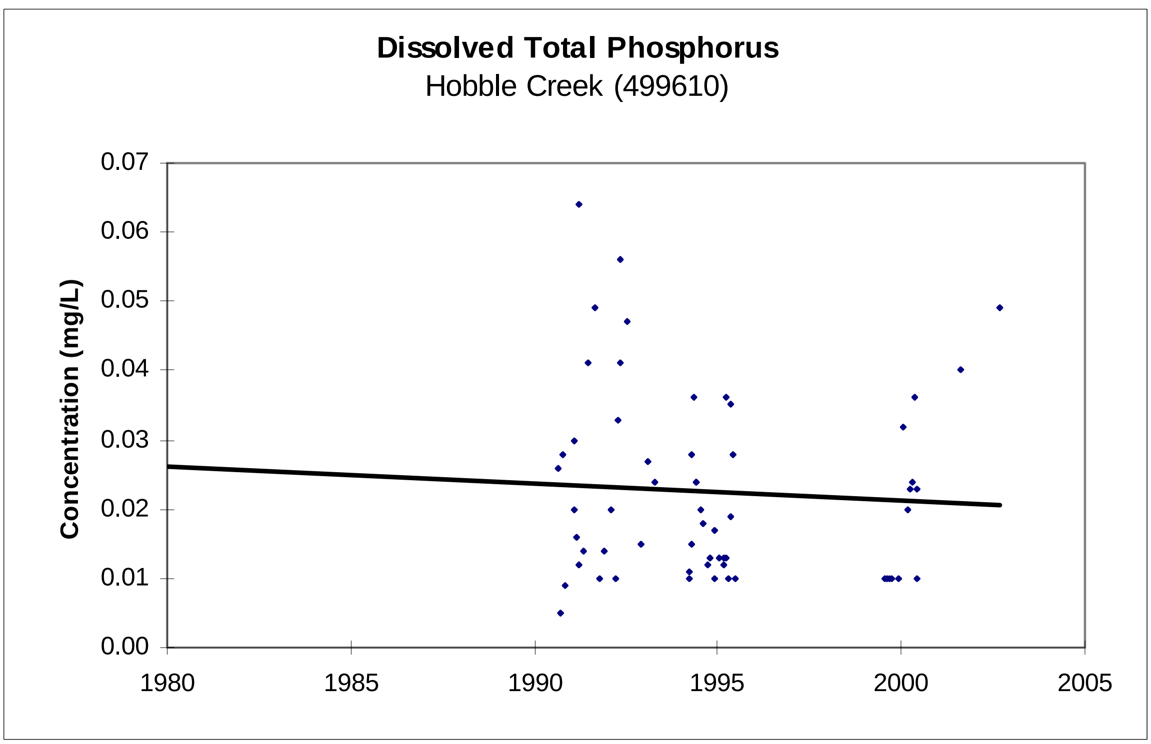


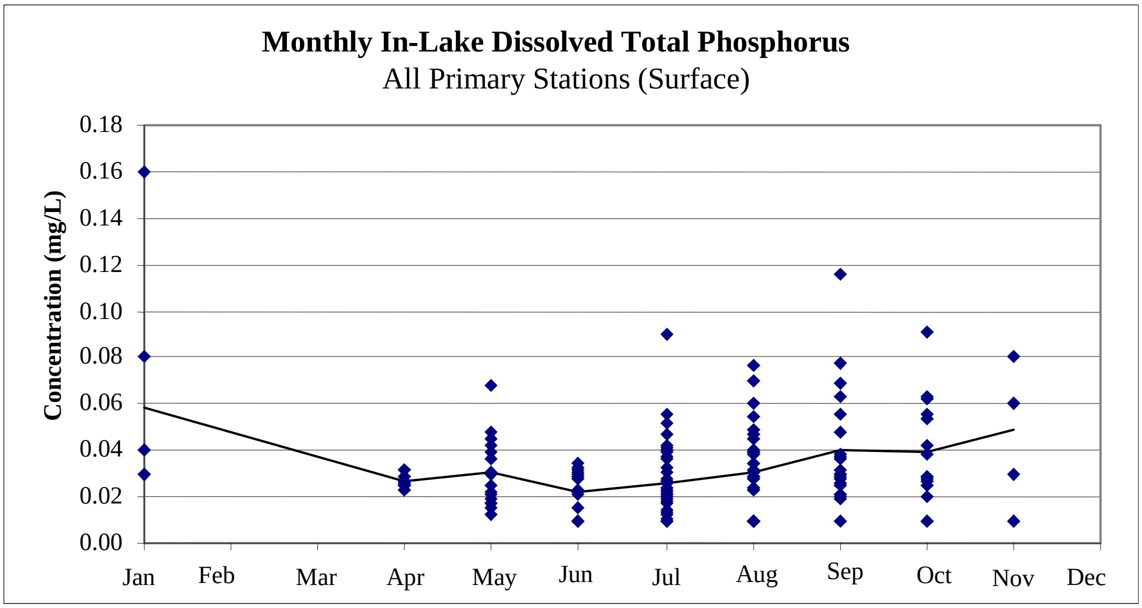
Figure 18: Dissolved Total Phosphorus Historical Data – Hobble Creek



7.2.2.2 In-Lake

Utah Lake receives water from several significant inflows. The relatively shallow depth of Utah Lake allows wind and turbulence to stir up bottom sediments and re-suspend phosphorus and other materials. Although generally high, DTP is not as susceptible to rapid changes in concentration as TP. Unfortunately, Utah Lake has not been sampled consistently at all stations for all months. July and August are typically well characterized, but data for the other months, particularly December, February, and March, are few or non-existent. In order to accrue enough data to facilitate a statistical analysis and determine seasonal trends the data from all primary lake stations had to be combined. (See Table 4 for primary lake stations). Monthly in-lake DTP values for the primary lake stations during the period of study are presented in Figure 19.

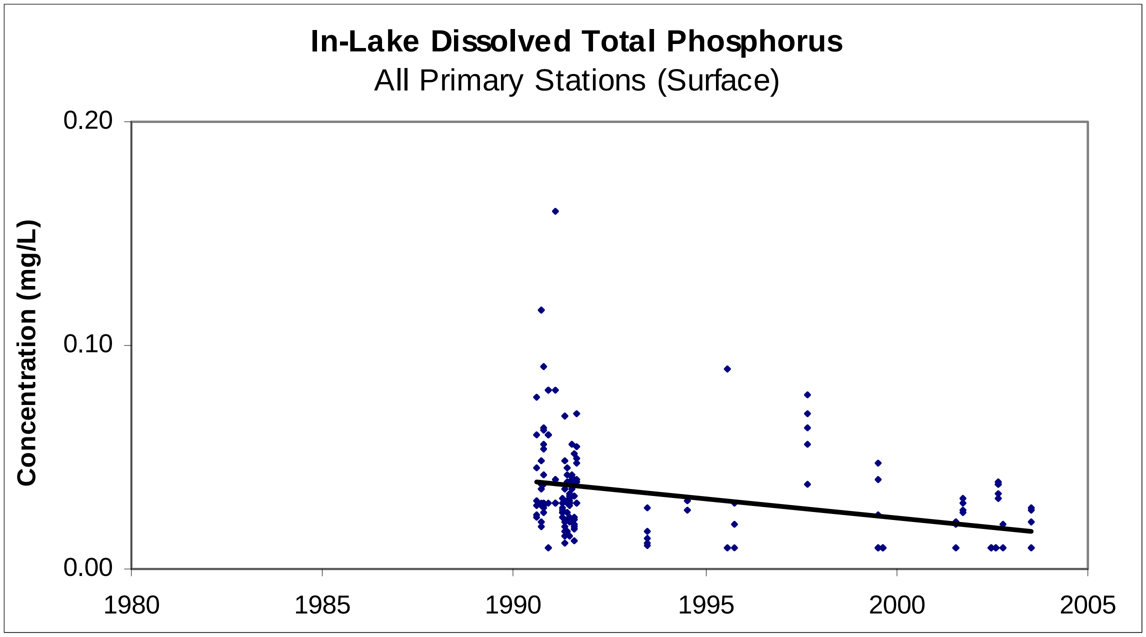
Figure 19: Dissolved Total Phosphorus Monthly Historical Data – All Primary Lake Stations



It appears that DTP may increase slightly from July to January. The seasonality of DTP from January to August is similar to what occurs with TP. The concentration of DTP frequently exceeds the state water quality pollution indicator value. Seasonal factors, such as temperature and precipitation, are only a few of several variables that potentially contribute to the changes in monthly DTP. As with TP, fluctuations in lake surface elevation, wind events, and human activity around the lake also contribute to variations in DTP levels.

Historical DTP concentrations at the surface of primary Utah Lake stations are presented in Figure 20. (See Table 4 for primary lake stations). A slight decrease in the concentration of DTP has occurred since sampling began in 1990; however, infrequent sampling prevents an accurate assessment of historical in-lake DTP trends.

Figure 20: Dissolved Total Phosphorus Historical Data – All Primary Lake Stations

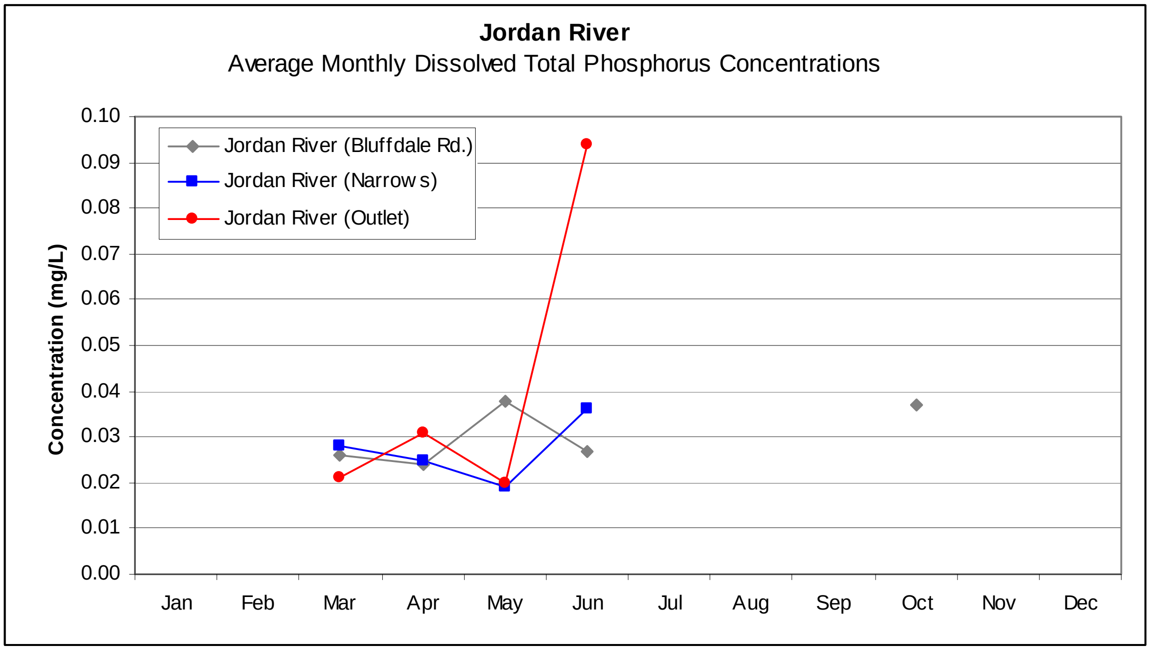


7.2.2.3 Outflow

The only major outflow from Utah Lake is the Jordan River. The river, which extends from Utah Lake to the Great Salt Lake, is protected for domestic purposes, recreation, and agriculture. The river is well characterized and data are available throughout its entire length. Figure 21 shows the average monthly concentration of dissolved total phosphorus in the Jordan River at Bluffdale Road (499460), Narrows (499472), and Utah Lake Outlet (499479). Station 499479 is the farthest upstream, followed by 499472, and 499460 respectively.

No seasonal trend can be determined from the data in Figure 21. DTP concentrations at all three Jordan River stations exceed the state pollution indicator values sporadically throughout the year, at times reaching levels above 0.10 mg/L. There is no clear pattern that would indicate a concentration increase or decrease in the Jordan River downstream of the Utah Lake outlet.

Figure 21: Dissolved Total Phosphorus Average Concentrations – Jordan River.



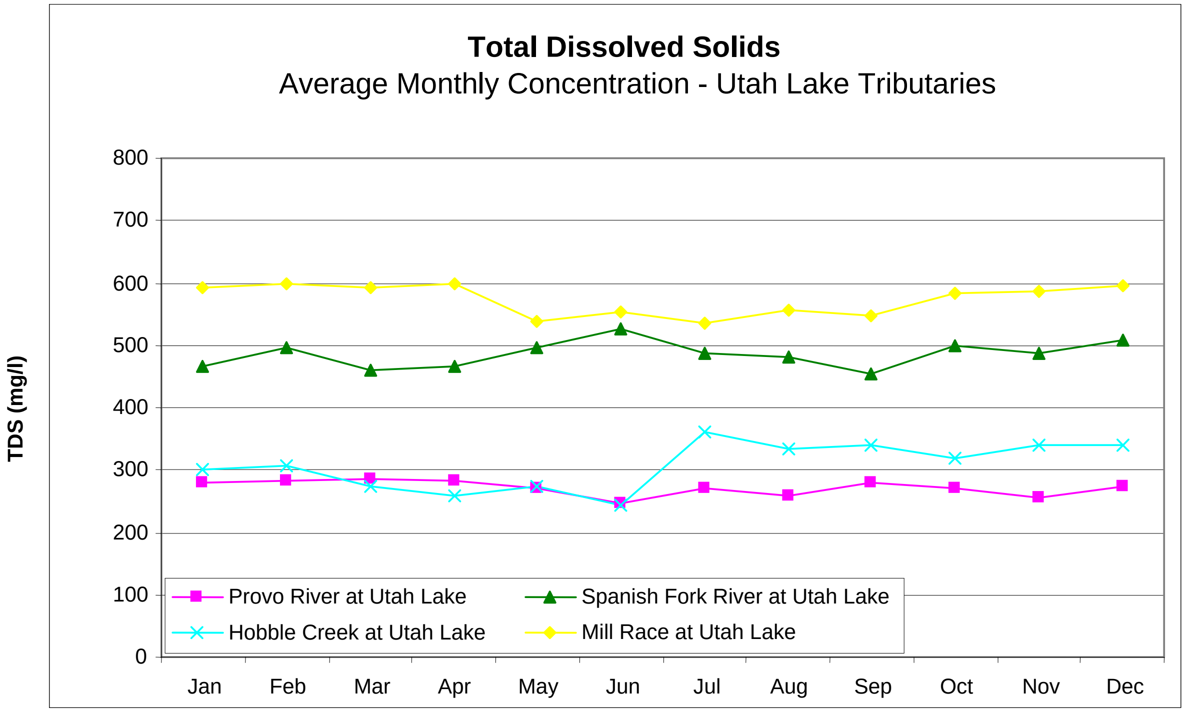
7.2.3 Total Dissolved Solids

7.2.3.1 Significant Inflows

The monthly Total Dissolved Solids (TDS) concentrations in 4 of the major Utah Lake tributaries are shown on Figure 22. These TDS values are the averages of at least 5 monthly measurements.

While there is not significant variation in the monthly averages, there is some fluctuation. The Provo River and Mill Race have slightly lower concentrations of TDS during the summer than in the winter. Conversely, the Spanish Fork River and Hobble Creek have slightly higher concentrations of TDS during the summer and fall.

Figure 22: Total Dissolved Solids Average Concentrations – Major Tributaries



<u>Provo River</u>

A historical summary of TDS concentrations in the Provo River is shown in Figure 23. TDS concentrations have remained relatively constant since 1980.

Historical monthly TDS concentration data for Provo River are presented in Figure 24. TDS monthly seasonality shows only slight fluctuation throughout the year.

<u>Spanish Fork River</u>

A historical summary of TDS concentrations in the Spanish Fork River (STORET station 499558) is shown in Figure 25. Significantly higher TDS values were observed in 1980-1982, 1987, 1989-1990, 1992, and 2002. However, the average long term trend remains the same or slightly decreasing.

Historical monthly TDS concentration data are presented in Figure 26. The higher values observed in Figure 25 typically occurred between April and September.

<u>Hobble Creek</u>

A historical summary of TDS concentrations in Hobble Creek (STORET station 499610) is shown in Figure 27. A long term assessment is difficult because the lack of recent data; however, the current data show concentrations similar to historic values.

Historical monthly TDS concentration data are presented in Figure 28. Seasonality trends show higher concentrations in July.

Figure 23: Total Dissolved Solids Historical Data – Provo River

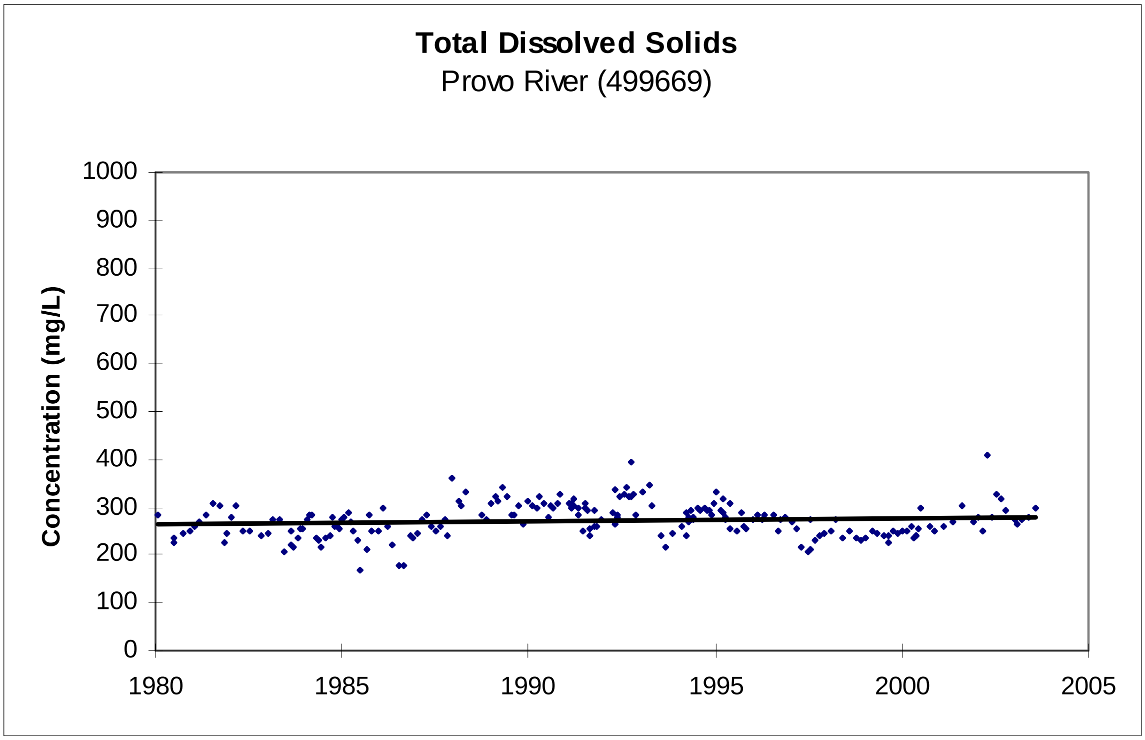


Figure 24: Total Dissolved Solids Monthly Historical Data – Provo River

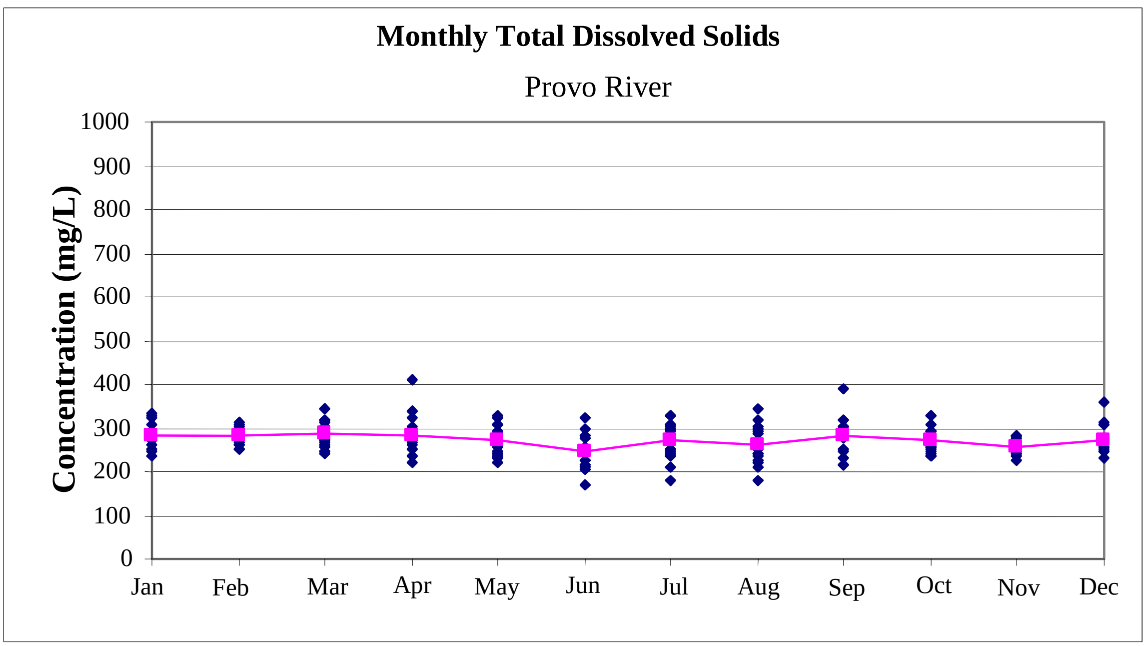


Figure 25: Total Dissolved Solids Historical Data – Spanish Fork River

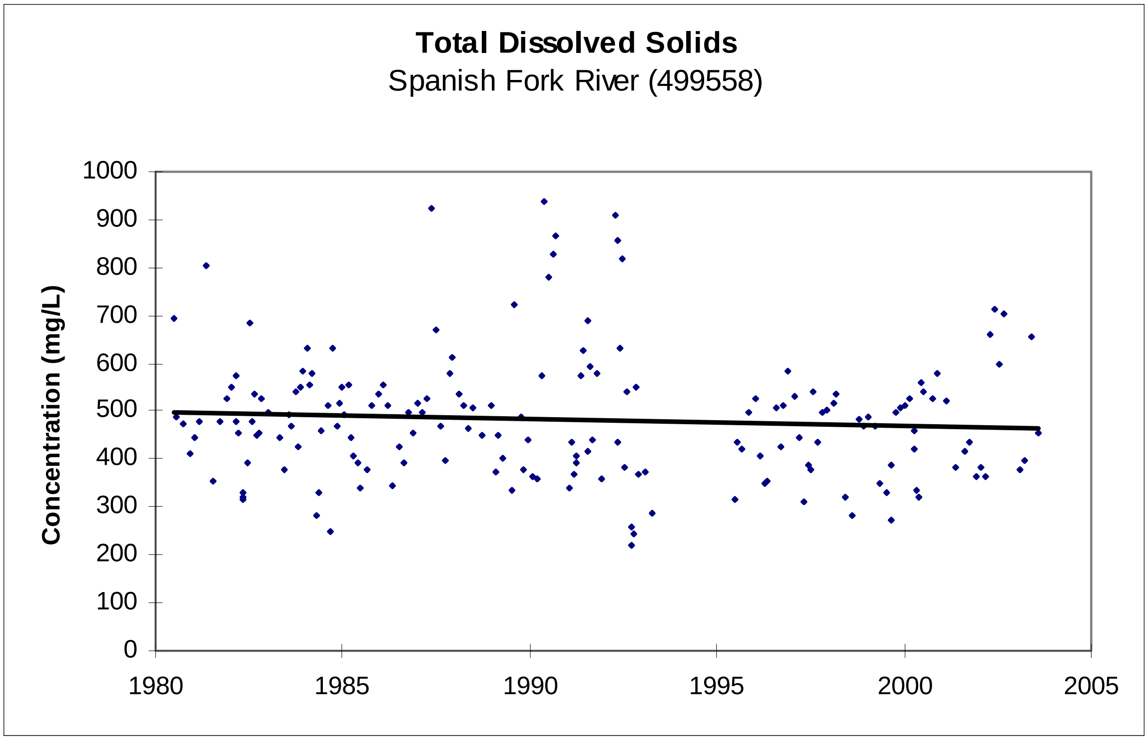


Figure 26: Total Dissolved Solids Monthly Historical Data – Spanish Fork River

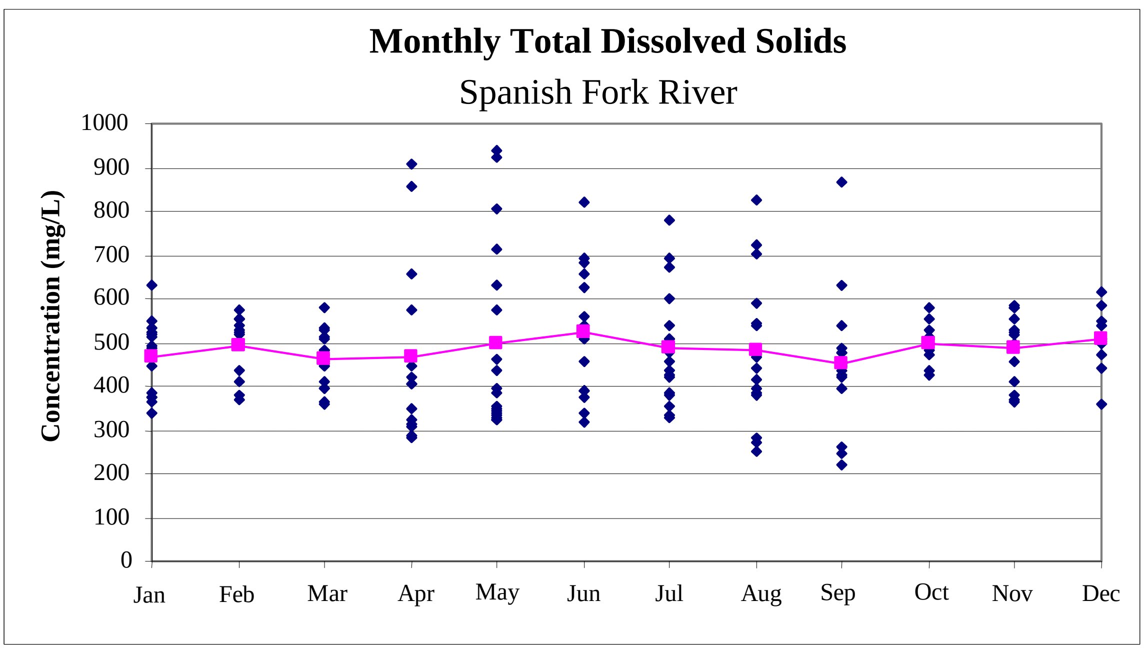


Figure 27: Total Dissolved Solids Historical Data – Hobble Creek

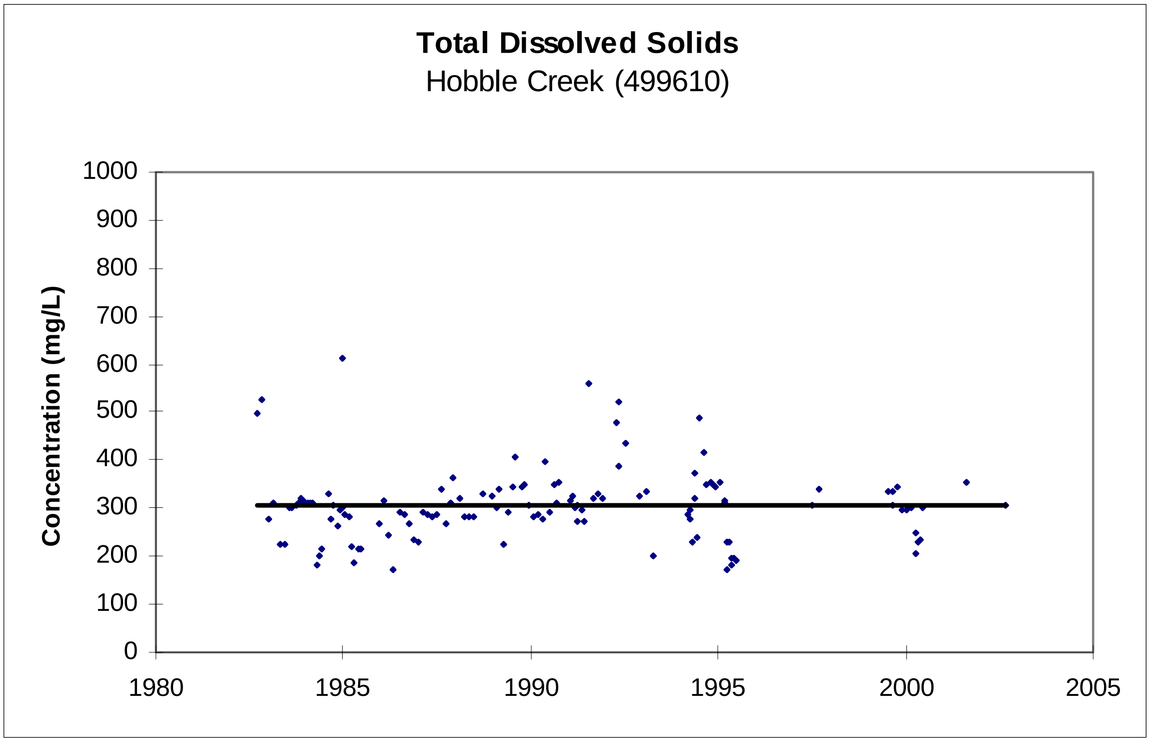
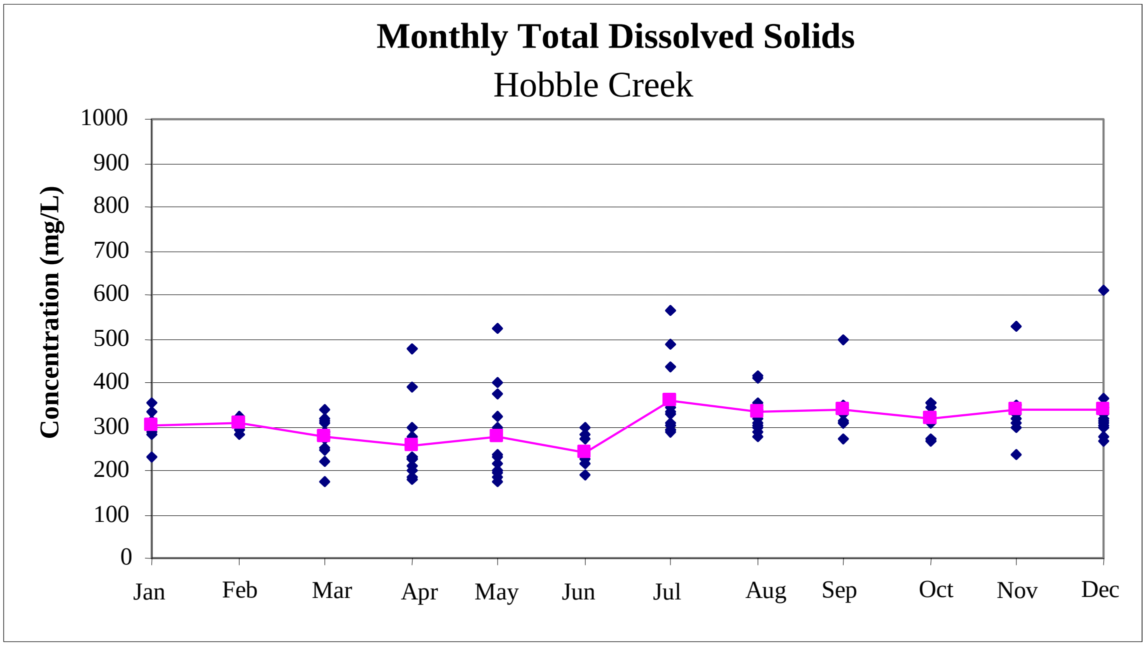


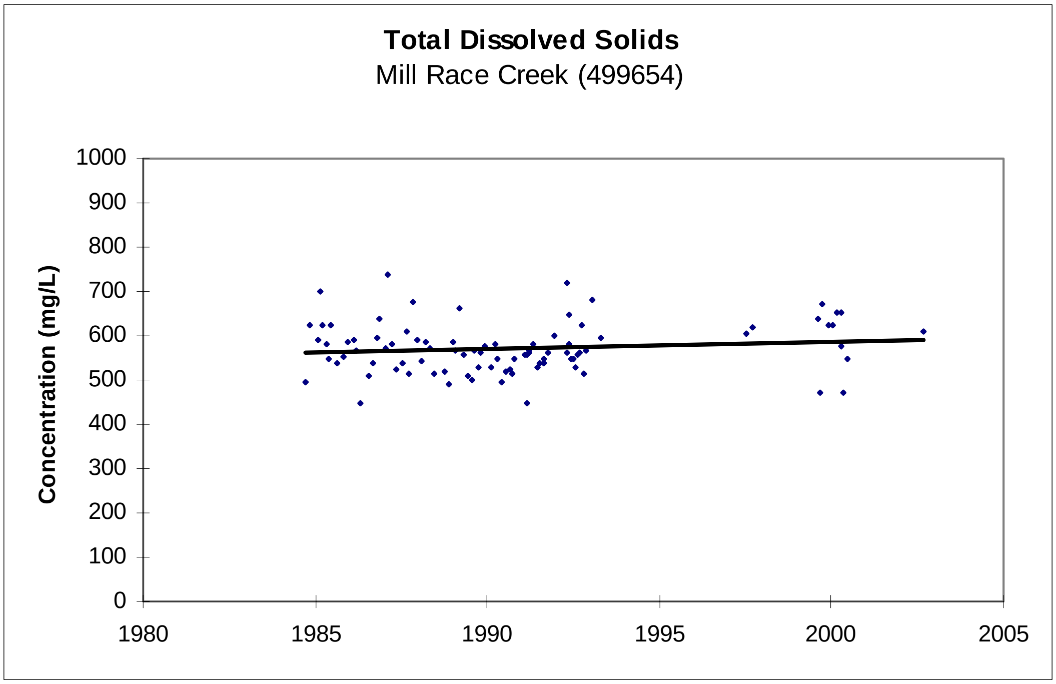
Figure 28: Total Dissolved Solids Monthly Historical Data – Hobble Creek



Mill Race Creek

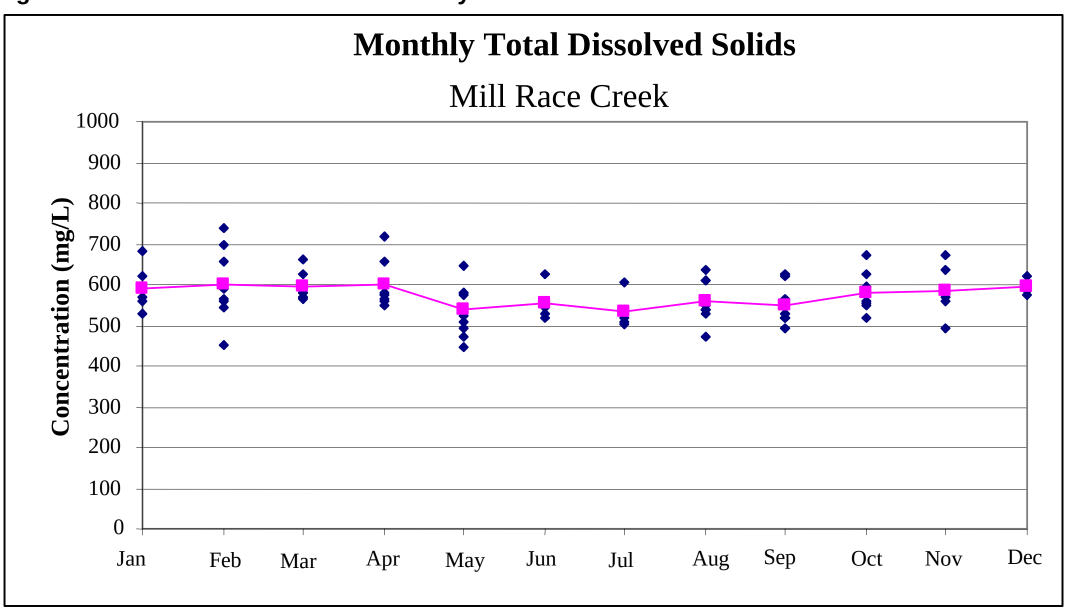
A historical summary of TDS concentrations in Mill Race Creek (STORET station 499654) is shown in Figure 29. A long term assessment is difficult because the lack of recent data. Mill Race Creek has the highest TDS concentrations of all the major inflows.

Figure 29: Total Dissolved Solids Historical Data – Mill Race Creek



Historical monthly TDS concentration data for Mill Race are presented in Figure 30.

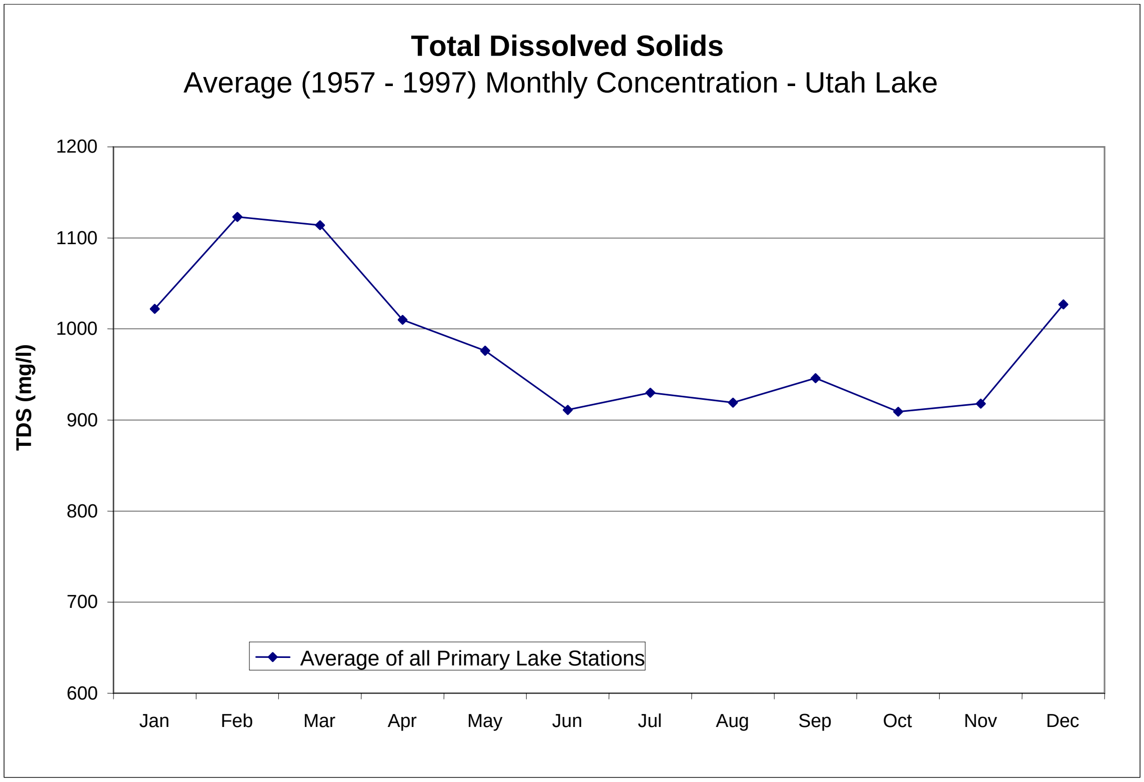
Figure 30: Total Dissolved Solids Monthly Historical Data – Mill Race Creek



7.2.3.2 In-Lake

Because Utah Lake was not sampled consistently throughout the year, the data for all primary lake stations was combined. (See Table 4 for primary lake stations). This approach allows for a statistical analysis of the data based on 5 or more data points. The long-term monthly averages of essentially all the TDS data taken in the lake for all primary lake stations are presented in Figure 31. Average in-lake TDS conditions are typically higher in February and March. However, as shown in Figure 22 and Figure 31, the tributary and in-lake average TDS concentrations are always below the TDS criteria for irrigation water (1200 mg/L).

Figure 31: Total Dissolved Solids Average Concentrations – All Primary Lake Stations



7.2.3.3 Outflow

The outlet TDS concentration of the Jordan River should approximately reflect the in-lake TDS concentration, at least the lake area near the outlet. In fact it does, as indicated on Figure 32, which shows the long-term monthly average compared to the Jordan River outflow concentrations. In every month except for December, the Jordan River outflow average TDS concentrations are below the TDS water quality standard for irrigation water (1200 mg/L).

The seasonality of the monthly TDS concentrations in the Jordan River at 3 locations is shown on Figure 33. The Utah lake outlet is farthest upstream, followed by the Narrows and Bluffdale respectively. The concentrations are lowest in the spring and highest in the winter, which inversely correspond with the high spring and low fall outflow discharges (Figure 5).

Figure 32: Total Dissolved Solids Average Lake and Outflow Concentrations

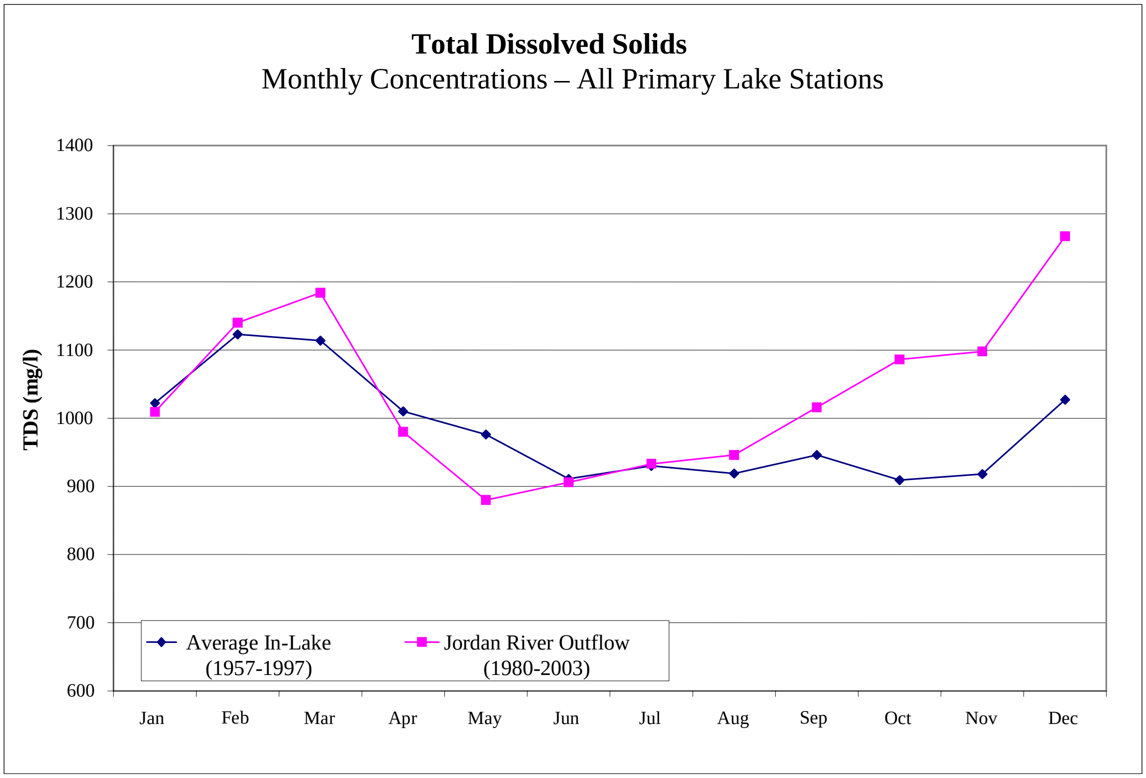
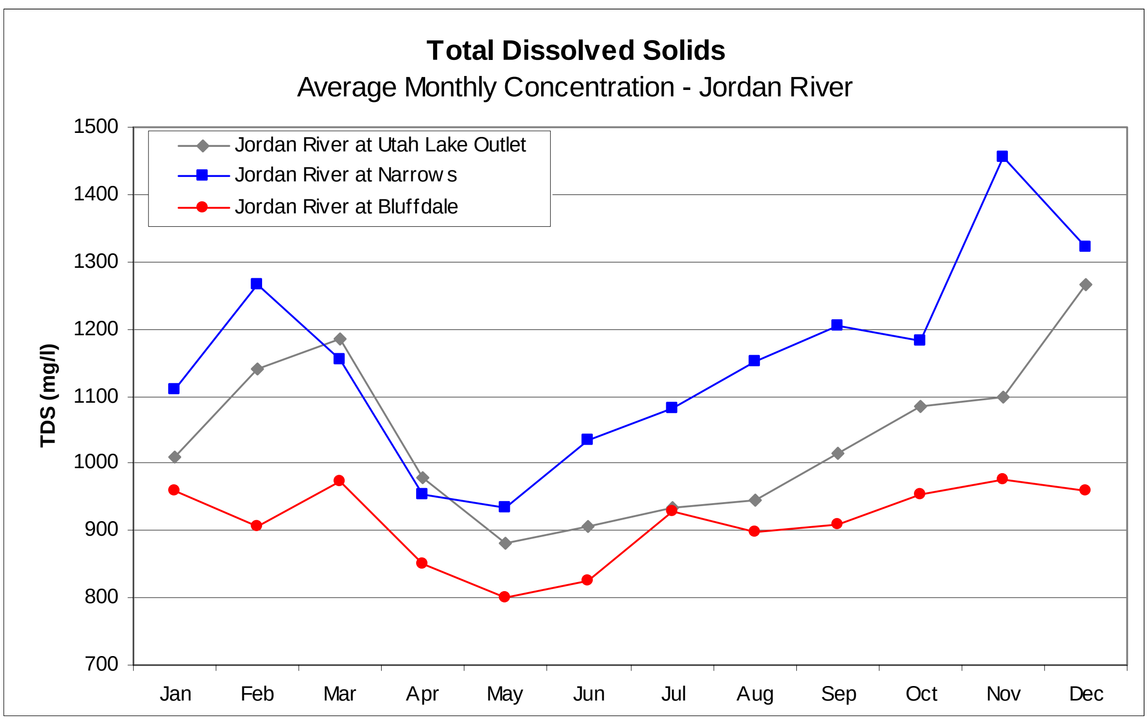


Figure 33: Total Dissolved Solids Average Concentrations – Jordan River



As shown in Figure 33, TDS concentrations at the outlet are typically below the TDS standard (1200 mg/L), rise at the Narrows, and fall below the standard again at Bluffdale. This may indicate the presence of saline springs or other phenomenon between the Utah Lake outlet and the Narrows that requires further investigation.

7.2.4 Specific Conductivity

Monthly conductivity data were plotted in order to assess the seasonality. Figure 34 and Figure 35 show respectively the corresponding Provo and Spanish Fork Rivers, Hobble Creek and Mill Race monthly specific conductivities, and the Jordan River outlet, at Narrows, and at Bluffdale monthly conductivities.

Figure 22 and Figure 34 show that the TDS and conductivity seasonal patterns for the tributaries are very similar, and Figure 33 and Figure 35 also show that the patterns are quite similar for the Jordan River.

Figure 34: Average Monthly Specific Conductivity– Significant Tributaries

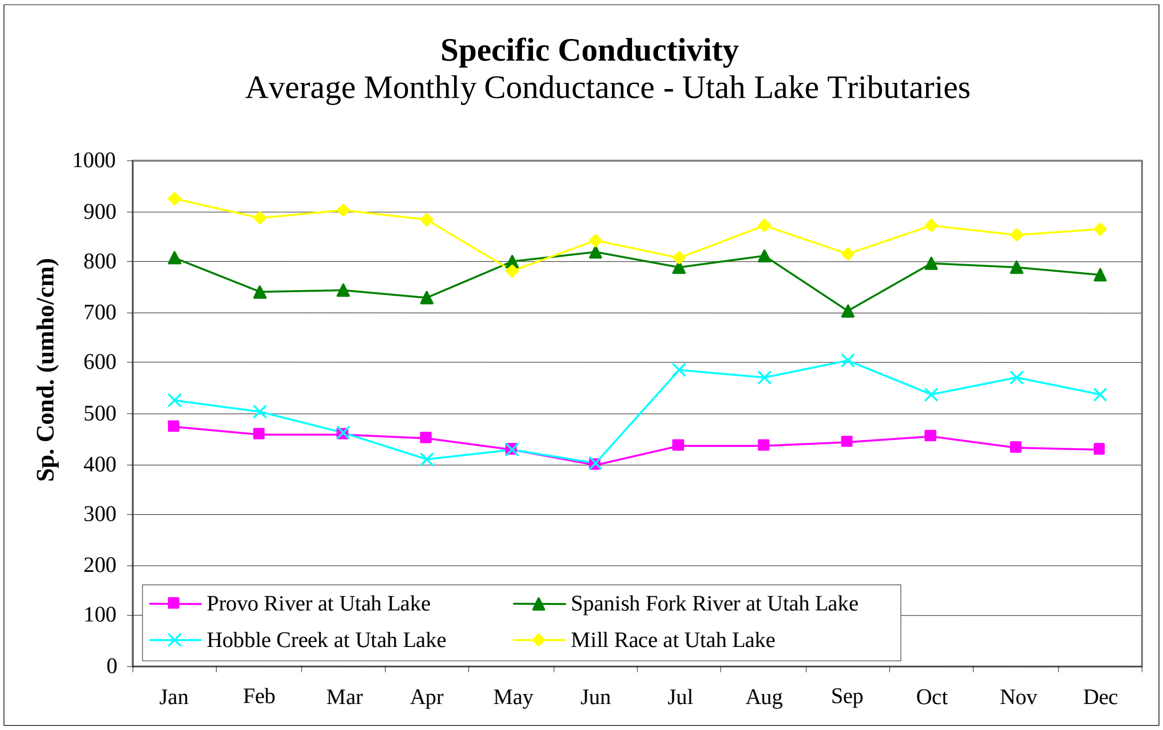
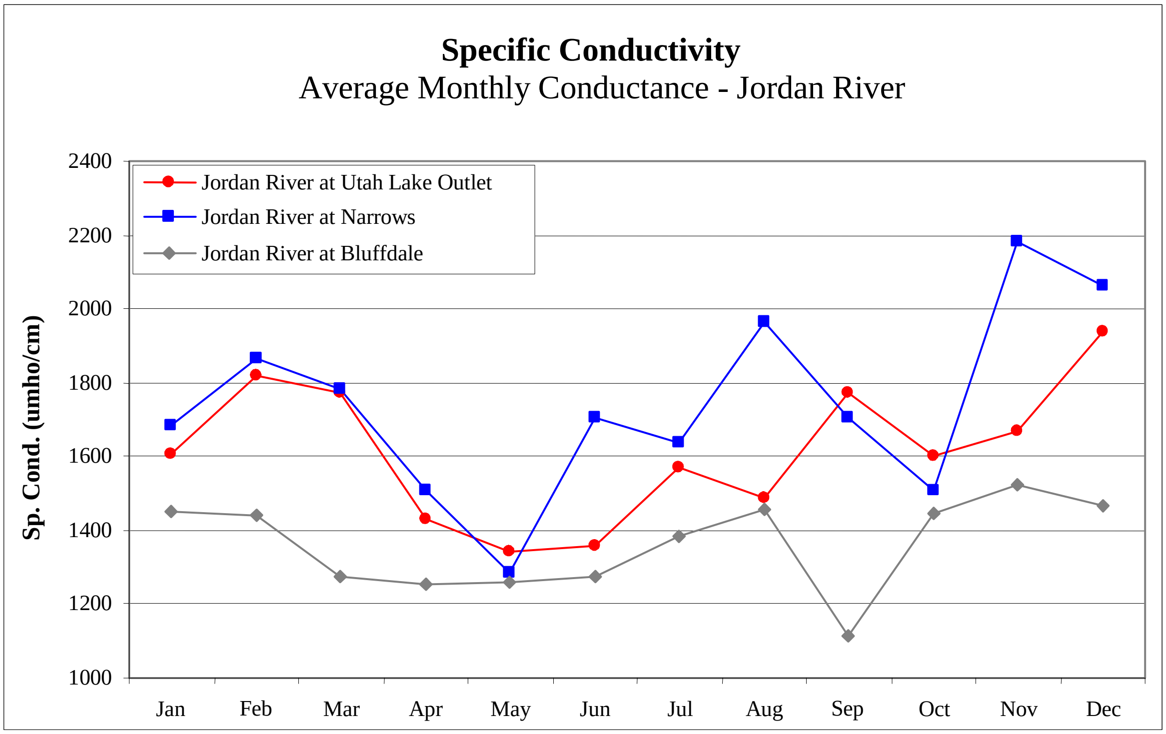


Figure 35: Average Monthly Specific Conductivity – Jordan River

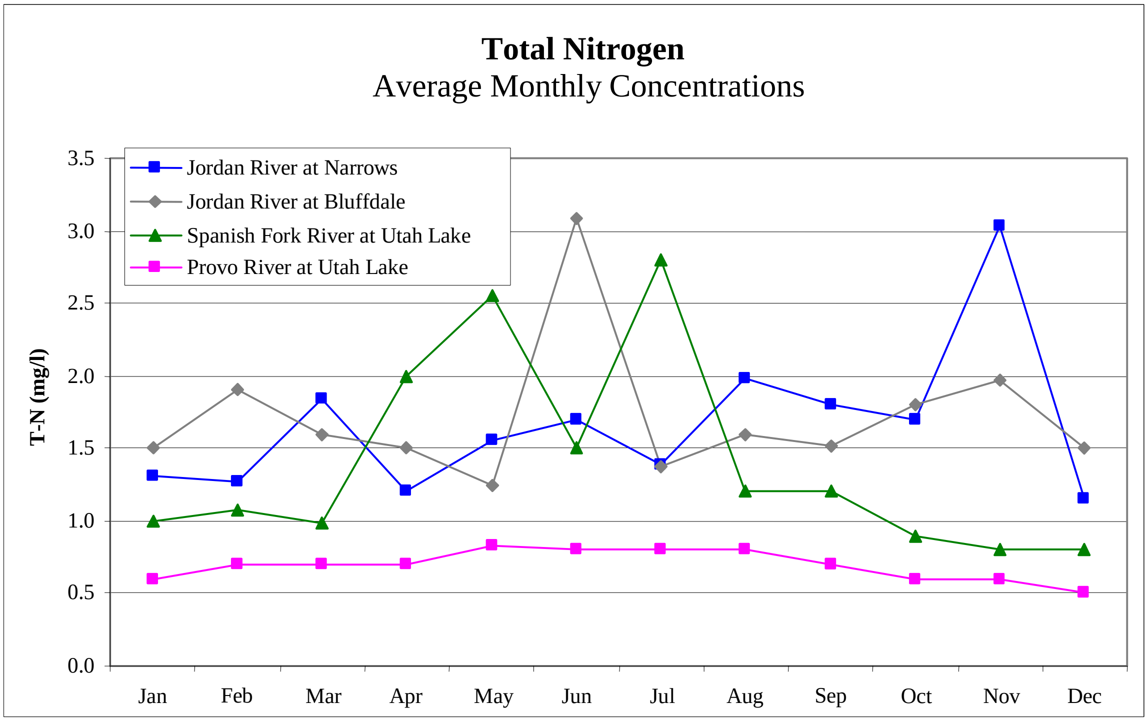


7.2.5 Total Nitrogen

Along with TDS, the seasonality of Total Nitrogen was also studied. Figure 36 shows the Nitrogen concentrations at the two major tributaries as well as two locations in the Utah Lake outflow.

There is significant variation in the monthly averages of Nitrogen, especially in the outflow. The Provo River (average ~ 0.7 mg/l) may show little seasonal variation, but the Spanish Fork River (average ~1.4 mg/l) seems to show more seasonality, increasing concentrations in the spring and summer. The Jordan River also seems to show seasonality, increasing at Bluffdale in June and at Narrows in November.

Figure 36: Average Monthly Total Nitrogen – Significant Tributaries



7.2.6 Bicarbonate

In the same way as the seasonality of the TDS concentrations was analyzed, the seasonality of the ions which make up the TDS was also analyzed. The figures are similar to those discussed above, first for the Utah Lake tributaries and then for the Jordan River at 3 locations. Figure 37 and Figure 38 show the monthly Bicarbonate concentrations.

For the tributaries, Spanish Fork River is highest and Provo River is lowest, and there is a slight rise in concentration during summer and fall. For the Jordan River, all 3 locations look about the same with the concentrations higher in the winter and lower in the summer.

Figure 37: Average Monthly Bicarbonate – Significant Tributaries

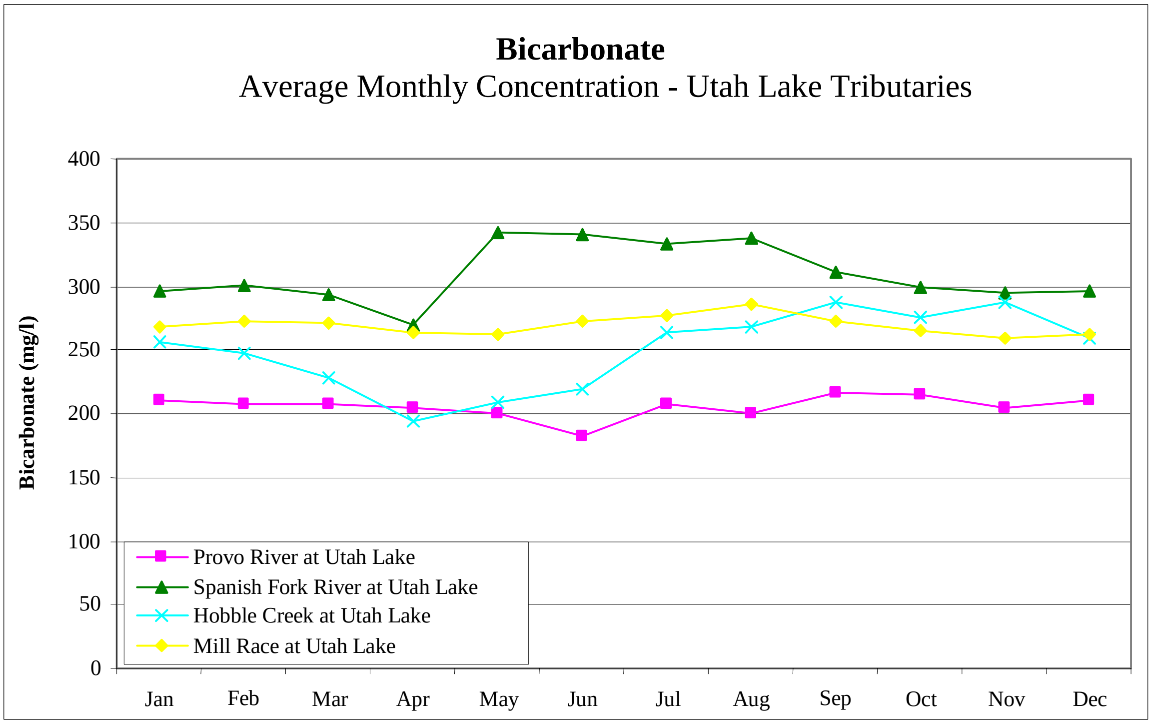
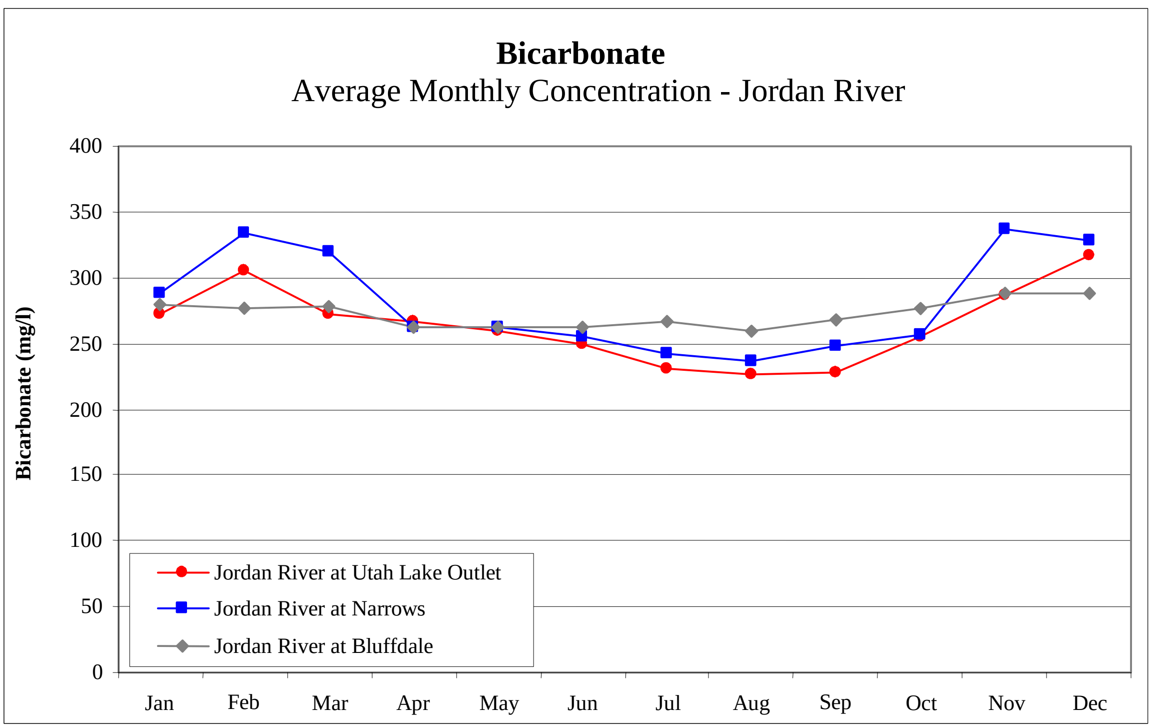


Figure 38: Average Monthly Bicarbonate – Jordan River



7.2.7 Calcium

Figure 39 and Figure 40 show the seasonality pattern of the monthly Calcium concentrations.

Among the tributaries, Mill Race is by far the highest and the other 3 streams are about the same, with very little seasonal variation. For the Jordan River, the concentrations are higher in winter and lower in summer, and the 3 locations are quite similar.

Figure 39: Average Monthly Calcium – Significant Tributaries

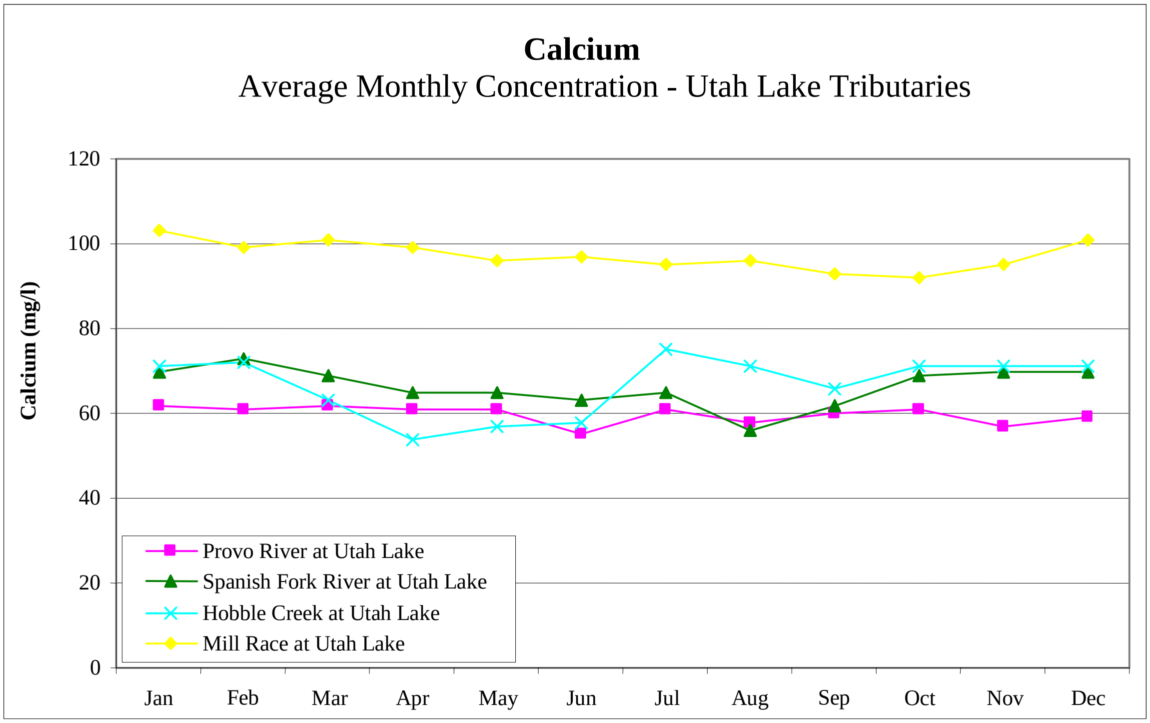
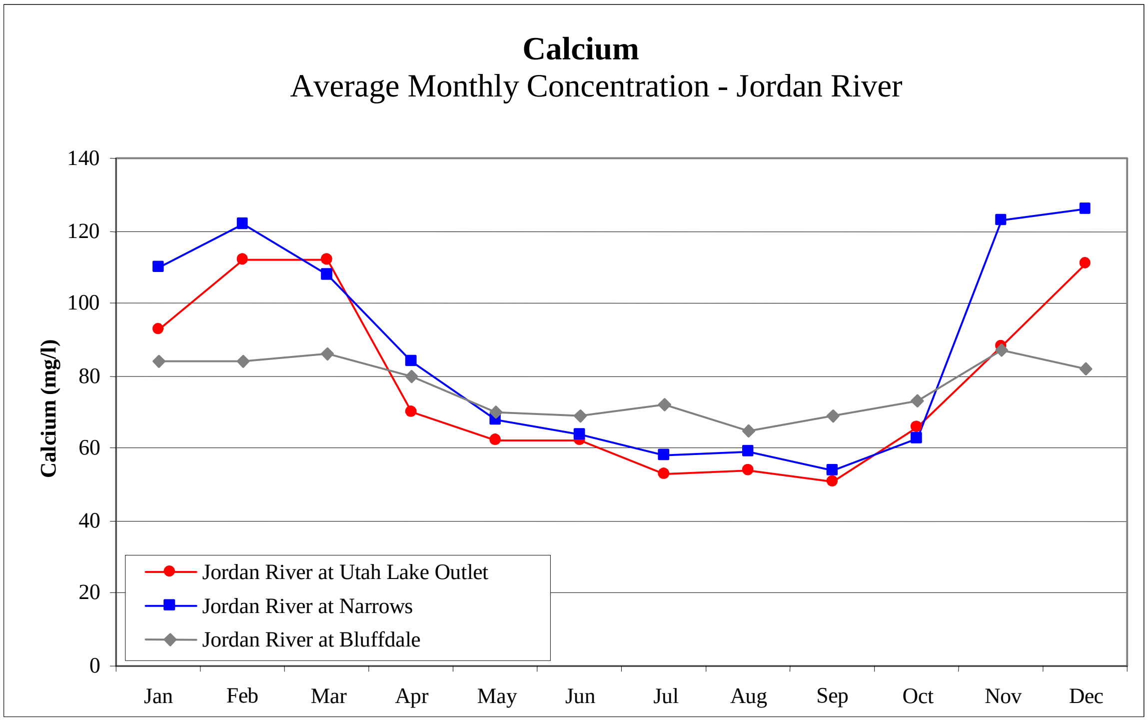


Figure 40: Average Monthly Calcium – Jordan River



7.2.8 Chloride and Magnesium

Monthly Chloride concentrations for Utah Lake's inlets and outlet are presented in Figure 41 and Figure 42 respectively. Magnesium concentrations for Utah Lake's inlets and outlet are presented in Figure 43 and Figure 44 respectively.

Hobble Creek and Provo River, with little seasonal variation, are lower than Mill Race and Spanish Fork River, with some seasonal variation. Concentrations at the 3 Jordan River locations are somewhat different with the outlet being the lowest, and there are slightly higher concentrations in the late summer.

Figure 41: Average Monthly Chloride – Significant Tributaries

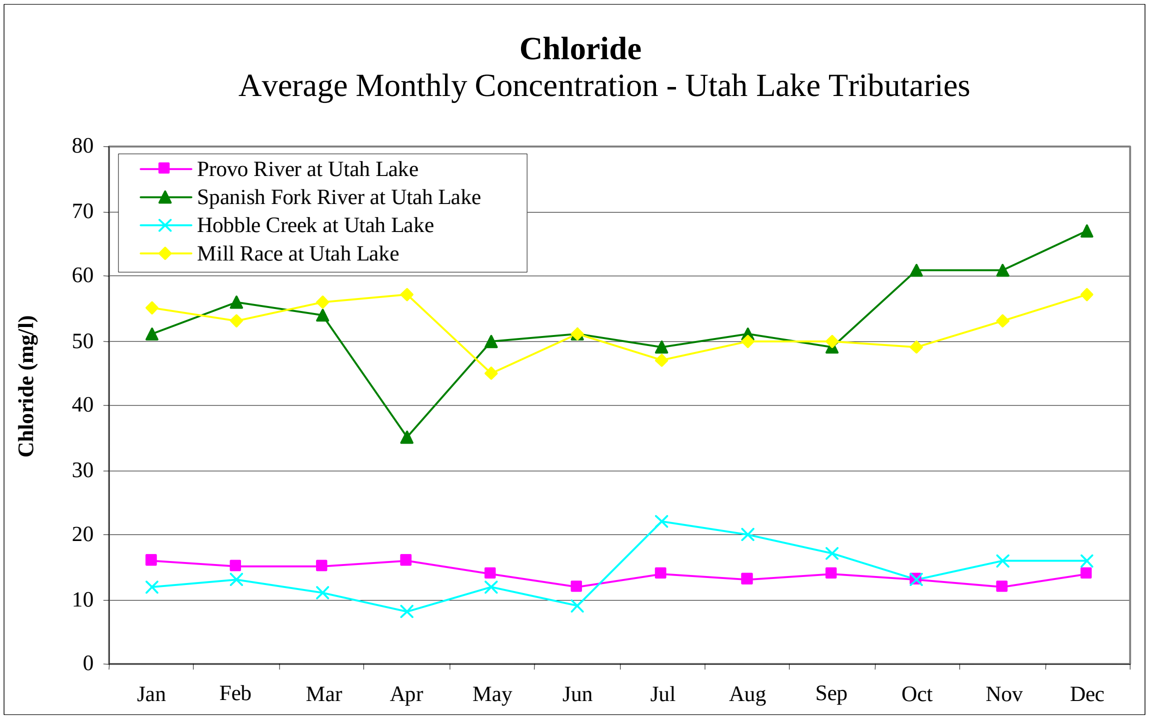


Figure 42: Average Monthly Chloride – Jordan River

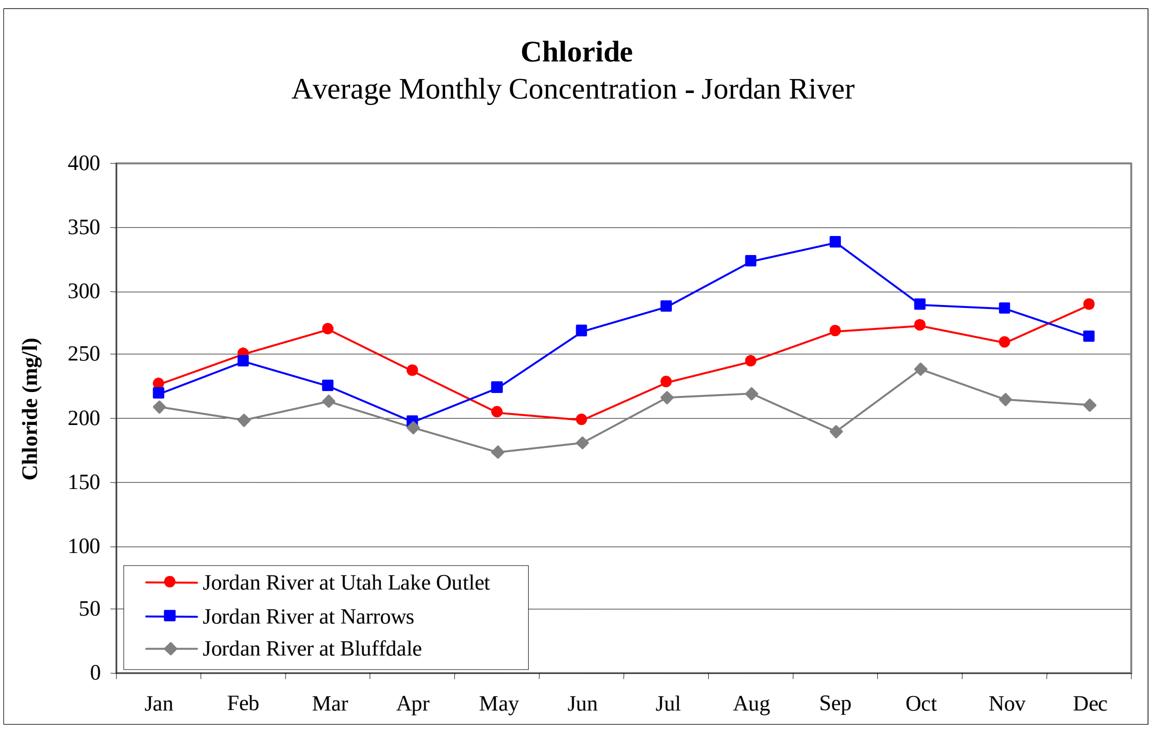


Figure 43: Average Monthly Magnesium – Significant Tributaries

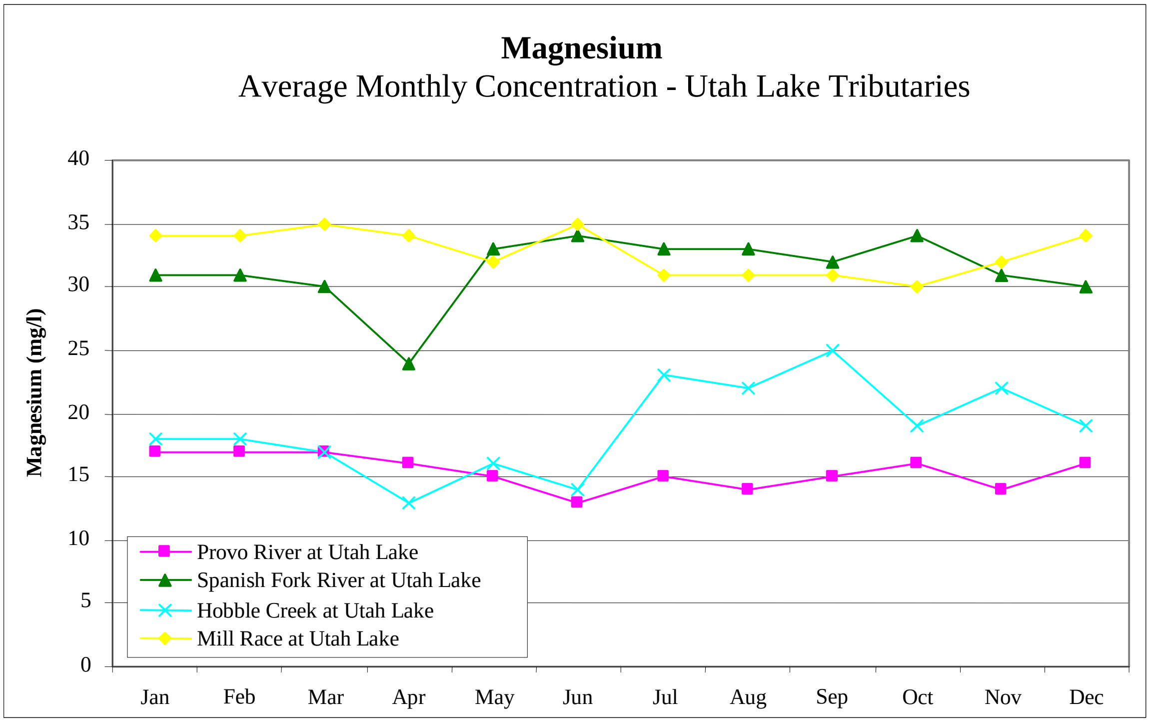
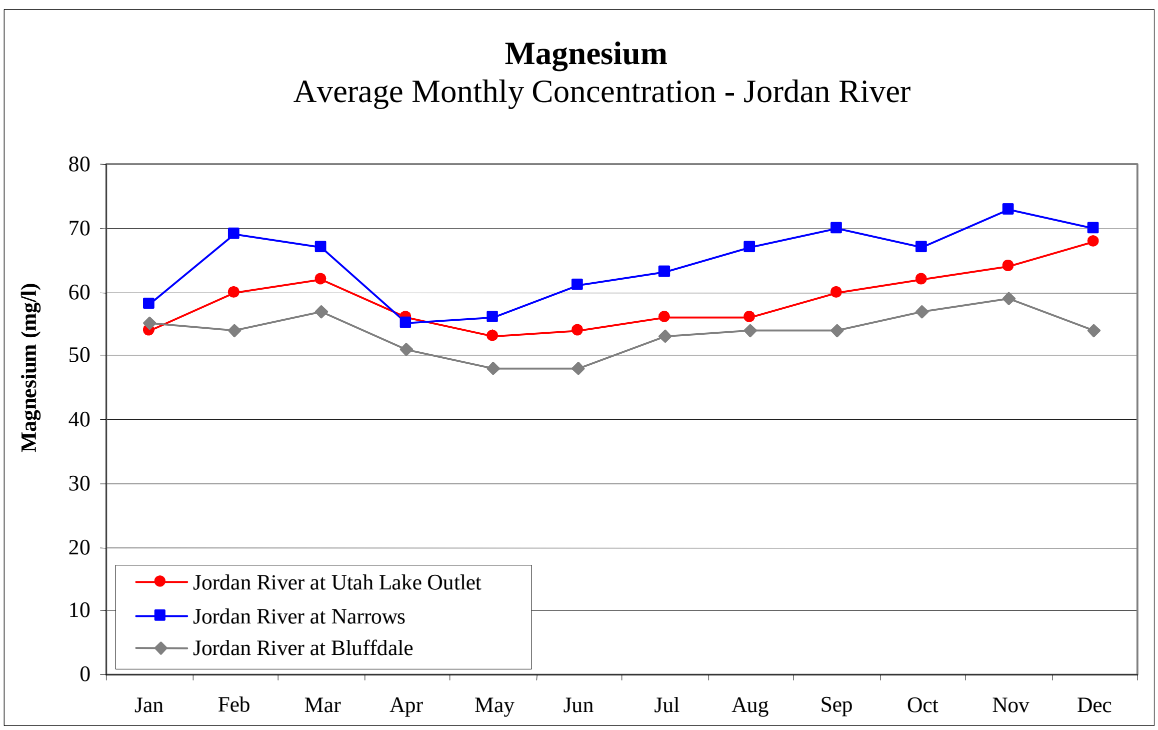


Figure 44: Average Monthly Magnesium – Jordan River



7.2.9 Potassium

Monthly Potassium concentrations for Utah Lake's inlets and outlet are shown on Figure 45 and Figure 46 respectively.

Mill Race is higher than the other 3 streams, and all 4 have only slight seasonal variability. Concentrations at the 3 Jordan River locations are all around 15 to 20 mg/l with slightly higher values in late summer and fall.

Figure 45: Average Monthly Potassium – Significant Tributaries

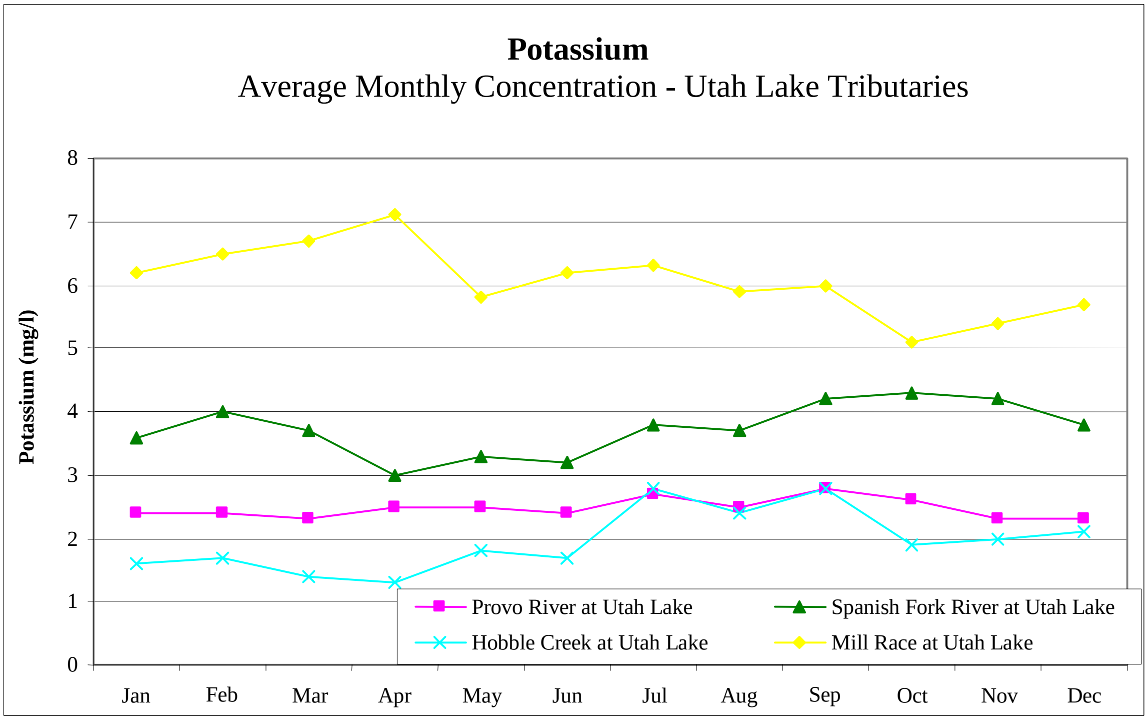
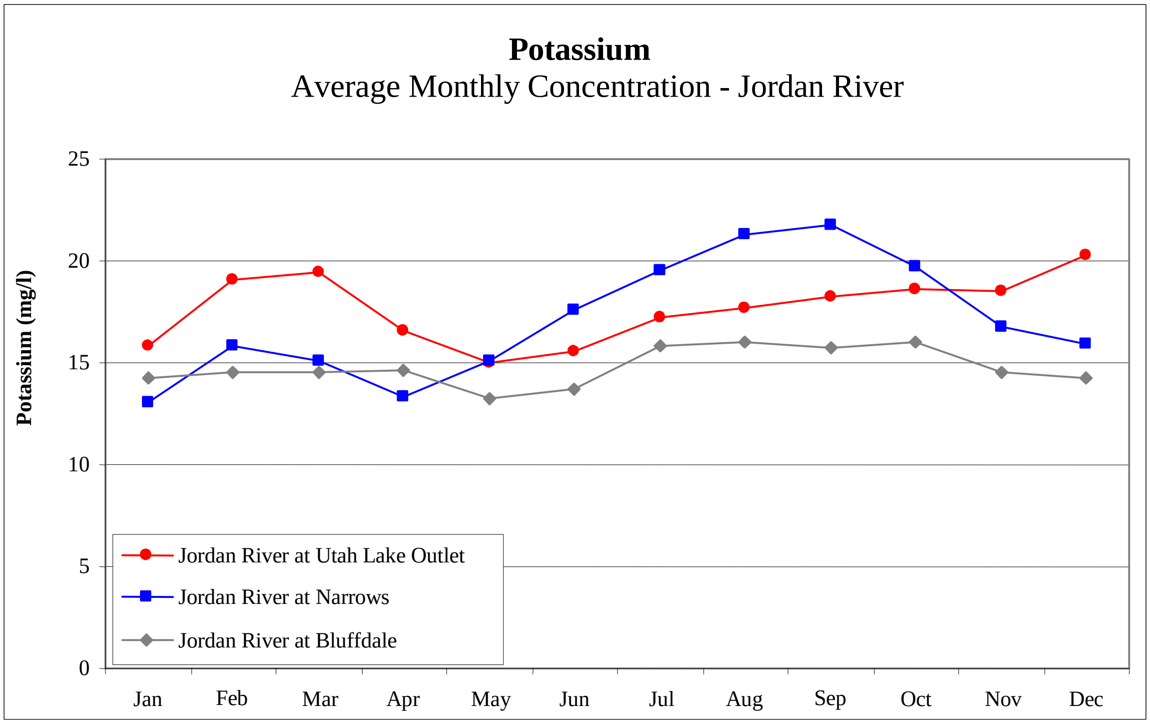


Figure 46: Average Monthly Potassium – Jordan River



7.2.10 Sodium

Figure 47 and Figure 48 show the seasonality pattern of the monthly Sodium concentrations. For the tributaries, Spanish Fork River is highest, with some seasonal variation, and Hobble Creek and Provo River are lowest, with no seasonal variation. For the Jordan River, the 3 locations are close in concentrations, and they are lower in the spring and higher in the fall.

Figure 47: Average Monthly Sodium – Significant Tributaries

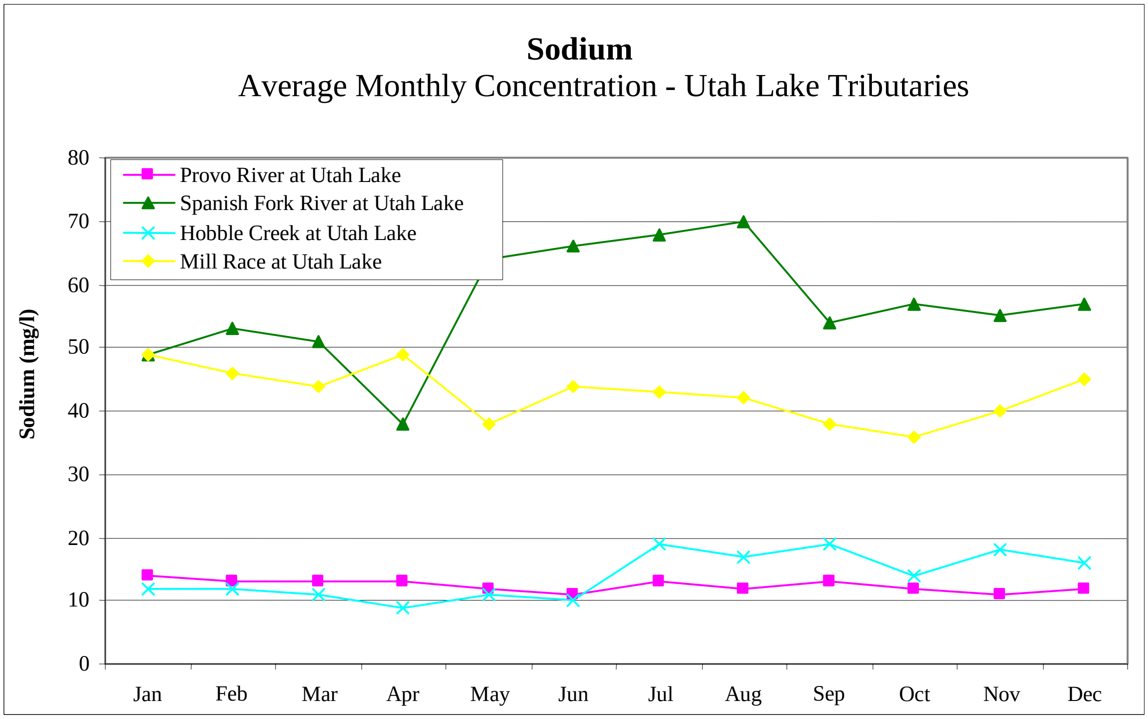
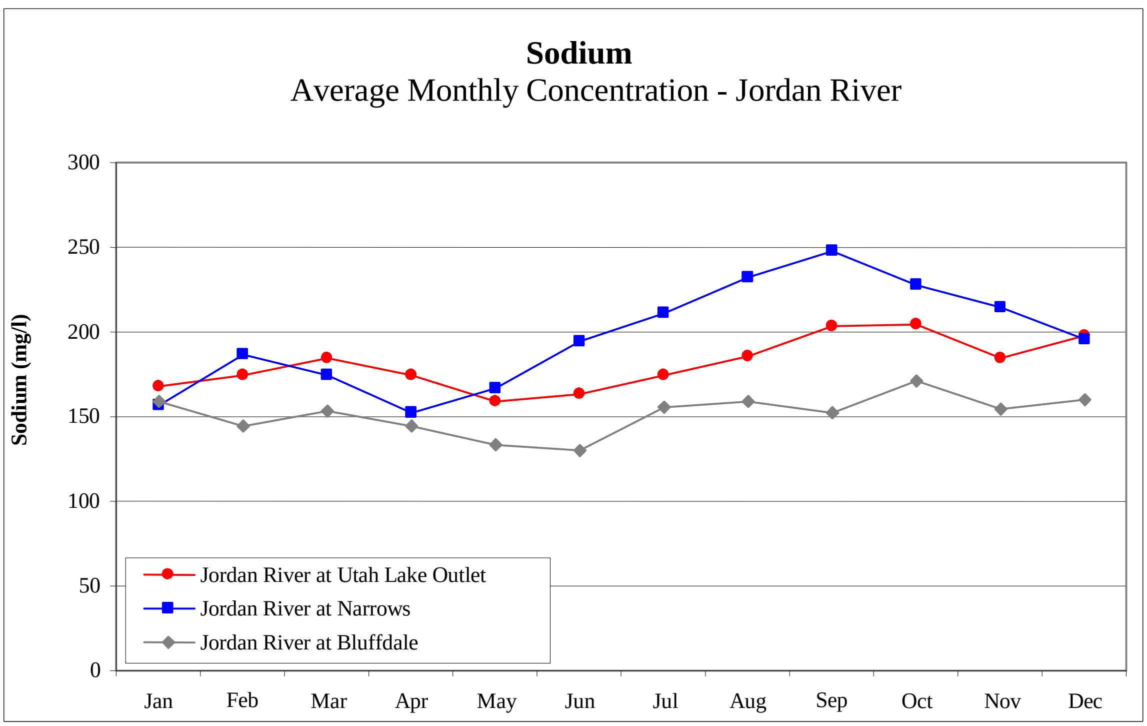


Figure 48: Average Monthly Sodium – Jordan River



7.2.11 Sulfate

Monthly Sulfate concentrations are shown on Figure 49 and Figure 50. Among the tributaries, Mill Race is the highest, with up and down seasonality, and again, Hobble Creek and Provo River are lowest, with little seasonal variation. Concentrations at the 3 Jordan River locations are quite similar with the Narrows being the highest, and the seasonality shows low values in the summer and high values in the winter.

Figure 49: Average Monthly Sulfate – Significant Tributaries

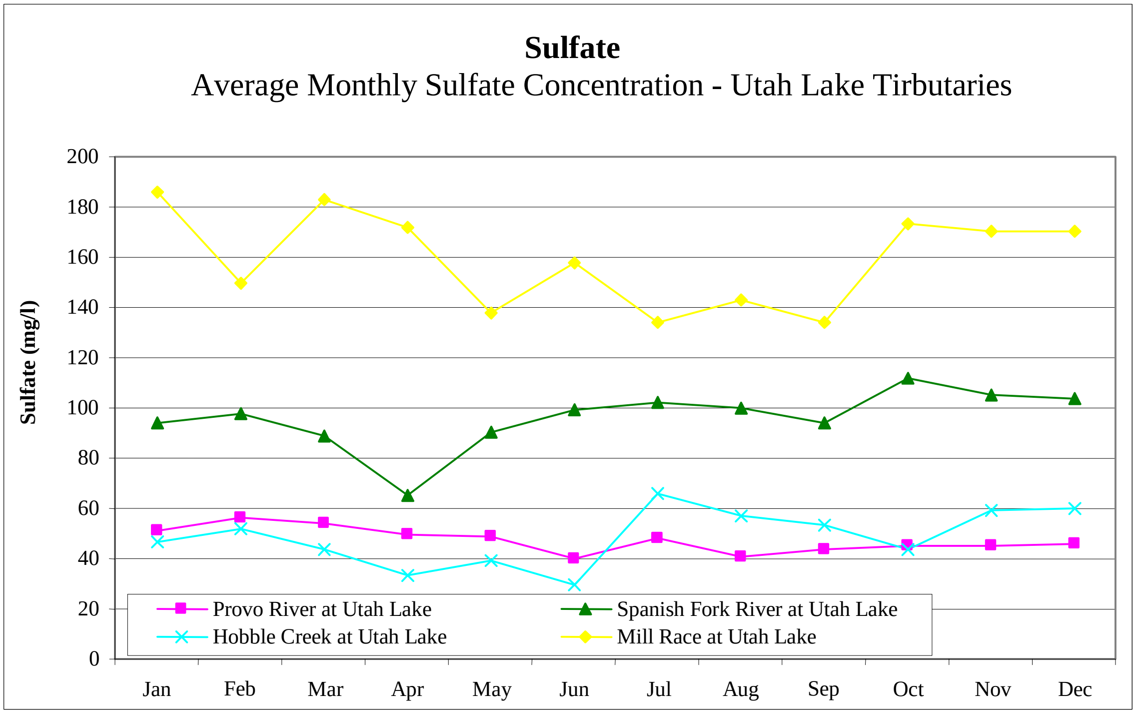
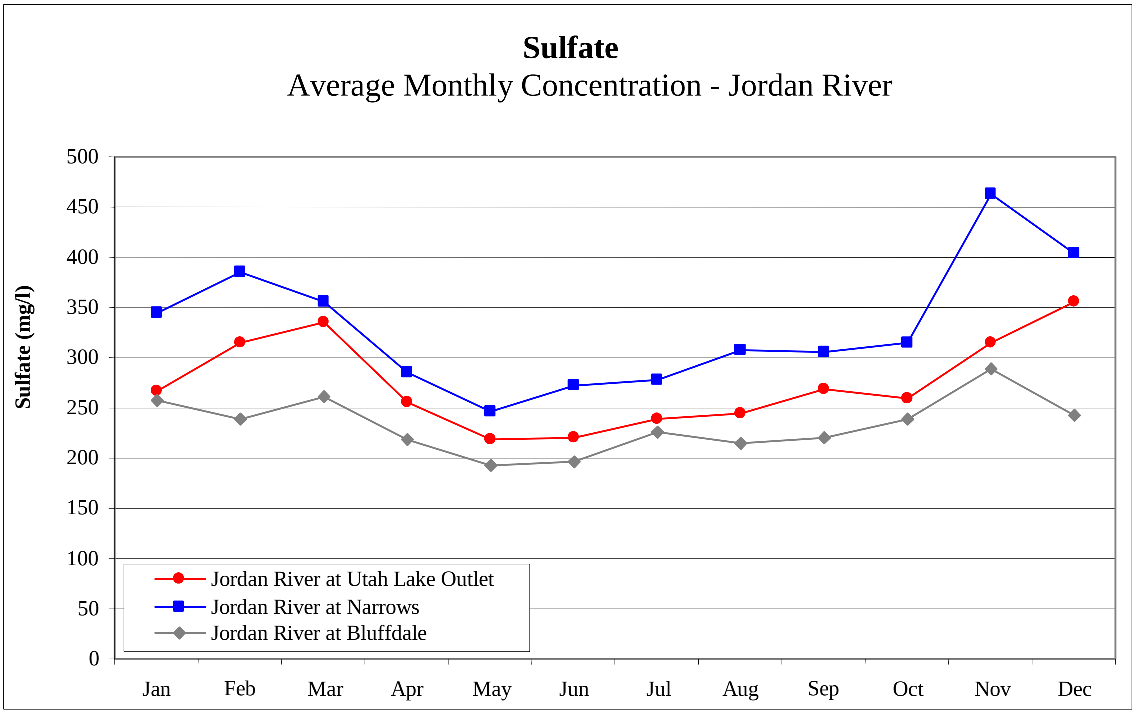


Figure 50: Average Monthly Sulfate – Jordan River



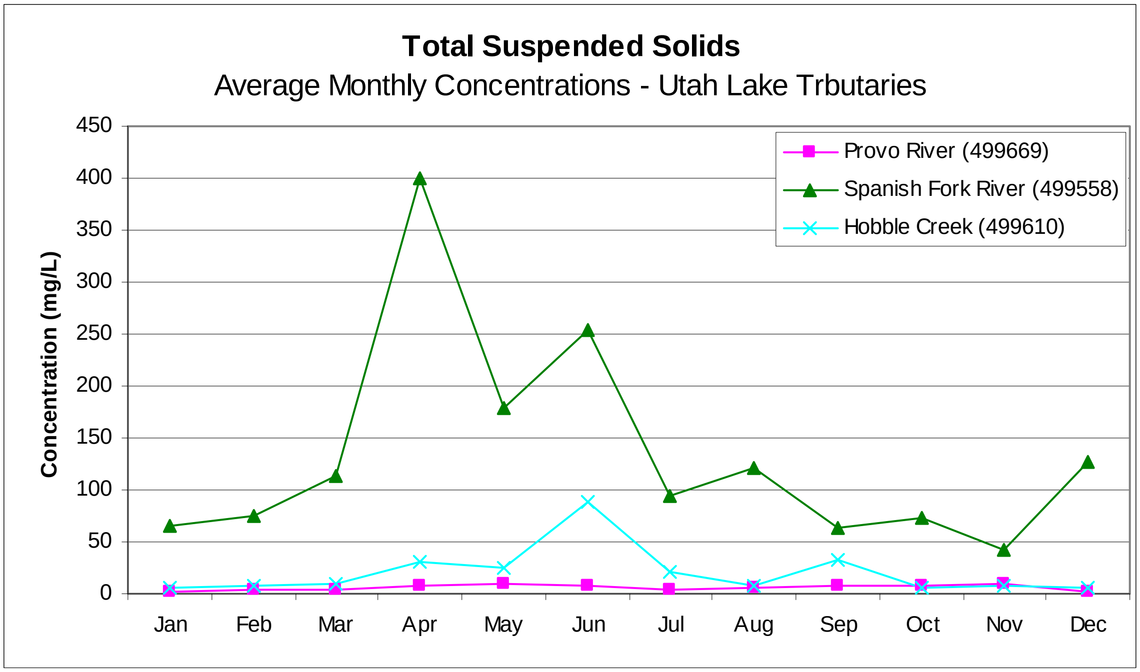
7.2.12 Total Suspended Solids

TSS concentrations are influenced by several factors, including surface water runoff, changes in stream velocities, erosion, turbulence in lakes and reservoirs, and plant and animal decay. Because many of these factors are functions of temperature and/or precipitation, TSS concentrations tend to be highly seasonal.

7.2.12.1 Significant Inflows

Figure 51 shows the average monthly concentration of total suspended solids in the three most significant inflows into Utah Lake; the Provo River, the Spanish Fork River, and Hobble Creek.

Figure 51: Total Suspended Solids Average Concentrations – Significant Inflows



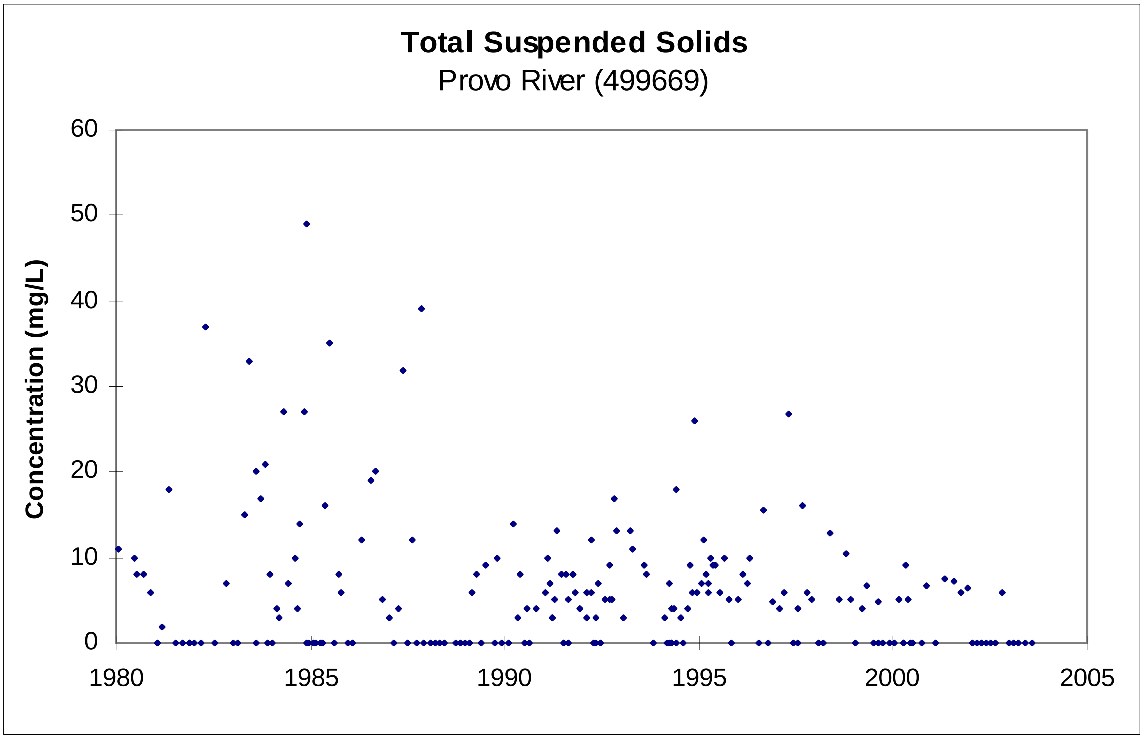
Concentrations of total suspended solids in the Spanish Fork River and Hobble Creek are greater during the spring and summer months. TSS in the Provo River, however, does not appear to follow any seasonal trend. The Spanish Fork River is the most heavily influenced by seasonal changes. Peak concentrations of TSS in the Spanish Fork River occur in the spring, coinciding with high rainfall and runoff from melting snow. In April, TSS concentrations are approximately four times the annual average. In Hobble Creek, TSS increases in April but does not peak until June. A second, smaller peak is observed in September. Provo River consistently has the lowest TSS of any of the major inflows.

Provo River

The Provo River delivers nearly one third of the total inflow to Utah Lake. Figure 52 shows the historical profile of TSS in the Provo River (STORET station 499669).

TSS in the Provo River decreased in the late 1980's. Since that time concentrations have been relatively constant. Small spikes are observed in 1995 and then again in 1997, but the trend remains unchanged.

Figure 52: Total Suspended Solids Historical Data – Provo River



Spanish Fork River

A historical summary of TSS in the Spanish Fork River (STORET station 499558) is shown in Figure 53. Spanish Fork River has the highest TSS concentrations of any of the major inflows. The higher concentrations between 1995 and 2000 possibly may be contributed to construction impacts upstream. Except for that phenomenon, general TSS concentrations have decreased since 1990.

Hobble Creek

Figure 54 shows historical TSS data at Hobble Creek (STORET station 499610). Since 1983, concentrations of TSS have decreased steadily. The most rapid decrease occurs in the late 1980's; however, a consistent downward trend is observed during the entire period of record. TSS levels spike in 1996.

Figure 53: Total Suspended Solids Historical Data – Spanish Fork River

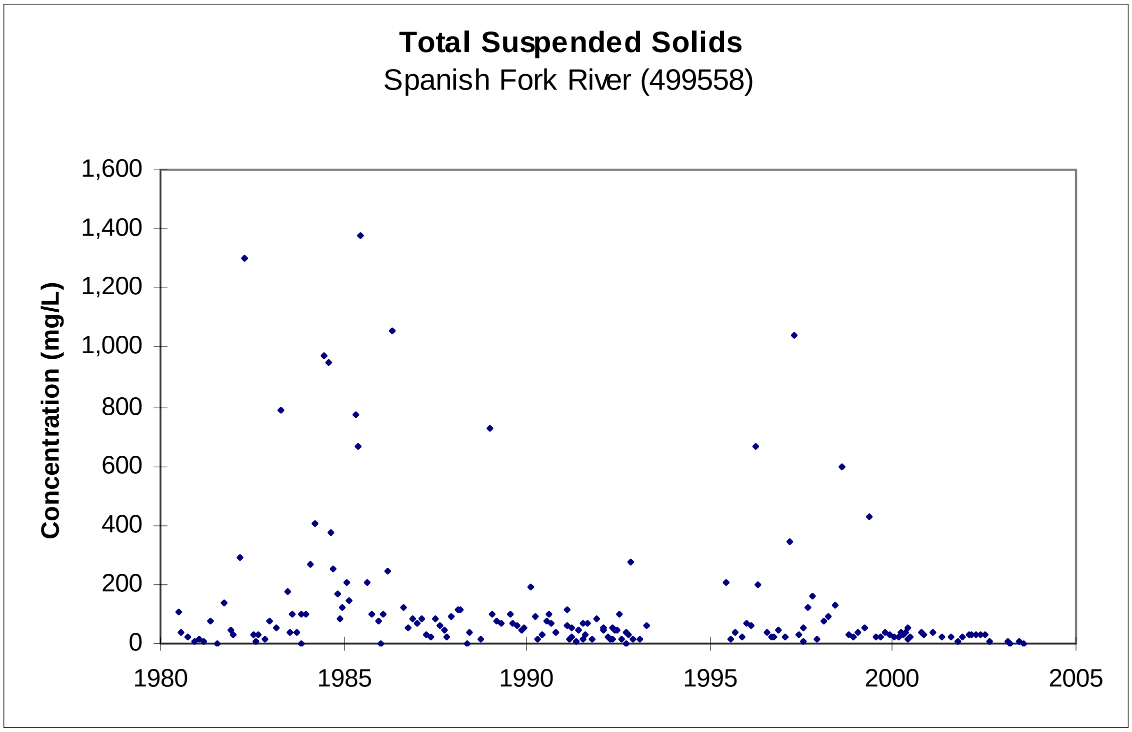
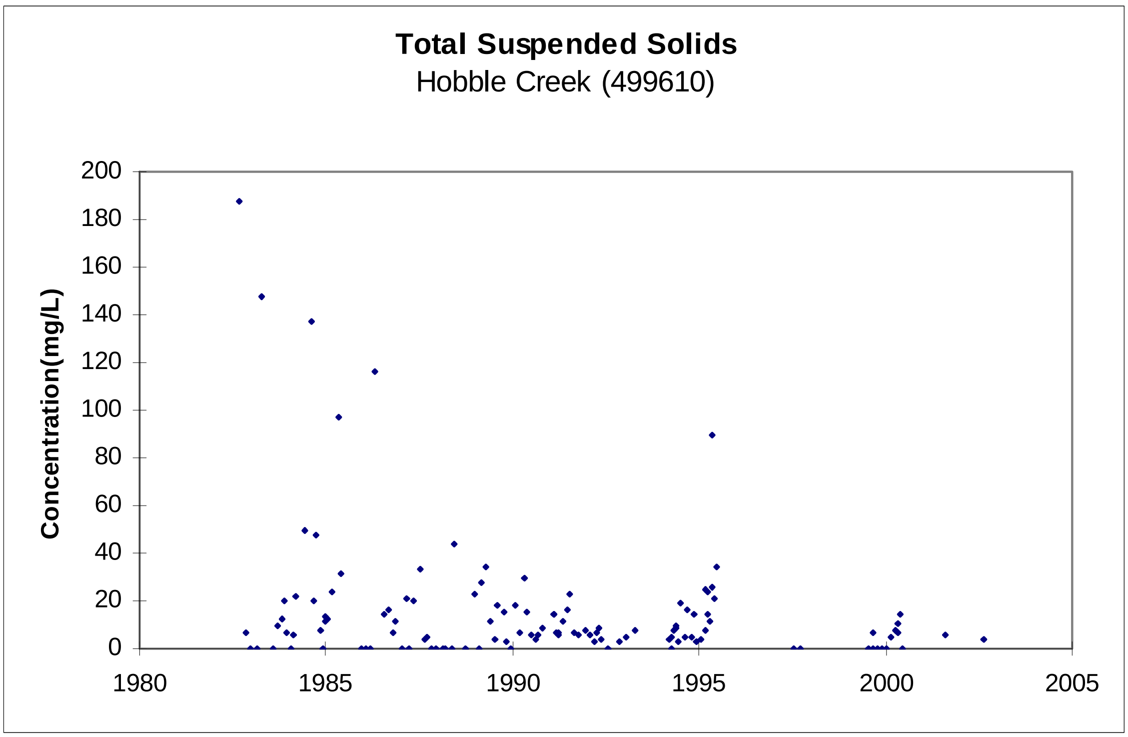


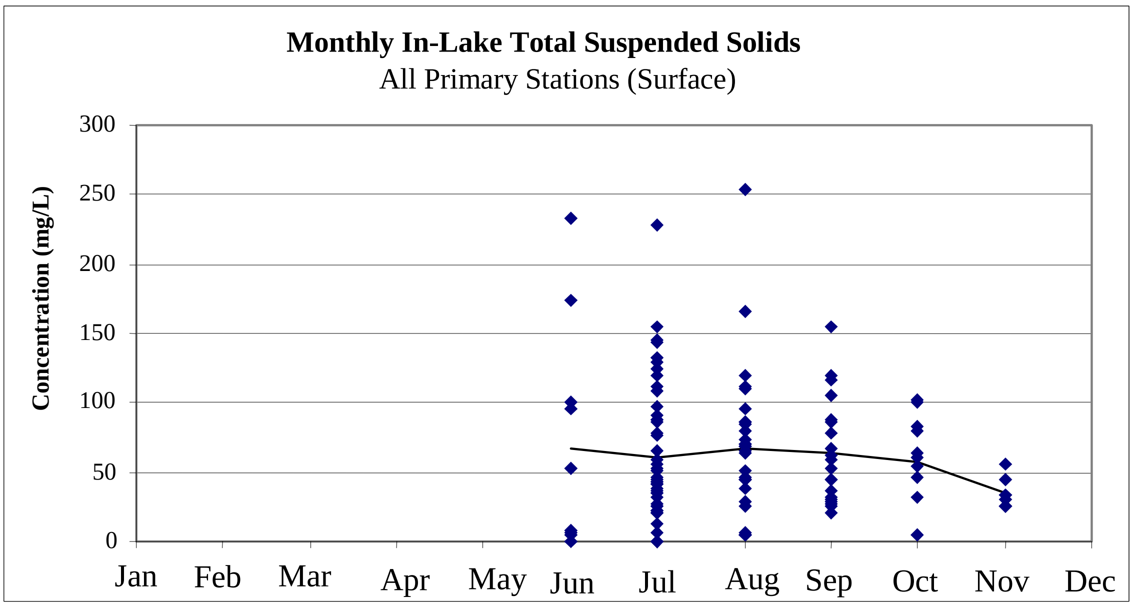
Figure 54: Total Suspended Solids Historical Data – Hobble Creek



7.2.12.2 In-Lake

Suspended solids enter Utah Lake by way of several significant inflows. The relatively shallow depth of Utah Lake allows wind and turbulence to stir up bottom sediments and re-suspend phosphorus and other materials. As a result, in-lake TSS concentrations are extremely high. High TSS in Utah Lake is largely to blame for its reputation as a highly polluted water body. Because Utah Lake was not sampled consistently throughout the year, the data for all primary lake stations was combined. This approach allows for a statistical analysis of the data based on 5 or more data points. Monthly in-lake TSS data for all the primary lake stations are presented in Figure 55. (See Table 4 for primary lake stations).

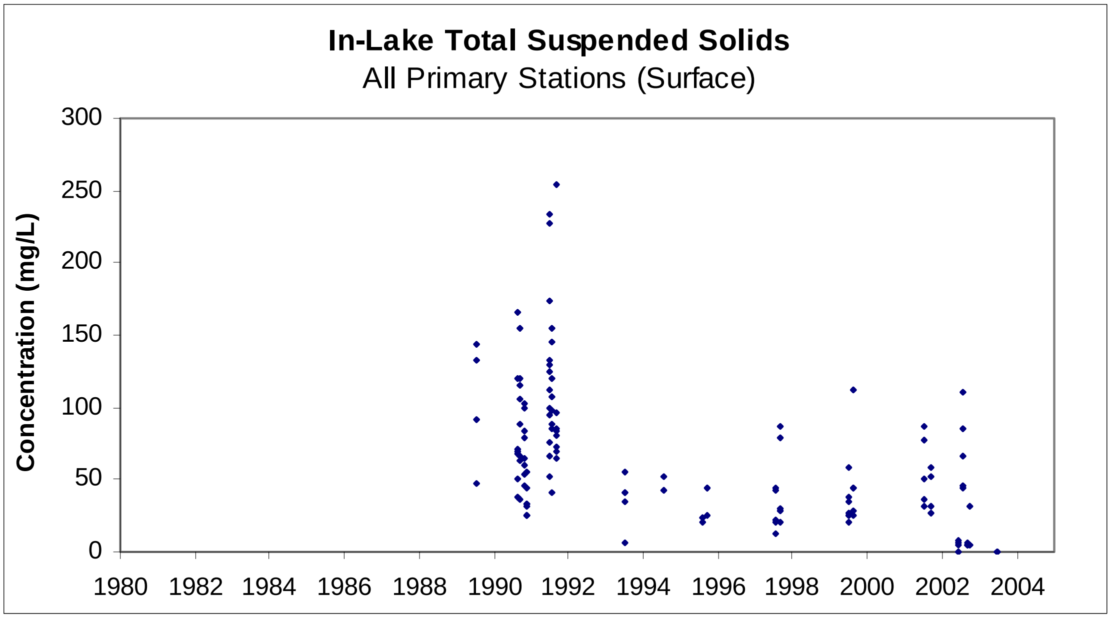
Figure 55: Total Suspended Solids Monthly Historical Data – All Primary Lake Stations



An assessment of the TSS data for Utah Lake is difficult because only six months of data are available. However, it appears there may be a decrease from August to November. Also, the frequency and magnitude of peak monthly values decreases in the fall.

Historical TSS concentrations at the surface of Utah Lake are presented in Figure 56. TSS measured between 1989 and 1992 is significantly higher than values measured post-1992; although concentrations have increased gradually since 1995.

Figure 56: Total Suspended Solids Historical Data – All Primary Lake Stations

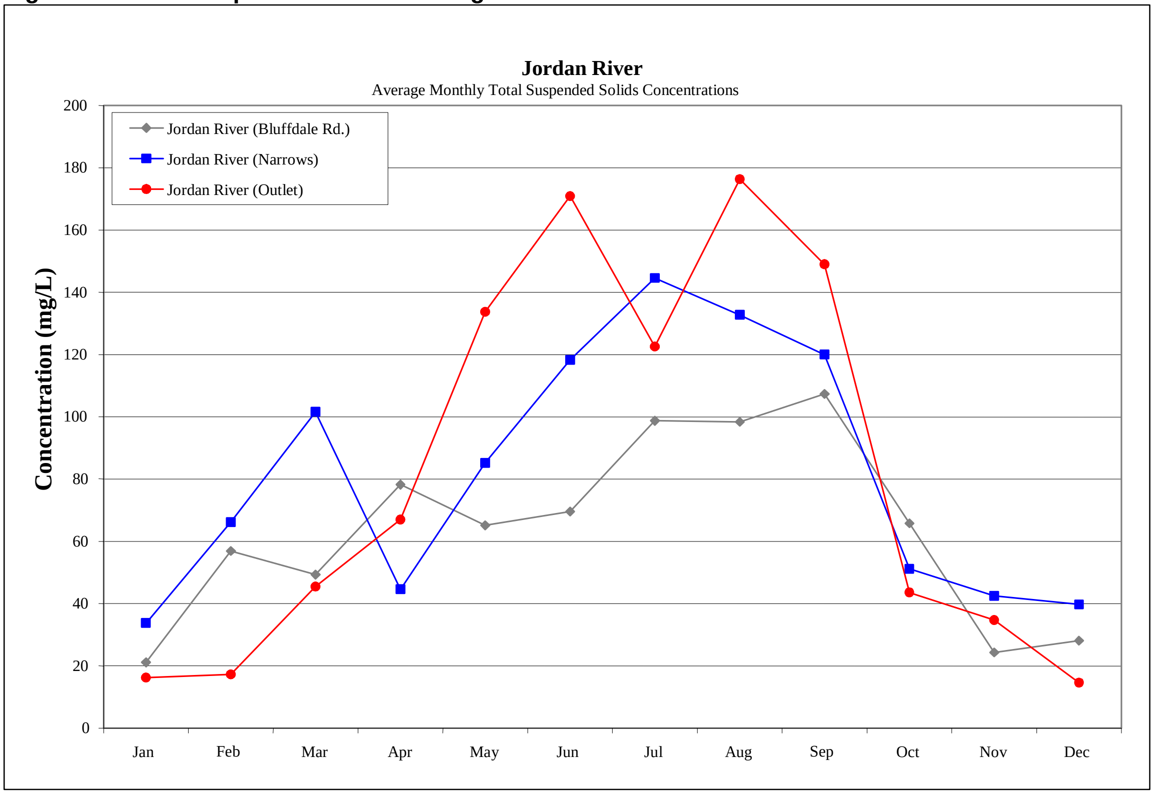


7.2.12.3 Outflow

The Jordan River, which is the only major outflow from Utah Lake, is frequently sampled and several years of TSS data are available. The average monthly concentrations of TSS in the Jordan River are shown in Figure 57.

A strong seasonal pattern is observed in the Jordan River. At the outlet and narrows, concentrations increase rapidly in the spring before peaking in the summer. In October, TSS levels plummet and remain relatively low until the following spring. Concentrations in the summer at the Utah Lake outlet are nearly ten times greater than winter values. Changes in concentration downstream at the narrows and at Bluffdale are not as pronounced. The seasonal trend observed at the Bluffdale station shows a more gradual increase in the spring and summer that doesn't peak until September. TSS in the Jordan River at Bluffdale does, however, decrease in October similar to the other stations.

Figure 57: Total Suspended Solids Average Concentrations – Jordan River



7.2.13 Summary

The previous paragraphs and figures describe and show the seasonality for several parameters in Utah Lake tributaries and outflow. There are many differences and some similarities. In some cases one tributary has the highest concentrations and in other cases the same tributary has the lowest. Likewise, sometimes the highest concentrations are in the winter and sometimes in the summer.

The most useful parameter to emphasize for the chemical analysis of Utah Lake is TDS. For analysis of productivity in the lake, the most useful parameter is phosphorus. Study of these figures is suggested as being the most efficient method of analyzing and summarizing these findings.

7.3 Biological

Utah Lake has a diverse habitat type, although some 95% of the lake bottom is comprised of loosely compacted, watery sediments (including calcium carbonate, clay, and others). Often the lake appears grey-green depending upon the time of year due to suspended sediments, precipitated calcium carbonate and dense algal and cyanobacterial “blooms”.

The Lake is a highly productive ecosystem with the majority of algal production occurring as cyanobacterial blooms in the late summer and fall. Utah Lake could be considered to be hyper-eutrophic, although the unusually high algal species diversity in the system perhaps makes a classification of somewhat saline-eutrophic a better description of this system. Systems with high TDS and high species diversity are sometimes referred to as saline-eutrophic. Utah Lake sometimes has been referred to as saline-eutrophic since it meets these conditions.

Winter floras in the lake are dominated by diatoms and the biomass is much lower than during other parts of the year. Spring and early summer phytoplankton communities tend to be composed of a diverse group of diatoms, chlorophytes and cyanophytes. This is also the time when the environment of the lake tends to be most heterogeneous. As the season progresses the lake becomes more homogeneous and algal diversity decreases (Squires, et al. 1979).

Community seasonality is evident in Utah Lake. During winter months, biomass is substantially lower than during other times of the year. Likewise, though the dominant winter species are present throughout the year, they are much more important during winter months. These include Carteria stellifera, Euglena gracillis, Chlamydomonas gracillis and low numbers of Aphanizomenon flos-aquae. Spring and early summer, diatom floras tend to show greater similarity across the lake than chlorophytes or cyanophytes. Conversely, during late summer and fall, cyanophyte and chlorophyte floras are very similar across the lake while the diatoms have some tendency to show greater diversity.

Seasonality is also confounded to some extent by distribution of area-specific diatom assemblages. Goshen Bay, Provo Bay and the main body of the lake all demonstrate somewhat different diatom assemblages regardless of season. Nevertheless, the species from these regions are relatively similar even though they differ in rank of importance. When Spearman's Rank Correlation Analysis is applied to the diatom assemblages of the three main areas of the lake, Provo Bay, Goshen Bay and the main lake body, the diatom assemblages of these three areas across the spring, summer and fall, the three are not significantly correlated. Diatom floras are most similar across the lake during fall months.

By mid August, the lake is quite homogeneous and is often dominated by a very few species of phytoplankton. Perhaps the most typical assemblage through the late summer and fall is the cyanobacterium Aphanizomenon flos-aquae, the dinoflagellate Ceratium hirundinella and sometimes the diatom Melosira granulata var. angustissima (Whiting et al. 1978). Often the phytoplankton flora is nearly entirely comprised of Aphanizomenon flos-aquae and Ceratium hirundinella. Furthermore, these species tend to "separate" spatially so that samples comprised of nearly 100% Aphanizomenon may be collected a few meters from samples comprised of nearly 100% Ceratium (Squires, et al. 1979).

During some years for reasons as yet undetermined, the cyanophyte Aphanizomenon flos-aquae may be replaced by the cyanophyte Anabaena spiroides var. crassa. This may be important since the literature suggests that the latter taxon may create more toxins than Aphanizomenon, although this remains to be proven.

By mid August, the number of Aphanizomenon flos-aquae filaments may exceed 11,000 per milliliter. Ceratium hirundinella may reach numbers of nearly 1000 per milliliter by the same time. These are very high numbers of organisms and suggest that Utah Lake is one of the most productive aquatic ecosystems in western North America (Squires, et al. 1979).

Along with these high densities, prevailing winds often "windrow" the Aphanizomenon flos-aquae or Anabaena spiroides var. crassa so that large, dense "patches" of these organisms are evident across rather large areas of the lake. When conditions are such that this occurs, these organisms often end up lining the shoreline and creating bad odors as they decompose. These odors may be carried during late summer and fall into the local municipalities.

7.3.1 Chlorophyll A

Figure 58 shows average monthly concentration of Chlorophyll A. Concentrations appear to be highest in August and lowest in June and September. Figure 59 shows historical values of Chlorophyll A observed in the lake (all stations). A pronounced decrease in average concentration is observed over the past fifteen years. Annual peak values, typically occurring in August, also appear to be decreasing over time.

Figure 58: Chlorophyll A Concentrations – Primary In-Lake Station

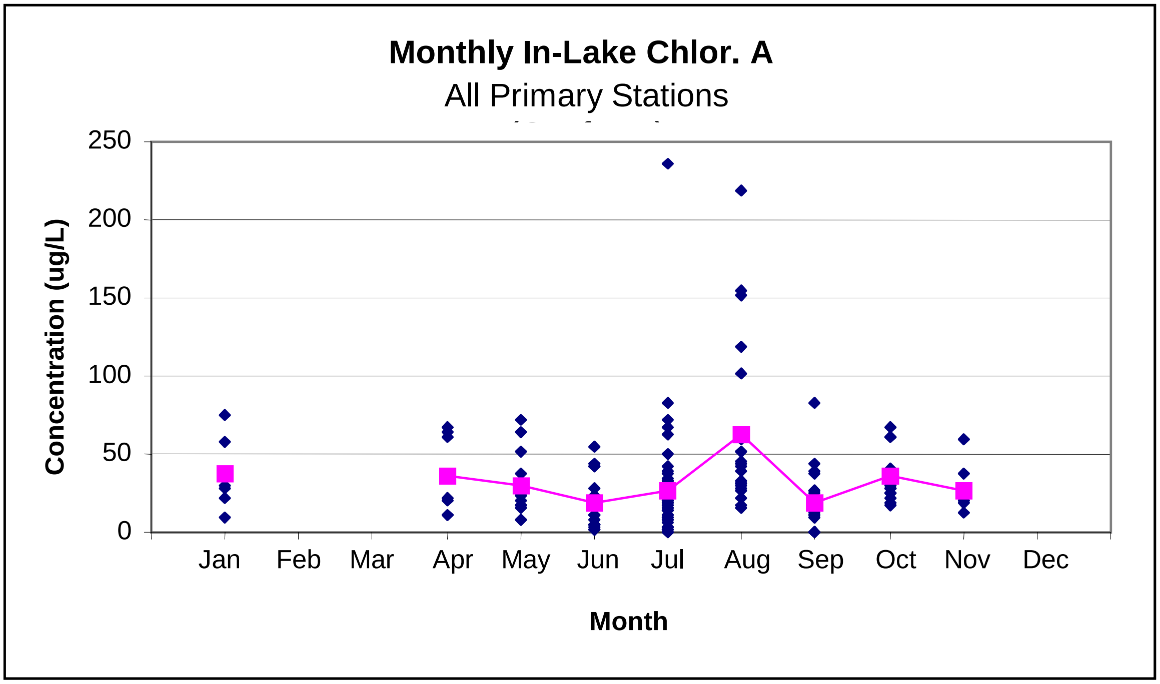
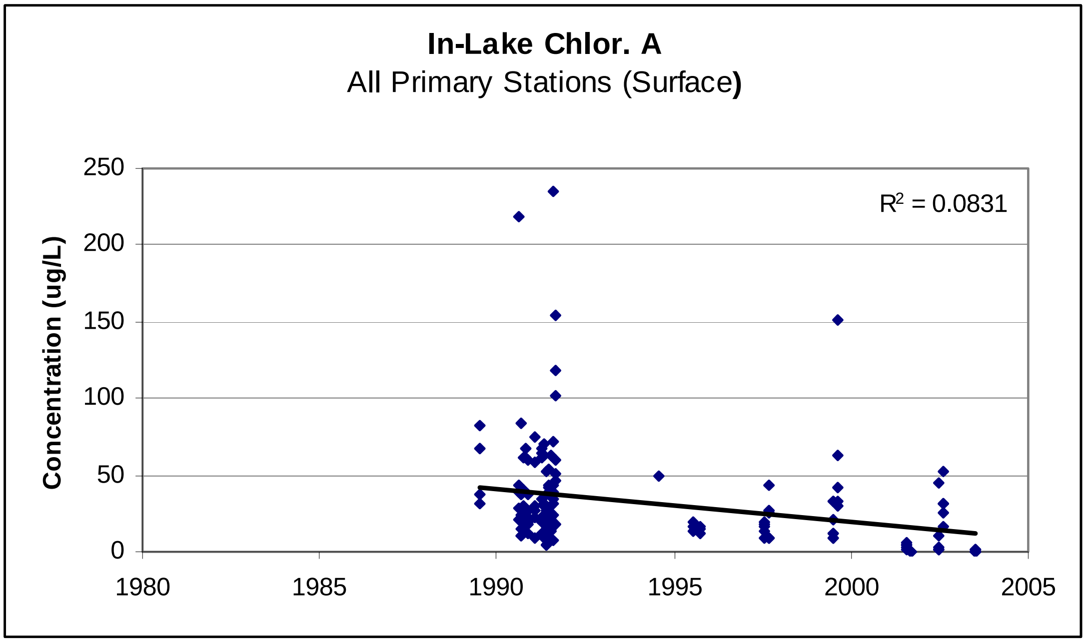


Figure 59: Chlorophyll A Historical Data – Primary In-Lake Stations



7.4 FISHERY

Fish populations in Utah Lake at the arrival of white settlers to the area were reported as healthy and robust, and as such, furnished an important part of the diet of early settlers. Preferred food fishes from Utah Lake were trout (Bonneville cutthroat trout) and suckers (June sucker and Utah sucker). By the late 1800's however, year-round fishing and unrestricted harvest had greatly reduced the numbers of fish in Utah Lake (Carter 1969). Population decline in Utah Lake suckers is predominantly due to commercial fish harvest starting in the late 1800s and early 1900s and from crowding and freezing during drought conditions and extensive irrigation withdrawal (Tanner 1936).

Recognition of the importance of fish as a food resource in the area of Utah Lake began as early as 1870 with the establishment of a committee on fish propagation to request fish from the U.S. Fish Commission for release as a food supply in the territory. Until 1899, the majority of fish introductions into Utah were part of this program. After 1900, most introductions of nonnative fishes were instituted by demands of sportsmen.

7.4.1 Fish Species Currently and Historically

Many native fish species have been extirpated (gone locally extinct) from Utah Lake, or do not exist in viable populations in Utah Lake including Bonneville cutthroat trout, June sucker, Utah sucker, Utah chub, leatherside chub and redside shiner. Multi-agency conservation plans are currently in place to manage Bonneville cutthroat trout and least chub, while the leatherside chub is considered a species of special concern by the State of Utah. The Utah Lake sculpin is considered extinct, and the June sucker is federally listed as endangered.

Table 10 presents a listing of fish species native to Utah Lake, non-native fish species currently present in the Lake, and a brief description of the current population status. The non-native species are listed in order of their introduction to the lake.

Table 10: Common Name, Scientific Name, and Status of Fish Species in Utah Lake

Common Name	Scientific Name	Status
Native Species		
Bonneville cutthroat trout	Oncorhynchus clarki utah	Extirpated from Utah Lake; reintroduced in small numbers in tributaries
mountain whitefish	Prosopium williamsoni	Rare in the lower Provo River, Locally common in the upper and midsection of the Provo River and drainages northward
June sucker	Chasmistes liorus	Federally endangered; rare in Utah Lake; small numbers of spawners in Provo River in spring
Utah sucker	Catostomus ardens	Rare in Utah Lake; small numbers of spawners in Provo River in spring; common in tributaries
mountain sucker	Catostomus platyrhynchus	Abundant in tributaries
Utah chub	Gila atraria	Extirpated from Utah Lake; common in tributaries
redside shiner	Richardsonius balteatus	Extirpated from Utah Lake; common in tributaries
leatherside chub	Gila copei	Rare in tributaries
least chub	Iotichthys phlegethontis	Extirpated from Utah Lake; persist in small numbers in the West Desert and Juab County; managed as a State Conservation Species
speckled dace	Rhinichthys osculus	Common to abundant in tributaries
longnose dace	Rhinichthys cataractae	Common in tributaries
mottled sculpin	Cottus bairdi	Abundant in tributaries
Utah Lake sculpin	Cottus echinatus	Extinct
Non-native Species		
black bullhead	Ameiurus melas	Introduced in 1871. Common in Utah Lake and tributaries; locally common statewide
common carp	Cyprinus carpio	Introduced in 1881. Abundant in Utah Lake and tributaries; common to abundant statewide
goldfish	Carassius auratus	Introduced in 1889. Rare in Utah Lake; some found in local stock ponds and aquaria
green sunfish	Lepomis cyanellus	Introduced in 1890. Locally common in Utah Lake; locally common statewide

Common Name	Scientific Name	Status
bluegill	Lepomis macrochirus	Introduced in 1890. Locally common in Utah Lake; locally common statewide
largemouth bass	Micropterus salmoides	Introduced in 1890. Locally common in Utah Lake
black crappie	Pomoxis nigromaculatus	Introduced in 1890. Locally common in Utah Lake; locally common statewide
yellow perch	Perca flavescens	Introduced in 1890. Common in Utah Lake; locally common in some lakes statewide
rainbow trout	Oncorhynchus mykiss	Introduced in 1897. Common in Utah Lake tributaries; stocked state wide to maintain recreational fishing
brown trout	Salmo trutta	Introduced in Utah in late 1890s. Common to abundant in Utah Lake tributaries; locally common in cold water streams statewide
channel catfish	Ictalurus punctatus	Introduced in 1911. Common in Utah Lake and tributaries; locally common statewide
smallmouth bass	Micropterus dolomieu	Introduced in 1912. Rare in Utah Lake, present in Jordanelle and Deer Creek Reservoirs
red shiner	Cyprinella lutrensis	Introduced in 1920. Rare in Utah Lake
western mosquitofish	Gambusia affinis	Introduced about 1930. Common to abundant in wetlands and marshes surrounding Utah Lake; still distributed for mosquito control
walleye	Stizostedion vitreum	Introduced in 1952. Common in Utah Lake
white bass	Morone chrysops	Introduced in 1956. Abundant in Utah Lake; present in the Sevier River drainage
fathead minnow	Pimephales promelas	Introduced in 1968. Locally common in Utah Lake and tributaries
smallmouth bass	Micropterus dolomieu	Stocked in Jordanelle Reservoir on the Provo River in 1994. Rare in the lower Provo River and Utah Lake

Of 30 species introduced, 16 exist as self-sustaining populations in Utah Lake, some of which represent the most abundant species in the basin and the main basis of the recreational sport fishery in Utah Lake (white bass, black bullhead, and black crappie). Black bullhead was the first nonnative fish species released into Utah Lake in 1871. A successful population was established and harvested commercially for several years. Common carp experienced similar success following their introduction in 1881, as did black crappie, bluegill, green sunfish, largemouth bass, and yellow perch in 1890. Recent introductions include channel catfish in 1911, walleye in 1952, and white bass in

1956. Nonnative fish species that are common to abundant in Utah Lake and its tributaries include carp, white bass, black crappie, yellow perch, black bullhead and others (Crowl and Thomas 1997). Together, carp and white bass account for most of the biomass and numbers of fish present in Utah Lake. Channel catfish are the third most abundant species as identified by gill-netting and observed catch rates. Distribution of fish within Utah Lake varies with species. Carp and white bass dominate open water habitat, littoral zones and vegetated areas have higher concentrations of young of all species.

7.4.2 Water Quality

Given the current low water and increased summer temperature trends identified for Utah Lake, appropriate fish habitat volumes as defined by acceptable dissolved oxygen and water temperature ranges are expected to be smaller than historic habitat volumes. This information will be used within the ongoing TMDL process to assess site potential for available habitat and designated beneficial use support.

The literature references and associated studies reviewed to date have demonstrated that the current populations of many fish species are greatly reduced relative to historic populations in Utah Lake. Many native fish species have been extirpated or do not exist in viable populations in Utah Lake today including Bonneville cutthroat trout, June sucker, Utah sucker, Utah chub, and redside shiner. Many nonnative fish species have been established in Utah Lake, some of which (carp, white bass, black crappie, yellow perch, channel catfish, walleye, and black bullhead) represent a threat to the continued survival of native species including June sucker (an endangered species). Together, carp and white bass account for most of the biomass and numbers of fish present in Utah Lake followed by channel catfish.

8.0 CONCLUSIONS AND RECOMMENDATIONS

One of the decisions that must be made during the initial phase of a TMDL study is the determination of whether the available data are sufficient to complete the study with a reasonable amount of confidence in the results. The amount of data which has been gathered for Utah Lake over the past two decades is substantial. There are, however, gaps in the data. Such gaps may be temporal (missing over an entire date range), seasonal (missing during certain seasons of the year), spatial (missing at specific locations), or a combination of these. Working with and drawing conclusions from data with significant gaps requires assumptions to be made where data are unavailable. Such assumptions are based on experience, professional judgment, and comparison with other systems. We recommend proceeding with the study and making any necessary assumptions. We also recommend the following additional sampling as the study moves forward. Acquiring data for one or two years would not be expected to significantly change the current data set, however, many years of sampling would serve to confirm results, validate assumptions, and to provide additional data for future studies.

Type of Data	Recommendation
Inorganic	▪ Ongoing, monthly, sampling of in-lake stations for as much of the year as possible. In-lake data is currently extremely limited, typically only occurring in July. This will aid in assessing water quality conditions at various locations within the lake. ▪ Monthly sampling of several of the minor tributaries for a period of one year. Water quality data for these tributaries is practically non-existent.
Flow	▪ Monthly sampling of several of the minor tributaries for a period of one year. This will serve to verify the water budget for the lake. Flow data for the minor tributaries dates back to the 1970s.
Biological	▪ Algae samples should be gathered whenever other water quality data are obtained. This will aid to further characterize diatom populations and distributions.

Appendix A
Bibliography

Year	Title and Author	Summary Information
1997	**Utah State Water Plan, Utah Lake Basin** Division of Water Resources (UDWR).	Summary: The State Water Plan provides the foundation and general direction for managing waters in the state. The Utah Lake Basin Plan identifies the principles that guide the water planning process. It also forecasts water demands through population projections then describes problems related to providing adequate water supplies, reducing shortages, improving instream flow for fish and wildlife, increasing recreational opportunities, and maintaining or improving water quality. Conclusion: Eighteen point sources, including eight municipal sewage treatment plants, discharge into Utah Lake. Non-point sources of pollution include agriculture, urban runoff, hydrologic modification, construction, recreation, habitat modification and natural background sources. Phosphorus concentrations are the biggest concern.
2002	**Utah Lake - Jordan River Watershed: Management Unit Stream Assessment** Thomas W. Toole Division of Water Quality	Summary: Samples collected at eighty monitoring sites from July 1, 1995 to June 30, 2000 within the Utah Lake-Jordan River Watershed Management Unit were used to assess water quality and to determine whether or not rivers and streams were supporting their designated beneficial uses. Conclusion: The major causes of impairment were metals, habitat alterations, flow alterations and pH. The major sources of impairment were resource extraction, habitat modification, hydromodification, and agricultural activities. Urban storm-water runoff is considered a significant source of organic loading that creates a large oxygen demand in the lower parts of the Jordan River that causes the oxygen level in the stream not to meet State standards.
2002	**Utah Water Quality Assessment: Report to Congress 2002** Dianne R. Nielson Don O. Ostler Jay B. Pitkin Michael K. Reichert Division of Water Quality	Summary: This report consists of the summary evaluations of the Sevier River and Utah Lake-Jordan River Watershed Management Units. The lake water quality assessment - Trophic Status - Control and Restoration Efforts - Impaired and Threatened Lakes - Acid Effects on Lakes - Toxic Effects on Lakes - Trends in Lake Water Quality Conclusion: The major sources of stream impairment were resource extraction, habitat modification, hydromodification, and agricultural activities. They affected 5.0, 4.3, 3.8, and 3.8 percent respectively of the stream miles assessed.

Year	Title and Author	Summary Information
2003	**Utah Lake Drainage Management Plan: Hydrologic Unit 16020201** Charles W. Thompson Donald E. Wiley Kristine W. Wilson M. Jane Perkins	Summary: The Utah Division of Wildlife Resources (UDWR) is developing Drainage Management Plans for each Hydrologic Unit in Utah. The intent of these plans is to identify and provide comprehensive management objectives for hydrologic units and to outline actions necessary to meet these objectives. Management by UDWR will focus on maintenance of healthy aquatic habitats and native species biodiversity, as well as meeting the public demand for recreational sport fishing opportunities. Conclusion: Changes in water quality ultimately affect the fish and wildlife species, often times making the habitat less suitable. Significant flow reductions often result in increased water temperatures and concentrations of minerals and nutrients, decreased dissolved oxygen levels, as well as an increase in undesirable vegetation such as algae. Measures are currently being taken to address water quality issues; however, management activities will need to continue to focus on implementing actions that improve and/or maintain water quality in streams, reservoirs, lakes, and wetlands.
2000	**Utah Lake: Lake Reports** Division of Water Quality	Summary: The Utah Lake Report (Division of Water Quality (2000) assesses the recreational, limnological, and water quality aspects of the Utah Lake Watershed. This document summarizes current events and activities in the watershed. Conclusion: Nonpoint pollution sources include the following: waste and litter from recreation; treated sewage, household chemicals, and oils from urban areas; toxins, nutrients, and heavy metals from industry; pathogens, sediments, nutrients, chemicals from agriculture; and sedimentation and nutrient loading from grazing, construction or development. Gravel pits and constant construction in Utah Valley result in a continuous influx of sediments. All commercial mines and timber sales are buffered by one or more reservoirs. Agricultural use of lands occurs in direct proximity to the lake shore in many areas. Point sources of pollution in the watershed include municipal and industrial discharges directly into the lake or in tributaries that are in close proximity to the lake itself.

Year	Title and Author	Summary Information
2003	**Water Quality at Fixed Sites in the Great Salt Lake Basins, Utah, Idaho, and Wyoming, Water Years 1999–2000** Steven J. Gerner U.S. Department of the Interior U.S. Geological Survey	Summary: This report describes the GRSL study unit fixedsite network and summarizes water quality data collected at the fixed sites; which includes measurements of major ions, nutrients, trace elements, suspended sediment, and organic compounds in water samples. Occurrence and distribution of these constituents is compared to land use to evaluate the effect of land use on stream water quality. Nutrient concentration in water samples from sites was compared with established guidelines to assess whether a site may have a propensity for eutrophication. Trace metal, pesticide, and volatile organic compound (VOC) concentrations in water samples from sites were evaluated by comparing them with established toxicity guidelines for aquatic life. Conclusion: Areas of concern identified in the Utah Lake/Jordan River drainage basin include metals, dissolved-solids concentration, sediment, fecal coliform, flow and riparian alteration (Utah Department of Environmental Quality, 2002a, 2002b).

Year	Title and Author	Summary Information
1980	**Utah Lake Phase I, Report #1: Quantity and Quality of Goshen Bay Inflows.** Eyring Research Institute, Inc. Brigham Young University. July 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Ashcroft, Wallis and LaVere B. Merritt.	Goshen Bay, Utah Lake's southern arm, occupies approximately one-fourth of Utah Lake. It has been proposed by the U. S. Bureau of Reclamation that Goshen Bay be diked off from the main lake. This would decrease the evaporation from the surface of the lake. Although no perennial surface flows enter Goshen Bay, water enters the basin from groundwater sources, surface runoff, and one intermittently flowing surface tributary. The quantity and quality of the water entering Goshen Bay affects the water and salt balances of the lake. This report presents existing information concerning the inflows to Goshen Bay, and to develop estimates of the diffuse groundwater inflows. Simple techniques of estimation of inflows using correlation of existing groundwater quality and lake water quality data and previous observations of the lake. Total average inflow to Goshen Bay is tentatively estimated to be about 37,000 ac-ft/yr.
1981	**Utah Lake WHAB Phase I Report: Utah Lake Littoral Community Analyses**, October 1978. Eyring Research Institute, Inc. Brigham Young University. February 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Barnes, James R., Dennis K. Shiozawa, Reed Y. Oberndorfer, J. Vaun McArthur.	In order to understand the littoral communities of Utah Lake, samples were taken along two distinct shorelines in October, 1978. The data were analyzed to determine relationships between species and the surface area of the rocks. Diversity indices were computed for each site and compared. The high significant difference between the total communities at the different locations indicates that lake location is more important to community production than substream type.
1998	**Geologic Analysis of Continuous High-Resolution, Seismic-Reflection Data From the Lincoln Point – Bird Island Area, Utah Lake, Utah.** U. S. Geological Survey, Water-Resources Investigations Report 96-4236. Salt Lake City, UT. 1998. Baskin, Robert L. and Henry L. Berryhill, Jr.	U.S. Geological Survey investigated the hydrology of the Lincoln Point – Bird Island area in the southeast part of Utah Lake. The investigation included measurements of the discharge of selected springs and measurements of the physical and chemical characteristics of water from selected springs and wells. This report contains data for twenty-one distinct springs in the study area including two springs beneath the surface of Utah Lake at Bird Island. Total discharge in the study area is estimated to be about 5 cubic feet per second. Temperatures from springs ranged from 16.0 degrees Celsius to 36.5 degrees Celsius. Dissolved-solids concentrations ranged from 444 milligrams per liter to 7,932 milligrams per liter. Spring water from Lincoln Point was identical to the water from Bird Island springs, indicating a similar source for the water.

Year	Title and Author	Summary Information
1994	**Physical Characteristics and Quality of Water From Selected Springs and Wells in the Lincoln Point – Bird Island Area, Utah Lake, Utah**. U. S. Geological Survey, Water-Resources Investigations Report 93-4219. Salt Lake city, UT. 1994. Baskin, Robert L., Lawrence E. Spangler, and Walter F. Holmes.	The U.S. Geological Survey conducted a seismic investigation of the shallow subsurface sediments in the Lincoln Point-Bird Island area of Utah Lake, using a continuous, high-resolution profiler. This investigation was designed to identify the depositional , structural , and erosional features preserved in the sediments of areas where spring water may be entering Utah Lake to estimate the path that groundwater may take to the springs. Faulting is prominent with only minor offset. Faults possibly underlie mound-shaped structures. The principal structure is a dome beneath and including the Bird Island area. The mound-shaped structures are probably travertine deposits deposited by precipitation from warm water leaking upward along faults.
1963	**Lake Bonneville: Geology of Southern Utah Valley Utah.** Geological Survey Professional Paper 257-B. U. S. Department of the Interior. U. S. Government Printing Office. Washington. 1963. Bissell, Harold J.	Southern Utah Valley is an area at the east edge of Pleistocene Lake Bonneville. The valley floor consists mostly of sediments of Lake Bonneville and younger lakes. The sediments of Lake Bonneville consist of three formations: the Alpine (oldest), Bonneville, and the Provo (youngest). Post-Provo deposits include those of Utah Lake and alluvium of Utah Lake age, deposited on the youngest fans and modern stream flood plains.
1976	**Reconnaissance Study of Deep- Water Springs and Strata of Utah Lake.** Mountainlands Association of Governments Technical Report 3. Provo, UT. 1976. Brimhall, Willis H., Irvin G. Bassett, and LaVere B. Merritt.	The purpose of this paper is to report the results of a new way to examine the floor of the lake with respect to the character and distribution of its sediments and its springs. Little direct information has been available about the lake floor because the waters are so opaque that direct inspection of the floor is impossible. Means to “see” through the water and into the sediments is afforded by a sonar-like device called an “acoustical sub-bottom profiler” which sends short bursts of sound energy into the water and the sediments below and records the reflections of the sound from differing layers in the substrate. Such an instrument is well-suited to the recognition of springs, faults folds, and varying sediment layers in the substrate of the lake. The thickness, distribution, and character of the sediments of Utah Lake, to a depth of as much as 20 meters (66 feet) were evaluated. Thirty-eight deep-water spring areas were located: twenty-five eastern and northeastern shore and the remaining distributed sporadically over the remainder of the lake.

Year	Title and Author	Summary Information
1981	**Geology of Utah Lake: Implications for Resource Management.** *Great Basin Naturalist Memoirs: Utah Lake Monograph* . No. 5. Brigham Young University. Provo, UT. 1981. Brimhall, Willis H. and LaVere B. Merritt.	Utah Lake is a remnant of Lake Bonneville, from which it originated about 8,000 years ago. Analysis of sediment cores reveals significant variations in lake salinity and sedimentation rates. Long-term sedimentation rates are estimated at about 1 mm (0.039 in) per year, but post-colonization rates appear to be about 2 mm (0.079 in) per year. Faults in the lake appear to be lowering the lake bottom at about the same rate as sediment has been filling it. Lake bottom springs are localized along the eastern and northern lake margins where all major tributaries occur and groundwater recharge is largest. In a geological sense, Utah is an old lake—shallow, turbid, and slightly saline—and has been since its “birth” with the demise of Lake Bonneville.
1980	**Utah Lake WHAB Study: Goshen Bay Sediments: Carbonate Concentrations, Particle Sizes, Shrinkage, and conversion of Sediment to Soil.** Eyring Research Institute, Inc. Brigham Young University. July 1980. (prepared for Water and Power Resources Service, U.S. Department of the Interior) Brimhall, Willis H. and LaVere B. Merritt.	In Utah Lake the sediments are especially noteworthy because the lake is so broad and shallow. Intimate contact of sediment and water is not only inevitable, but extraordinarily expressed. The present investigation is a detailed study of the distributions of carbonate content, shrinkage characteristics, particle size distribution, and conversion of lake sediment to soil in those sediments flooring Goshen Bay. During February and March 1979, 102 specimens of Utah Lake sediments were obtained in Goshen Bay. Inspection showed that the great majority were fine grained; only a few of the more than 100 samples were suitable for dry sieving. The distribution of sediments percent grain size passing a 230 mesh sieve was 97 percent, and such sediments occupy all but the near shore region.
1999	**Diamond Fork System Final Supplement to the Final Environmental Impact Statement.** Bonneville Unit Central Utah Project. Central Utah Water Conservancy District. July 1999. Central Utah Water Conservancy District	This Diamond Fork System Final Supplement addresses potential impacts related to construction and operation of the features proposed for completing the Diamond Fork System. This document is intended to satisfy disclosure requirements of NEPA and, as the document for contracts, agreements and permits would be required for construction and operation of the Diamond Fork System. Features proposed to complete the Diamond Fork System were covered in the Spanish Fork Canyon-Nephi Irrigation System Draft Environmental Impact Statement. Concerns dealt with purpose and need and operation of the irrigation portion, not the features required to complete the Diamond Fork System. This contains four chapters: Description of the Proposed Action and No Action, Comparative Analysis, Environmental Consequences, and Consultation and Coordination.

Year	Title and Author	Summary Information
1980	**Hydrolgeology of Utah Lake with Emphasis on Goshen Bay.** Utah Geological and Mineral Survey Water Resources Bulletin 23. Salt Lake City, UT. 1980. Dustin, Jacob D. and LaVere B. Merritt.	This investigation of the hydrogeology of Utah Lake indicates that available aquifer recharge has been traditionally underestimated; the depth of valley fill is probably twice that previously supposed; artesian pressures force a considerable amount of groundwater upward through confining sedimentary layers; and water may pass from Cedar Valley into Goshen Valley. Diffuse seepage accounts for the majority of subsurface inflow to the lake; and the total annual subsurface inflow is in excess of 100,000 acre-feet. Groundwater flowing into Goshen Bay is of a relatively low quality and the maximum volume is estimated to be on the order of 18,000 acre-feet per year.
1981	**Hydrology and Water Quality of Utah Lake.** *Great Basin Naturalist Memoirs: Utah Lake Monograph*. No. 5. Brigham Young University. Provo, UT. 1981. Fuhriman, Dean K., LaVere B. Merritt, A. Woodruff Miller, Harold S. Stock.	This paper summarizes hydrological and water quality findings from investigations over the past 10 years. Water and salt balances on Utah Lake for the July 1970 to July 1973 period show both evaporation and groundwater to be somewhat larger than previously estimated by others. The lake is eutrophic, turbid, and slightly saline, as might be expected in a shallow, basin-bottom lake in a semi-arid area. Overall water quality in the lake is fair to good and appears to be controlled more by natural factors than by the activities of man. An increase in total dissolved solids (TDS) from about 300 mg/l in major surface and shallow groundwater inflows to about 900 mg/l in the main lake is the most significant water quality change. Calcium carbonate precipitation from the lake waters accounts for about 40 percent of the long-term rate of sediment buildup.
1975	**Water Quality Effect of Diking a Shallow Arid-Region Lake.**" National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency. Corvallis, Oregon. April 1975. Fuhriman, Dean K., LaVere B. Merritt, Jerald S. Bradshaw, and James R. Barton.	The inflow, outflow, and in-lake water quality and quantity of Utah Lake in Central Utah were studied over a 36-month period. The work was undertaken to determine the effect of a proposed diking project on the quality and quantity of lake water. A computer model was developed to analyze the effect of a given management program on the water quality of the lake, particularly as related to the "conservative salts." The research indicates that the diking of Utah Lake will have a positive beneficial effect upon the water quality of the lake and will also result in considerable saving of water. Diking will result in salvaging about 75,000 acre-feet of water per year. It will improve the water quality since much of the water that would evaporate remains in the lake as "dilution" water. The computer simulation model developed as part of this project may be used to investigate effects of many other water management alternatives.

Year	Title and Author	Summary Information

Year	Title and Author	Summary Information
1981	**Utah Lake Phase I, Report #12: Utah Lake Surface Inflows and Outflows, 1920-1980.** Eyring Research Institute, Inc. Brigham Young University. January 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Fuhriman, Dean K. and LaVere B. Merritt.	Utah Lake surface and subsurface waters fluctuate widely on a seasonal basis and during longer wet and dry cycles. This report gives the estimated and measured flowrates for surface inflows during the 1930-1980 period which were developed for hydrologic and simulation purposes. This report addresses only the surface inflows. The U. S. Bureau of Reclamation has made measurements of some tributary inflows to the lake and these have been made available. Intensive measurement of surface water inflows into Utah Lake were initiated in July of 1970 and continued through June of 1973. Long-term management and efficient utilization of the water resources of Utah Lake requires quantitative estimates of historic inflows. The resulting simulations for the 1930-1980 period are discussed in the report. Developing correlations for tributary inflows complicated by the fact that most of the tributaries are subject to many diversions.
1969	**Hydrologic Inventory of the Utah Lake Drainage Area.** Utah Study Unit No. 4-1 (Upper Jordan). Utah Water Research Laboratory, College of Engineering, Utah State University. Logan, UT. November 1969. Hyatt, M. Leon, Gaylord V. Skogerboe, Frank W. Haws, and Lloyd H. Austin.	Utah State Legislature authorized the Utah Division of Water Resources to develop a state water plan concerned with Utah's water resources. The work reported herein was conducted by the Utah Division of Water Resources and the Utah Water Research Laboratory. The hydrologic basin described in this report is above the "Jordan River at Narrows" gaging station or the Utah Lake drainage area. A study designed to account for the water which appears an runoff, to isolate opportunities for improvement in the way water is managed and to indicate opportunities for increasing the effective supply by eliminating nonproductive uses.
1940	**A Report of Utah Lake Drainage Area Irrigation Surverys.** Utah Agricultural Experiment Station (Projects 151 and 179c); U. S. Soil Conservation Service, Irrigation Division (Project 3201); U. S. Work Projects Administration (Utah) (Project 665-01-3-4). 1940. Israelsen, O. W., Wayne D. Criddle, and Eldon M. Stock.	This volume constitutes irrigation surveys in the three Counties of Utah, Wasatch, and Summit during the years 1937 to 1939 inclusive. The irrigation surveys include nearly all of the cultivated land from which water flows by gravity toward the Utah Lake. There has been well-recognized need for reliable and detailed information concerning the basic agricultural resources and the translation of such information into programs of more efficient use. The resume of the activities of Experiment Station is presented to clarify their aims and progress.

Year	Title and Author	Summary Information
1981	**Physical and Cultural Environment of Utah Lake and Adjacent Areas.** *Great Basin Naturalist Memoirs: Utah Lake Monograph*. No. 5. Brigham Young University. Provo, UT. 1981. Jackson, Richard H. and Dale J. Stevens.	Utah Lake and its surrounding area have a rich natural and cultural background. The moderate climate, abundant fresh water, and fertile soils of Utah Valley made it an oasis to aboriginal dwellers as well as to the present inhabitants. An overview of the physical setting, geology, climate, human use, and recent history of Utah Lake is presented.
1992	**Draft Preliminary Planning Report, Utah Lake Salinity Control Studies.** Provo River/Utah Lake Special Studies Program. Central Utah Water Conservancy District. August 1992. James M. Montgomery Consulting Engineers. (Contributing team members LaVere Merritt and Woodruff Miller.)	This Preliminary Planning report has been prepared to document the investigations for the Utah Lake Salinity Control Studies of the CUP Completion Act. The objective of the Utah Lake Salinity Study is to identify and evaluate the potentially viable alternative plans to reduce salinity levels in Utah Lake. At the present time it is envisioned that plans will be needed to reduce future impacts on the salinity levels in the lake by approximately 400 mg/L. Quality control measures included strict adherence to federal water planning procedures and proper attention to public and environmental concerns. The U.S. Geological Survey is under contract to study the location, flow, and water quality of saline springs which enter Utah Lake. The early findings of the USGS have been used in the analyses of salt reduction plans. LKSIM model was used to predict reduction in salinity levels in Utah Lake to several scenarios. Probable future conditions on Utah Lake can be identified and conceptual plans for reducing salinity levels can be based on future scenarios. A total of four basic concepts were formulated for reducing salt inflow to Utah Lake: desalt or evaporate saline springs, desalt Utah Lake water from the Goshen bay area, accelerated salt transport mechanism, and sheet pilings around Saratoga area springs.

Year	Title and Author	Summary Information
1992	**Draft Preliminary Planning Report Appendices, Utah Lake Salinity Control Studies.** Provo River/Utah Lake Special Studies Program. Central Utah Water Conservancy District. August 1992. James M. Montgomery Consulting Engineers. (Contributing team members LaVere Merritt and Woodruff Miller.)	Appendices: (A) ULTAC Meeting Minutes, (B) Public Involvement, (C) USGS Work Plan, (D) Tributary Correlations and Precipitation Inflows, (E) Statistical Analysis of Major Ions, (F) Evaporation Study, (G) Task 1.0 Memorandum, (H) Updated Hydrologic and Quality Data, (I) Computer Runs, (J) Cost Estimates of Desalting Plants, (K) Costs of Concepts, (L) Water Users, and (M) Future Work.
1981	**Utah Lake Phase I, Report #17: Ground Water Quality Along the Eastern Margin of Utah Lake.** Eyring Research Institute, Inc. Brigham Young University. March 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) King, Robert V., LaVere B. Merritt.	One of the most difficult investigations in water resources is the investigation of ground water quantity and quality. This is due to inaccessibility of the water. Ground water can vary considerably in quality over relatively short distances, since the character of the underground strata and/or recharge source may change considerably. Residence time also is a determining factor in the quality of the water; the longer the residence time, the greater the quantity of dissolved salts. Utah Lake receives considerable underground inflow along its eastern margin. This ground water flows in the many aquifers which begin along the Wasatch fault to the east of Utah Lake. The ground water quality along the eastern margin of Utah Lake does not vary significantly with the depth. The exception is the Tertiary aquifer where there is a significant improvement in the quality. The northern section of Utah valley is estimated to contribute approximately twice as much inflow as does the southern section.
1981	**Utah Lake Phase I, Report #23: Simulation of Future Water Balances and Lake Quality for Utah Lake for Several CUP Alternatives.** Eyring Research Institute, Inc. Brigham Young University. December 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Merritt, LaVere B., A. Woodruff Miller, Dean K. Fuhriman, Willis H. Brimhall.	This report is the sequel to WHAB Phase I report #19: "Simulation of Utah Lake Water Balance and Water Quality, 1930-1979" which established the data base and presented simulations for the 50-year "historical" period. This report is also a companion report to report #20, "Present and Projected Water Quality Conditions in Utah Lake and Relationship to the CUP". Simulated future conditions are presented herein for a number of different diking alternatives being considered for Utah Lake as part of the Bonneville Unit of the Central Utah Project. These correspond in general, to conditions simulated in earlier USBR studies. The LKSIM model was used to calculate "simulations" for various Utah Lake alternatives. The LKSIM model is a "bookkeeping" model that carries along a mass balance of both the water and the ions (salts) in the lake.

Year	Title and Author	Summary Information
1981	**Utah Lake Phase I, Report #21: Tabulation of Water Quality Data for Utah Lake and Its Tributaries, Volume I: Tributaries.** Eyring Research Institute, Inc. Brigham Young University. June 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Merritt, LaVere B. and A. Woodruff Miller.	This report contains water quality data for Utah Lake (Volume II) and its tributary waters (Volume I), including its outflow, the Jordan River. The main purpose of this report is to present a tabulation of raw data generated from May 1977 to November 1980 in studies sponsored by the U. S. Bureau of Reclamation. To make this data tabulation more useful, other available data for the WHAB field sites were collected and included herein. Available data for sites not used in the WHAB studies were not included. Since the WHAB sites were selected to give the overall water quality picture of the lake, little was sacrificed by this limitation. Data in this report are from the following sources: WHAB studies, “208” water quality planning, and unpublished USBR report (Veirs, 1964).
1981	**Utah Lake Phase I, Report #21: Tabulation of Water Quality Data for Utah Lake and Its Tributaries, Volume II: Lakes Sites.** Eyring Research Institute, Inc. Brigham Young University. June 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Merritt, LaVere B. and A. Woodruff Miller.	This report is a tabulation of all water quality and flow data.
1980	**Utah Lake WHAB Study: Simulation of Utah Lake Water Balance and Water Quality, 1930-1979.** Eyring Research Institute, Inc. Brigham Young University. December 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Merritt, LaVere B., Dean K. Fuhriman, Willis H. Brimhall, A. Woodruff Miller.	Chemical water quality data for Utah Lake prior to 1956 are very limited. The Lake’s hydrology presents great difficulties in accurately quantifying some components of the water budget. Inflowing waters vary widely in quality during annual and long-term cycles. Man’s activities in the Utah Lake drainage basin have caused significant water quality changes in addition to changes in the basin’s hydrology. This report sets forth one major part of the evaluation of the hydrologic and water quality impacts of the Central Utah Project on Utah Lake; namely a 50-year simulation of the Lake from October, 1929 to October, 1979.

Year	Title and Author	Summary Information
1980	**Utah Lake WHAB Study: Utah Lake Evaporation Study.** Eyring Research Institute, Inc. Brigham Young University. July 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Miller, A. Woodruff and LaVere B. Merritt.	See paragraph below for summary of this report.
1980	**Utah Lake Phase I, Report #24: Utah Lake Evaporation Study.** Eyring Research Institute, Inc. Brigham Young University. July 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Miller, A. Woodruff, LaVere B. Merritt, Dean K. Fuhriman.	Lake water budgets require precipitation, surface inflow and outflow, groundwater inflow and outflow, evaporation, and storage (water level) changes. Typically, all terms except groundwater and evaporation can be measured to some reasonable reliability. Groundwater has been very difficult to measure or estimate. Therefore, accurate evaporation data are essential. Evaporation pan measurements are available. However, at least two problems occur with the use of these data: no winter evaporation pan measurements and the pan coefficients. The Morton mathematical model determines reliable monthly evaporation values. The report was completed in July 1980. Subsequent studies indicated evaporation is likely some 12% larger. Also, there is a newer version of the model which now includes a heat storage component. This gives an improved monthly distribution of evaporation; lower values in the spring and early summer when water temperatures are low and higher values in the late summer and fall when the water temperatures are higher.
1980	**Utah Lake WHAB Study: Climatological and Hydrological Data from Utah Lake Studies for May 1977 Thru October 1980.** Eyring Research Institute, Inc. Brigham Young University. December 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Miller, A. Woodruff, LaVere B. Merritt, Dean K. Fuhriman.	Climatological and hydrological data were collected and analyzed by investigators from May 1977 to October 1980. Measurements included lake stage, tributary flow rates, precipitation, summer and winter evaporation, air and water temperatures, humidity, solar radiation, and windspeed. Measuring stations were at the LDS Church Farm near Mosida, at West Mountain near Lincoln Point, at Pelican Point, at the Provo Airport, at the BYU boat house, and on all ungaged tributaries. In addition, data were collected from existing stations.

Year	Title and Author	Summary Information
1980	**Utah Lake Phase I, Report #26: Utah Lake Tributaries Water Quality Study.** Eyring Research Institute, Inc. Brigham Young University. April 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Miller, L. Steven.	A study has been made to evaluate the environmental impact on Utah Lake due to possible diking schemes. Routine tributary sampling defines the quality of the lake inflow and the flowrate and quality patterns of the tributaries. These data, along with that of previous studies, were merged in this study as the base for determining the quality of the tributaries. For the purpose of determining the quality of changes in the lake, correlations between ion concentration and flowrate magnitude and/or time of year in the tributaries were developed. For the “minor” tributaries the arithmetic mean value of the ion concentration can be used. The major tributaries needed a more intensive statistical analysis with correlation equations between the concentration of the ions in the water and the quantity of water flowing.
1992	**Utah Lake Development Feasibility Study.** Economic Development Administration. October 1992. Naylor, Clyde and Homer C. Chandler.	Utah Lake is a resource that has virtually gone untouched in recent years. Utah Lake has a recreational potential as yet unrealized. Pioneers recognized the lake as a source of recreation and took steps to develop it. However, most of these went out of business. A renewed interest could be critical to the future of Utah County. Present developmental efforts are at a standstill. This is not to say that there is no interest in further development. Many ideas have been presented but have been unsuccessful because of the lack of plan funding and approvals for development.
1980	**Utah Lake WHAB Study: Winter Phytoplankton Communities of Goshen Bay, Utah Lake, Utah.** Eyring Research Institute, Inc. Brigham Young University. December 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Rushforth, Samuel R., Judith Grimes, Adchara Javakul.	Due to a need to assess water quality and biological communities during winter months, it was decided to perform a systematic collection of water and biological samples through the ice on Goshen Bay during February and March of 1979. Total phytoplankton samples were collected by obtaining unfiltered water directly from the lake through holes opened in the ice. A total of 21 non-diatom species and 159 diatom species were identified during this study.

Year	Title and Author	Summary Information
1999	**Phase I EPA Clean Lakes Study: Diagnostic and Feasibility Report On Utah Lake.** Brigham Young University. Provo, UT. May 1999. Sowby and Berg Consultants, A. Woodruff Miller, Ray Loveless, Dave Wham.	A Clean Lakes 314 Water Quality Study for Utah Lake was jointly funded by the Environmental Protection Agency, Utah Department of Environmental Quality and Mountainland Association of Governments. Field and laboratory monitoring of water quality in the lake and watershed started in August of 1990 and continued until August of 1992. The objectives of the study included: review of background information, identify and quantify pollution sources, develop a nutrient budget, define existing water quality conditions and trophic state, evaluate the lake's sediments, inventory macrophyte diversity, determine agricultural impacts on the lake, determine loss and benefits from water quality problems. The study assessed the data collected Clean Lakes Phase I Diagnostic and Feasibility Study and by the Utah division of Water Quality. Utah Lake is a hyper-eutrophic lake which is subject to excessive algae growth from year to year due to high level of nutrients, primarily phosphorus, which enter the lake from several sources. Eighteen point sources, which include eight municipal sewage treatment plants, have discharges which enter Utah Lake. Those discharges contribute the largest percentage of phosphorus to the lake. Nonpoint sources of pollution which also contribute to the lake include agriculture, urban runoff, hydrologic modification, construction activities, recreation, habitat modification, and natural background sources.
1994	**Phase I Clean Lakes Study: Diagnostic and Feasibility Report on Utah Lake.** December 1994. Sowby and Berg Consultants and Ray Loveless.	A Clean Lakes 314 Water Quality Study was conducted. Field and laboratory monitoring of water quality in the lake and watershed started in August of 1990 and continued until August of 1992. The objective of the study included: background, identify pollution sources, nutrient budget, existing conditions and trophic state, sediments and nutrients, macrophytes, agricultural impacts, benefits of water quality, alternatives, and costs.

Year	Title and Author	Summary Information
1998	**Spanish Fork Canyon-Nephi Irrigation System Bonneville Unit Central Utah Project.** Summary of the Draft Environmental Impact Statement. Central Utah Water Conservancy District. March 1998. Central Utah Water Conservancy District	This document provides a summary of the Draft Environmental Impact Statement prepared for the Spanish Fork Canyon-Nephi Irrigation System (SFN System). The CUWCD prepared the DEIS to assess the environmental effects related to the construction and operation of the proposed SFN System. The SFN System develops Utah's water resources for irrigation, municipal and industrial (M&I), fish and wildlife, and recreational uses to southern Utah County and eastern Juab County, extending as far south as the Nephi area. Also proposed changes in the Diamond Fork System were addressed. The two systems are interdependent and the components and operation of the Diamond Fork System have changed.
1998	**Spanish Fork Canyon-Nephi Irrigation System Bonneville Unit Central Utah Project.** Draft Environmental Impact Statement. Central Utah Water Conservancy District. March 1998. Central Utah Water Conservancy District	This report describes water conveyance facilities to (1) deliver transbasin supplemental irrigation water to southern Utah and eastern Juab Counties, (2) deliver transbasin M&I water to Utah Lake in exchange for M&I water developed from groundwater, and (3) deliver water to Utah Lake for exchange to Jordanelle Reservoir. The facilities consist of the hydraulic connection between the Diamond Fork System and the Main Conveyence Aqueduct. This contains a comparative analysis of the Proposed Action and alternatives on Utah Lake, Jordan River, Great Salt Lake, and Colorado River fish.
1998	**Spanish Fork Canyon-Nephi Irrigation System, Draft Environment Impact Statement.** Draft Hydrology and Water Resources Technical Report. Central Utah Project Completion Program. Central Utah Water Conservancy District. March 1998. Central Utah Water Conservancy District	The *Hydrology and Water Resources Technical Report* analyzes potential impacts to surface water, groundwater, and water quality, exclusive of constituents such as metals and organics that are considered in the *Environmental Contaminants Technical Report*. The impacts considered in this report include those of the Spanish Fork Canyon-Nephi Irrigation System (SFN System) and those of local actions related to the SFN System to improve water use efficiencies. This report also considers impacts in Sixth Water Creek and Diamond Fork Creek, which could be impacted by the coordinated operation of the Diamond Fork System and by minimum streamflows as mandated by CUPCA. Related information is also presented in the *Utah Lake Hydrology Technical Report*. The significance of water resources and hydrology effects are assessed in this report with relation to regulatory standards.

Year	Title and Author	Summary Information
1998	**Spanish Fork Canyon-Nephi Irrigation System, Draft Environment Impact Statement.** Draft Utah Lake Hydrology Technical Report. Central Utah Project Completion Program. Central Utah Water Conservancy District. March 1998. Central Utah Water Conservancy District	The purpose of the Utah Lake Hydrology Technical Report is to identify and document impacts of the Bonneville Unit on Utah Lake water resources. This information is a basis for describing the total and cumulative impacts on Utah Lake for the Spanish Fork Canyon-Nephi Irrigation System. The technical studies described herein reflect CUPCA re-formulation of the SFN System and other project modifications.
1976	**Draft Environmental Impact Statement for Utah Lake-Jordan River Water Quality Management Planning Study.** Region VIII, Denver, Colorado. April 1976. U.S. Environmental Protection Agency.	This environmental impact statement (EIS) is the end result of a decision by EPA to issue a full scale EIS on the Utah Lake-Jordan River Water Quality Management Planning Study. This report deals with the background, facility alternatives, and environmental impacts. The detailed environmental impacts are divided into water, land, and air resources. As natural resources have dwindled, a greater emphasis on management of resources has occurred. Water quality management has come to the forefront as a critical resource management issue. The Utah Division of Health undertook a major water quality management study for the Utah Lake-Jordan River Hydrologic Basins. The basic purpose of the study was to develop a comprehensive plan for determining the direction of future water quality control activities.
1994	**Utah Lake Wetland Preserve.** U. S. Department of Interior and Utah Reclamation Mitigation and Conservation Commission. Central Utah Project Completion Act, Title III Section 306(c)(9). September 1994. Utah Division of Wildlife Resources. Joel Huener, Marilyn Pratt, Kevin Robinette, Bill James.	The work described herein was conducted for the fundamental purpose of producing a completed Acquisition and Management Plan to guide procurement and subsequent management of private land, water, water rights, easements, or other interests located adjacent to or near the Goshen Bay and Benjamin Slough areas of Utah Lake, to establish the Utah Lake Wetland Preserve. Public meetings were held in an attempt to identify issues and to highlight opportunities. Background data assembled for the report describe soils, water, existing ownership patterns, current land uses, water rights, vegetative communities, and endemic wildlife and fish populations.

Year	Title and Author	Summary Information
1994	**Recommendations for the Restoration, Protection, and Economic Development of the Water and Lands of the Utah Lake Environment.** A Report to Governor Michael O. Leavitt. November 1994. Utah Lake Task Force.	Recommendations for the restoration, protection, and economic development of the water and lands of the Utah Lake environment. The Utah Lake Task Force has studied the many and varied issues involving Utah Lake. The Task Force has listened to testimony of various specialists and has reviewed previous studies of the Lake. Utah Lake Task Force recommends the following: (1) create a Utah Lake Commission/Coordinating Council and (2) resolve boundary issues relating to Utah Lake.
1989	**Utah Lake Study Engineering Report.** Utah County Engineer. Provo, UT. March 1989. Utah County Engineer	Utah Lake should be developed and the water quality improved. This study of Utah Lake is being presented as a beginning point to identify likely elements which may be ready to proceed. The major elements are water quality improvements, dredging, Provo-Jordan River Parkway, improvements to the existing boat harbors, a causeway to link with the West Lake Freeway, and a bird refuge. Studies made during the past decade indicate that most people turn to our state's lakes and streams to satisfy their recreational pursuits. It is wise to consider how we can best develop our natural resources in order to provide for our future recreational needs. Utah Lake is one such resource that has virtually gone untouched in recent years. Utah Lake has a recreational potential as yet unrealized. The Lake's development and utilization could be critical to the future of Utah County in the competitive tourist industry. Prospects are encouraging, but there is little happening; not because there is not interest in further development.
1980	**Utah Lake WHAB Study Quality Data Update (Results of all water samples taken from 31 May 1977 through 28 April 1980).** Eyring Research Institute, Inc. Brigham Young University. September 1980. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Eyring Research Institute, Inc.	This document reports the results of water sampling from May 1977 to April 1980.

Year	Title and Author	Summary Information
1973	**A Water Resource Management Model, Upper Jordan River Drainage, Utah.** Utah Water Research Laboratory, College of Engineering. Utah State University. March 1973. Wang, Bi-Huei, James I. Felix, Rick L. Gold, Craig T. Jones, J. Paul Riley.	As demands upon available water supplies increase there is an increase in the need to assess the downstream consequences resulting from changes within the hydrologic system. This problem is approached in the study by digital computer simulation of the hydrologic system. The model was applied to the Provo River basin with emphases being placed upon operation of storage reservoirs within the system including Utah Lake. The river basin management simulates the hydrologic response to various water resources management alternatives. The Utah Lake operation submodel is linked with the river basin management submodel to comprise a combined Utah Lake operations model.
1981	**Shiozawa. Utah Lake Phase II Summary Report.** Eyring Research Institute, Inc. Brigham Young University. December 1981. (prepared for Bureau of Reclamation, U.S. Department of the Interior) Winget, Robert N., James R. Barnes, LaVere B. Merritt, Samuel R. Rushforth, Dennis K.	See paragraph below for summary of this report.
1982	**Shiozawa. Utah Lake Water Quality, Hydrology and Aquatic Biology Impact Analysis Summary for the Irrigation and Drainage System – Bonneville Unit Central Utah Project.** WHAB Phase II Summary Report (Final). Utah Lake Research Team, Eyring Research Institute, Inc. and Brigham Young University. October 1982. Winget, Robert N., James R. Barnes, LaVere B. Merritt, Samuel R. Rushforth, and Dennis K.	Alternative plans for development of Utah Lake are being studied, including different diking plans, dike designs, operation alternatives, and land uses. The summary matrix presents the projected impacts of each diking alternative. Extrapolation of the impact data for these alternatives will also provide bases for impact analyses of similar alternatives which may be identified at a later date.

Year	Title and Author	Summary Information
	Trend Determination	
1959	**Unpublished fish collection records**. Utah Division of Wildlife Resources. Springville, Utah. Arnold, B.B.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1969	**A history of commercial fishing on Utah Lake**. M.A. Thesis. Brigham Young University. Provo, Utah. 142 pp.	Summary Includes a history of commercial fishing in Utah Lake from the late 1800s until the present day. Describes fishing techniques, species sought, and relative fishery production and permitting issues. Also includes pictures of lakeshore showing macrophytes in littoral zone.
	Carter, D.	Conclusions: Fish furnished an important part of the diet of early settlers. Preferred food fishes from Utah Lake were trout (Bonneville cutthroat trout [Oncorhynchus clarki Utah]) and suckers (June sucker and Utah sucker [Catostomus ardens]). By the late 1800's, year-around fishing and unrestricted harvest had greatly reduced the numbers of fish in Utah Lake.
1955	**Reproduction of the white bass, Morone chrysops**. Invest. Indiana Lakes Riggs, C.D.	Summary Details reproductive life history and fecundity of white bass. Conclusions: White bass spawn typically begin to stage when the water reaches 12.8^{o} C to 15.6^{o} C, and commonly lasts 5 to 10 days between April and July.
1936	**A study of fishes of Utah**. Utah Academy of Science, Arts, Letters 13:155-183.	Summary Describes life history of fish species found in Utah. Includes life-history description of Utah sucker and June sucker and qualitative descriptions of the abundance of June sucker in Utah Lake.
	Tanner, V.M.	Conclusions: Population decline in Utah Lake suckers is predominantly due to commercial fish harvest starting in the late 1800's and early 1900's and from crowding and freezing during drought conditions and extensive irrigation withdrawal.

Year	Title and Author	Summary Information
1967	**Investigations into the spawning ecology of the white bass *Roccus chrysops*, (Rafinesque) in Utah Lake,** Vincent, F.	Summary Describes spawning life history of white bass in Utah Lake approximately 11 years after they were introduced to the lake. Conclusions: White bass spawn approximately 10 to15 feet from shore in 3 to 6 feet of water, from mid-April to mid-June in water temperatures of 14° to 21° C. Spawning in Utah Lake lasts for 10 to 15 days. Juvenile and adult fish concentrate in the south end of the lake during the winter. Juveniles disperse throughout the lake after ice breakup and the adults commonly congregate at Lincoln Beach to spawn.
1970	**Fish population studies, Utah Lake**. Division of Wildlife Resources. Springville, Utah. 45 pp. White, J., and B. Dabb.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
	Status Assessment	
1998	**Age and growth of June sucker (Chasmistes liorus) from otoliths**. Great Basin Naturalist, 58:390-392. Belk, M.C.	Summary: Describes the age and growth rates of June sucker based on examination of otoliths removed from larval suckers captured in the Provo River and Utah Lake. Conclusions: Growth of young June sucker in a hatchery averages 0.408"/month to 0.57"/month at 21°C (depending on food availability). Growth at 15.5°C averages only 0.3"/month to 0.42"/month (depending on food availability). At these growth rates, time required to reach maturity for males (440 mm TL) is about 30 months and for females (490 mm TL) is about 34 months). Growth rates for June suckers raised in cage culture in Utah Lake in 2001 appear to be much higher than those experienced in a hatchery environment.
2001	**Nonnative fishes and their impact on native fish. "Practical Approaches for Conserving Native Inland Fishes of the West."** A Symposium, June 6-8, 2001. 22-24. Buktenica, M.W., B.D. Mahoney, S.F. Girdner, and G.L. Larson.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1997	**June sucker studies 1995-1996: Provo River and Utah Lake fisheries management studies**. Contract F-47-R; Segment 11. Utah Division of Wildlife	Summary Summarizes studies of white bass predation on June sucker in the Provo River and Utah Lake. Includes information regarding June sucker feeding, growth and use of macrophytes and other habitat to avoid predation.

Year	Title and Author	Summary Information
	Crowl, T.A. and H.M. Thomas.	Conclusions: A number of introduced fish species have been identified as potential threats to the continued survival of the June sucker. Nonnative fish species that are common to abundant in Utah Lake and its tributaries and have the potential to limit June sucker recovery include carp, white bass, black crappie, yellow perch, channel catfish, walleye, and black bullhead. These species are relatively numerous in Utah Lake and the lower Provo River where they can readily feed on and/or compete with young June sucker. These nonnative species feed in a variety of habitats including pelagic, littoral, and benthic zones, which places them in all habitats used by various life stages of June sucker. Since the principal effect of nonnative fishes on June sucker is from predation on larval, young of the year, and juvenile life stages, nonnative control efforts should focus on removing the immediate threat of predation from the younger life stages of June sucker. The effect of nonnatives on adult June sucker is primarily from competition for food and space and reduced food supplies from increased turbidity related to feeding and spawning activities of carp. Recent studies suggest that food is currently not limiting survival of adult June sucker in Utah Lake. This is supported by the survival of June suckers reared in captivity and released into Utah Lake.
1998b.	**June sucker and Utah Lake fisheries management studies: 1995-1997**. Final report submitted to Utah Division of Wildlife Resources, Salt Lake City, Utah Crowl, T.A., H.M. Thomas, and D. Vinson.	Summary Summarizes studies of white bass predation on June sucker in the Provo River and Utah Lake. Includes information regarding June sucker feeding, growth and use of macrophytes and other habitat to avoid predation. Conclusions: See summary of Crowl, *et al.* 1997.
1995b.	**June sucker studies - 1995: Provo River and Utah Lake fisheries management studies**. Annual report submitted to Utah Division of Wildlife Crowl, T.A., H.M. Thomas, and G.P. Thiede.	Summary Summarizes studies of white bass predation on June sucker in the Provo River and Utah Lake. Includes information regarding June sucker feeding, growth and use of macrophytes and other habitat to avoid predation. Conclusions: See summary of Crowl, et al. 1997.
1998a.	**A synopsis of Provo River studies: Instream flows and June sucker recovery (1995-1997)**. Utah Division of Crowl, T.A., L. Lentsch, and C. Keleher.	Summary Analyzes historic flows in the Provo River and their impacts on June sucker spawning success. Conclusions: See summary of Crowl, et al. 1997.
1995a.	**Trophic interactions of gizzard shad, June sucker, and white bass: Implications for fishery enhancement and the management of the**	Summary Describes trophic interactions between white bass, June sucker, and gizzard shad in controlled tank experiments, including relative predation rates and prey selectivity of white bass on gizzard shad and June sucker.

Year	Title and Author	Summary Information
	Crowl, T.A., M.E. Petersen, R. Mellenthin, and G.P. Thiede.	Conclusions: See summary of Crowl, et al. 1997.
1980	**The influence of littoral macrohabitat on diel activity patterns of white bass in Utah Lake**. Unpublished thesis. Brigham Young University. Provo, Utah. Devine, M.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1981	**Fishes of Utah Lake**. Great Basin Naturalist Memoirs, No.5: Utah Lake Monograph. Provo, Utah: Brigham Young University. 169 pp. Heckmann, R.A., C.W. Thompson, and	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1996	**Utah Lake creel survey: Annual report based on 1995 season**. Utah Division of Wildlife Resources, Springville, Utah. Keleher, C.J.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).

Year	Title and Author	Summary Information
1998	**Evaluation of flow requirements for June sucker (*Chasmistes liorus*) in the Provo River: An empirical approach**. Publ. Number 99-06. Utah Division of Keleher, C.J., L.D. Lentsch, and C.W. Thompson.	Summary Includes predicted flows necessary to maximize June sucker spawning success. Studies indicate a flow peak, with a descending limb in the June hydrograph is helpful for spawning success. Conclusions: The wild population of June sucker has declined from one of the most abundant fish species in Utah Lake and its tributaries to about 300 spawning individuals in the Provo River. June suckers spawn primarily in May and June at water temperatures of about 11.6–17°C. Spawning currently occurs only in the lower Provo River. Flows greater than 100 cfs are required for passively drifting larvae to reach the mouth of the Provo River when the lake is at compromise elevation (i.e., 4,489.045 feet).
2001	**Westslope Warmwater Fisheries**. Federal Aid Projects: F-325-R6. Martinez, P.J.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below)
1981	**Distribution and evolution of *Chasmistes* (Pisces: Catostomidae) in western North America**. Occasional papers of the Museum of Zoology, No. 696. University of Michigan, Ann Arbor, Michigan. 46 pp. Miller, R.R., and G.R. Smith.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1990	**Emergence patterns and feeding behavior of larval June sucker**. Final Report. Utah Division of Wildlife Resources. Salt Lake City, Utah. Contract 90-0081. Modde, T., and N. Muirhead.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below)

Year	Title and Author	Summary Information
1998	**West 2** (CDs for Idaho and Oregon data); EarthInfo, Inc.; Boulder, Colorado. National Climatic Data Center (NCDC).	Summary: Contains recent and historical air temperature, solar radiance, precipitation, wind and other supplemental climatological data for stations in Idaho and Utah. Conclusions: Data show gradual trend toward warmer summer temperatures and lower overall precipitation amounts specific to Utah Lake and the associated drainage. Elevated air temperatures are directly related to elevated water temperatures in intermountain lakes. Given the current low water and increased summer temperature trends identified for Utah Lake, appropriate fish habitat volumes as defined by dissolved oxygen and water temperature are expected to be smaller than historic habitat volumes. This information will be used to assess site potential for available habitat and designated beneficial use support.
1996	**Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact**. North Amer. J. Fisheries Manage. Vol. 16 (4): 693 –727. Newcombe, C.P. and J.O.T. Jensen.	Summary: A review of 80 published reports on suspended sediment in streams and estuaries reported that lethal effects in rainbow trout begin to be observed at concentrations of 50 mg/L to 100 mg/L when those concentrations are maintained for 14 to 60 days. Similar effects were observed for other species. Conclusions: Presents baseline information that, together with Utah criteria for turbidity and total suspended solids, provides a viable assessment protocol specific to solids and sediment. Given the shallow nature of Utah Lake, turbidity, total suspended solids, and resuspension of sediments due to wind, wave and biota action, sediment is projected to be a fundamental indicator in determining for designated beneficial use support.
1996	**The effects of prey growth, physical structure, and piscivore electivity on the relative prey vulnerability of gizzard** Petersen, M.	Summary: Describes June sucker growth and morphology and the impacts of these traits on June sucker vulnerability to white bass predation. Conclusions: The declining forage base in Utah Lake remains low despite the introduction of several nonnative fish species as a forage base in the mid 1950's and 1960's, including red shiner, spottail shiner, and fathead minnow. Introduced species that grow faster than June sucker outgrow predation vulnerability sooner, thereby increasing the predation risk to young of the year June sucker. The presence of macrophytes can act to significantly decrease white bass selectivity for June sucker, as juvenile June sucker have been shown to have strong predator-avoiding behaviors and will utilize macrophytes as cover where available.

Year	Title and Author	Summary Information
1981	**Utah Lake fisheries inventory**. U.S. Bureau of Reclamation Contract 8-07-40-50634. Utah Division of Wildlife Resources. Salt Lake City, Utah. 244 pp. Radant, R.D. and D.K. Sakaguchi.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1987	**June sucker - Utah Lake Investigations**. U.S. Bureau of Reclamation Contract 8-07-40-S0634. Modification No. 5. Utah Division of Wildlife Resources. Salt Lake City, Utah. 46 pp. Radant, R.D. and D.S. Shirley.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1984	**Status of the June sucker (*Chasmistes liorus*)**. Proceedings of the Desert Fishes Council 15th Annual Symposium (1983). Death Valley, California. Radant, R.D., and T.J. Hickman.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
1983	**Spawning ecology and larval development of the June sucker**. Proceedings of the Bonneville Chapter of the American Fisheries Society 18-36. Shirley, D.S.	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).
2002	**Nonnative Fish Control Feasibility Study to Benefit June Sucker in Utah Lake.** June Sucker Recovery Implementation Program, Utah Department of Natural Resources, Salt Lake City, UT.	<u>Summary:</u> Summarizes fish population status in Utah Lake. Includes history of commercial fishing, non-native fish introductions, and population fluctuations from the early 1900s to the present day. Describes life history and status of the endangered June sucker and non-native fish in Utah Lake. Summarizes historical lake morphology and potential impacts of changes to physical habitat and water quality in the lake on the endangered June sucker. Includes potential strategies to improve habitat and decreases non-native fish in Utah Lake to benefit June sucker populations. Investigates the potential use of Lotka-Volterra predator-prey models to predict non-native fish removal methods on both non-native and June sucker fish populations.

Year	Title and Author	Summary Information
	SWCA Environmental Consultants, Inc.	Conclusions: Many native fish species have been extirpated from Utah Lake, or do not exist in viable populations in Utah Lake including Bonneville cutthroat trout, June sucker, Utah sucker, Utah chub, and redside shiner. 16 nonnative fish species have become established in Utah Lake, some of which represent the most abundant species in the basin and the main basis of the recreational sport fishery in Utah Lake (black bullhead, black crappie, white bass and others). Distribution of fish within Utah Lake varies with species. Carp and white bass dominate open water habitat, littoral zones and vegetated areas have higher concentrations of young of all species. Some nonnative species represent a threat to the continued survival of June sucker (an endangered species) in Utah Lake. The native prey base in Utah Lake has been significantly reduced since the drought of the 1930's. Surveys conducted in 1970 failed to find any Utah chub and only a small number of redside shiners and suckers; this decline was reported following introduction of white bass and walleye into Utah Lake. Although both white bass and walleye are known as efficient fish predators, it is presumed that white bass have had a greater impact on the forage base because of their ability to maintain a large population in Utah Lake by switching to zooplankton in the absence of a small fish forage base.
1996	**Fishes of Utah**. University of Utah Press, Salt Lake City. Sigler, W.F. and J.W. Sigler.	Summary Describes life history of fishes of Utah, including most species found in Utah Lake. Additional information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below).

Year	Title and Author	Summary Information
1999a.	**June sucker (*Chasmistes liorus*) Recovery Plan**. USFWS, Denver, Colorado.	<u>Summary:</u> Describes general goals and strategy for recovering the endangered June sucker. Strategies include non-native fish control in Utah Lake, habitat enhancement in Utah Lake and the Provo River, and establishment of refuge populations of June sucker in other water bodies in Utah.
	U.S. Fish and Wildlife Service (USFWS).	<u>Conclusions:</u> Small numbers of June suckers are found in spawning runs in the Provo River, but the young do not appear to be surviving in the lake environment. The abundance of white bass and walleye together with an absence of an alternate forage species suggest that predation is one of the primary causes for this lack of recruitment. In 1997, the wild spawning population was estimated to be between 311 and 515 individuals.
1998	**1997 Utah Lake fish population monitoring report**. Utah Division of Wildlife Resources. Springville, Utah. Utah Division of Wildlife Resources (UDWR).	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below)
1999	**1998 Utah Lake fish population monitoring report**. Utah Division of Wildlife Resources. Springville, Utah. Utah Division of Wildlife Resources (UDWR).	Information contained in this report is summarized in the Non-Native Fish Control Feasibility Study (please see summary below)
1968	**Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication**. OECD Technical Report DAS/CS1/68.27. 159 p.	<u>Summary:</u> Development and assessment of an empirical model developed to predict the trophic status of a lake as a function of annual phosphorus loading, chlorophyll concentrations, Secchi disk visibility, dissolved oxygen levels and others. The modified Vollenweider model is a simple set of input-output calculations that assume the following: (i) phosphorus enters the lake along with some volume of water; (ii) some of the phosphorus settles from the water column to the lake sediments, at a rate that depends on lake depth and water residence time; and (iii) some phosphorus and water exits the lake by outflows. The model can be used to identify a range of nutrient loading rates that are predicted to achieve a given trophic state.
	Vollenweider, R.A..	<u>Conclusions:</u> Utah Lake is a shallow, nutrient enriched water body. As such, changes in trophic status related to anthropogenic loading may be resulting in impairment of designated beneficial uses. Due to the unique nature of the lake (especially depth and turbidity) the model cannot be applied directly. However, variations of the model will be helpful in establishing a framework for the assessment of existing phosphorus loading and chlorophyll *a* concentrations as they relate to the support status of the designated beneficial uses.

Year	Title and Author	Summary Information
2001	**Evaluation of June sucker larvae movement (*Chasmistes liorus*) in the Provo River in 1998**. Publication Number 01-18. Utah Division of Wildlife Resources, Salt Lake City, Utah. Wilson, K.W., and C.W. Thompson.	Summary: Describes June sucker larval movement in Provo River, Indicates that high flows in July and August appear to move June sucker larvae to Utah Lake quicker, thereby preventing starvation of larval fishes. Low flows in the Provo River essentially change the lower Provo River into part of Utah Lake, preventing larval June sucker from drifting to the lake. Conclusions: Larval June suckers rarely survive more than about three weeks at the river/lake interface. Recent flow modeling suggests that in most years there is not enough flow near the mouth of the Provo River to pass drifting larval suckers to the lake. Lack of sufficient flow strands the majority of the yearly June sucker production in the channelized river system, where most probably starve to death because of the lack of zooplankton and cold temperatures. Due to channelization at the mouth of the Provo River and the construction of levees and breakwaters there is a distinct thermal and chemical barrier at the inflow of the river, which results in very little mixing between river and lake water. This barrier is extreme enough to be potentially fatal to small fish.

Year	Title and Author	Summary Information
1981	**Winter Zooplankton Communities of Goshen Bay, Utah Lake, Utah** Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #2	Summary: This paper is an analysis of zooplankton studies done through the ice during 1979. The study examined zooplankton communities undisturbed by wind. Distribution trend analyses were performed in Goshen Bay. Most taxa showed significant linear trends from north to south. However, there was no definite pattern in total numbers of zooplankton across Goshen Bay. Most taxa seemed to prefer the deeper water in the north part of Conclusions: With the absence of wind mixing or prevailing winds, zooplankton numbers tended to be more abundant in deeper waters. Distribution of zooplankton, and likely phytoplankton, appears to differ during times of low wind disturbance. This could have implications for the formation of spring phytoplankton blooms in Utah Lake.
1981	**Utah Lake Littoral Community Analyses: Intensive Site Zooplankton Studies** Barnes, James R. Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #4	Summary: Several substrate types in Utah Lake were intensively studied to identify and characterize zooplankton communities. Individual taxa and communities were compared on the basis of substrate type and location in the lake ecosystem. Substrate type did not tend to define community type. Wind patterns were suggested by Barnes to be responsible for community composition. Conclusions: This study demonstrated an extreme variability in zooplankton community type within the lake. Some substrata favored some species of zooplankton, though most taxa were present in all substrate types. Significant differences, therefore, were mostly due to species density rather than presence/absence of taxa. Zooplankton communities in Utah lake could not be characterized according to substrate type or locality within the lake. Wind likely plays an important role in assemblage structure.
1981	**The Soft Ooze Benthic Communities of Utah Lake** Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #5	Summary: 93-99 percent of the bottom of Utah Lake is comprised of soft ooze sediments. It follows that the soft ooze biotic community dominates the lake. The ooze is largely comprised of soft clay-sand-silt. The purpose of this study was to compare different soft ooze communities from different parts of the lake. Lower densities of oligochaetes and chironomids were found in Provo Bay than in the main lake and Goshen Bay. The soft ooze communities of Goshen Bay were more similar to those of the main lake than to those of Provo Bay. Conclusions: Utah Lake bottom sediments are primarily soft ooze. This limits to some extent the type of algal floras found in the lake since ooze substrates are algal depauperate.

Year	Title and Author	Summary Information
1981	**Utah Lake Littoral Benthic Community: an Intensive Study** Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #6	<u>Summary:</u> The littoral benthic or rocky shore habitat comprises some 5% of the lake bottom. The rocky shore and emergent vegetation demonstrates the highest diversity and density of invertebrates. The study differentiated between small rubble, large rubble, hardpan, sand and emergent vegetation. Barnes found that sand macroinvertebrate communities are similar throughout the lake. Rocky shore areas have high densities of macroinvertebrates, particularly in the large and small rubble. Goshen Bay demonstrates a variety of habitat types and high densities of macroinvertebrates. <u>Conclusions:</u> Macroinvertebrate populations in Utah Lake are densest and most diverse in only about 5% of lake bottom habitats. These habitats are those with hard sediments, primarily rubble. Furthermore, since 95% or more of the lake bottom is comprised of soft ooze habitat, this increases the propensity for wind disturbance of the sediments and possible light limitation of phytoplankton in the lake water column.
1981	**Utah Lake Transect Zooplankton Analysis** Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #7	<u>Summary:</u> Studies of transects for zooplankton indicated differences in Utah Lake during the study period. Provo Bay showed significant differences from the transects in the main lake and Goshen Bay. Provo Bay demonstrated significantly higher numbers of zooplankton for the majority of taxa than the main lake and Goshen Bay. Other transects behaved significantly similarly throughout the study. A significant linear decrease in number of taxa occurred from north to south throughout the study in the main body of the lake. <u>Conclusions:</u> Two important conclusions are noteworthy from this study. First, a trend of increasing zooplankton density was observed in Provo Bay. This continues to suggest that Provo Bay is substantially different from other parts of the lake. Second, the north-to-south decrease in zooplankton density is important. This trend likely is due to decreasing water quality in the southern part of the lake.
1981	**Utah Lake Littoral Community Analyses: October 1978 and May 1979** Barnes, James R. Shiozawa, Dennis K. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #3 and #8	<u>Summary:</u> Littoral community differences were influenced by two important factors: location in the lake and substrate type. Differences in lake location-related community type seemed to be due to wave action, lake bottom gradient and differences in water quality. Substrate differences in bottom communities were attributable to differing substrate type. Significant differences in communities at differing locations suggested that lake location was more important to macrobenthic community structure than substrate type. <u>Conclusions:</u> Lake locality was the most important factor in distribution of littoral communities in Utah Lake during the period of this study. This likely reflects the import of water quality and turbidity on littoral communities. It may be expected that water quality also plays an important role on structure of phytoplankton communities in these habitat types.

Year	Title and Author	Summary Information
1982	**Diatoms of Recent Bottom Sediments of Utah Lake, Utah** Grimes, Judith A. and Rushforth, Samuel R *Bibliotheca Phycologica* 55 1982, 69 plates 179 pp.	Summary: Diatoms in 57 surface sediment samples from Utah Lake were studied. 314 taxa were identified in a total of 43 genera in the combined living epipelic flora and residual planktonic, epilithic and epiphytic flora of the lake. The two genera Navicula and Nitzschia contained the highest number of species encountered. Centric diatoms comprised the highest absolute density of diatoms in these sediment samples. This study culminated three years of intense study of the diatom floras of Utah Lake. More work is necessary to complete our understanding of the diatom systems of the lake, particularly the full specific diatom Conclusions: This study indicated that the diatom assemblages of the surface samples of Utah Lake mirrored the living diatom floras of the lake during the period of this study. Most of the species were present in low numbers. A relatively small number of taxa dominated the diatoms present in the recent bottom samples. These included species of Melosira, Stephanodiscus and Cyclotella, three centric diatoms. When compared to other studies, the flora of the recent sediments is rather similar to that of the diatoms from assemblages through the past few thousand years of lake history. No surprising changes in type or abundance of diatoms were noted when compared to these other studies.
1974	**Paleoecological Interpretation of the Diatom Succession in the Recent Sediments of Utah Lake, Utah.** Bolland, Robert F. University of Utah Ph.D. Dissertation, 100 pp.	Summary: Bolland studied a core taken from the main body of Utah Lake. The core was five meters in length and was divided into 250 samples for analysis. Boland found 155 diatom taxa in this core. For the most part, the taxa are similar to those of the modern lake with some noteworthy exceptions. Bolland found an increase in planktonic species in the upper portions of his core. Many of these indicate eutroophic waters. Furthermore, Bolland found several species in the lowermost portions of his core that were either indicative of relatively mesotrophic waters or attached speceis tather than plankters. For this and other reasons, Bolland concluded that in the course of time during the deposition of his five meter core, the lake became more eutrophic and the biological water quality diminished substantially. In particular, the presence of Stephanodiscus niagarae in the deepest layers suggested to Conclusions: Bolland's conclusions may be accurate. Some contradictions exist, however. At the same time as the planktonic species were expanding during the time interval exhibited
1980	**Ecology of Diatom Surface Sediments of Utah Lake, Utah** Grimes, Judith A. and Rushforth, Samuel R. U.S. Bureau of Reclamation WHAB Phase One Report #13	Summary: The purpose of this study was to compare diatom assemblages from sediment collected throughout the lake. If diatom assemblages collected from different parts of the lake reflected differences in lake geography and morphology, our study would have direct application to proposals to diking Provo and Goshen Bays. Conclusions: Statistical analysis of gathered data showed that distinct geographical subregions of the lake could be delineated according to population patterns of bottom sediment diatoms. Specifically, Provo Bay and Goshen Bay are distinct from each other and from the main body of the lake. Provo Bay and inner Goshen Bay are the least alike of any areas of the lake and appear to support floras of their unique habitats. Provo Bay seems to be important to Utah Lake by acting as a natural processing area for the high organic load

Year	Title and Author	Summary Information
1980	**Taxonomy of Diatoms of Surface Sediments of Utah Lake, Utah** Grimes, Judith A., Javakul, Adchara, and Rushforth, Samuel R. U.S. Bureau of Reclamation WHAB Phase One Report # 14 - #15	<u>Summary:</u> Utah Lake is a turbid, rather warm-water lake with very high algal productivity. Since Utah Lake is a shallow system with large surface area, evaporative losses each year are high. This was noted soon after European settlement. This study was part of a larger body of work to determine the impact of decreasing the surface area of the lake and increasing the depth as has been often suggested. <u>Conclusions:</u> Utah Lake is a slightly saline, highly eutrophic system with massive cyanobacterial blooms in the late summer and fall. This lake differs from most other lakes and reservoirs in the same geographical region due to its somewhat elevated salinity, nutrient load and TDS and its resultant algal floras. The study was inconclusive concerning changes in the surface to depth ratio. Even so, if the heavy nutrient input continued following morphological change of the lake basin, algal blooms and resultant decreased water quality
1980	**Taxonomy and Ecology of Diatoms of Surface Sediments of Utah Lake, Utah** Grimes, Judith A. Brigham Young University Dept. of Botany and Range Science, Ph.D. Dissertation	<u>Summary:</u> Evaporative losses each year from Utah Lake exceed all other removal of water from Utah Lake for all uses. Since evaporation can be reduced by reducing the surface area of the lake, it was proposed as early as 1953 that the shallow bays of the lake be diked from the main body of the lake. Under the Central Utah Water Project, it was originally proposed that Provo Bay and Goshen Bay be diked and dewatered. We studied diatom assemblages in surface sediments throughout the lake to determine whether diatom associations differ in geographically distinct parts of the lake. This study was established especially to determine whether the main body of the lake, Goshen Bay and Provo Bay supported distinct diatom floras. Diatoms proved to be a sensitive ecological tool since they are reactive to environmental changes, their cell walls are often preserved in sediments and sediments contain diatoms from all seasons. Due to these factors, it is possible to study diatom assemblages in sediments and determine whether sensitive species are present or absent <u>Conclusions:</u> Provo Bay is important to Utah Lake since it seems to process the high organic nutrient load introduced into that part of the lake. Our analysis showed that diatom assemblages in Provo Bay and the inner regions of Goshen Bay are unlike those of the main body of the lake and they are unlike each other. As reflected by the diatom flora, Provo Bay is distinct from other parts of Utah Lake. The consequences of losing this bay and introducing nutrients directly into the lake would likely increase cultural eutrophication to Utah Lake. For example, it is likely that earlier and increased cyanophyte blooms would be
1980	**Diatoms in Sediment Cores in Utah Lake, Utah** Javakul, Adchara Grimes, Judith A. Rushforth, Samuel R. U.S. Bureau of Reclamation WHAB Phase One Report #16	<u>Summary:</u> Diatoms in sediment cores taken from Provo Bay, off of Geneva Steel and at midlake were studied and assemblages analyzed. This studies demonstrated that diatoms in Utah Lake have changed to some extent through time. Furthermore, it is important that the assemblages in Provo Bay are different from those in other parts of the lake. <u>Conclusions:</u> Provo Bay sediments are floristically unique and distinct from either those of mid-lake or near Geneva Steel. The upper sediments at all three sites are similar in assemblage and different from lower sediments which suggests some change in the recent history of the lake at all three locations.

Year	Title and Author	Summary Information
1981	**Projected Water Quality Conditions in Utah Lake and Relationship to the Central Utah Water Project** Merritt, LaVere B. and Miller, Woodruff U.S. Bureau of Reclamation WHAB Phase One Report #20	Summary: Data on Utah Lake ecosystems is new. Most data was collected since 1970 and more than half of the data analyzed in this article had been gathered since 1977. The data showed differences in water quality for different tributaries and, to a lesser degree, within the lake itself. Most water quality violations to input regulations are from ammonia, orthophosphorus and BOD standards. In addition, a few TDS and heavy metals violations were observed. The EPA National Eutrophication Survey of 1973-74 reported Utah Lake to be the most eutrophic lake of the 27 lakes surveyed in Utah. Conclusions: The results of this study show a very high nutrient loading. The study estimated that even with substantial limitation on nutrient loading, algal blooms (rapid late summer and fall growths) would be little effected. This is a very important conclusion that must be examined and discussed. On the other hand, it is possible that light is the dominant limiting factor during the algal growth season.
1980	**Utah Lake Tributaries Water Quality Study** Miller, Steven U.S. Bureau of Reclamation WHAB Phase One Report # 26	Summary: Annual evaporation loss from Utah is equal to about 1/3 of the total lake capacity and 1/2 of the average yearly inflow. This study examined tributaries into Utah Lake. Much of Utah Lake inflow is from minor tributaries including drainage ditches, overland drains, etc. The headwaters of the lake are in the Uintah and Wasatch Mountains. The major inflows are the American Fork River, Provo River, Spanish Fork River and Hobble Creek. A major tributary for this study was defined as a water source larger than 2000 acre feet per year Conclusions: It is important to know the sources of inflow into Utah Lake. It is especially critical to ascertain that a substantial amount of inflow enters through small to very small sources. Such sources may be harder to monitor and control than larger inflows. It seems critical to continue and increase monitoring efforts on inflow sources to Utah Lake.
1974	**Water Quality Reconnaissance of Surface Inflow to Utah Lake U.S. Geological Survey** Mundorff, J.C. U.S. Geological Survey Utah Dept. of Natural Resources Technical Publication #46	Summary: Utah Lake is a semi-terminal lake, low in the drainage basin of the Uinta and Wasatch Mountains. The total drainage basin of Utah numbers some 2180 square miles. 685 square miles occur in the Provo River Drainage, 725 square miles are in the Spanish Fork River Drainage and 770 square miles are in the drainage basins of several creeks and small sloughs that discharge directly into Utah Lake. Conclusions: The management of water sources that flow into Utah Lake is going to be a difficult task. Many sources exist, several of which are unregulated and difficult to measure. As is usual in such systems, measuring nutrient input into the lake will be much easier from the major sources, but very difficult from the small sources and non-point sources.

Year	Title and Author	Summary Information
1981	**Phytoplankton of Utah Lake** Rushforth, Samuel R., St. Clair, Larry L., Grimes, Judith A., and Whiting, Mark C. Utah Lake Monograph *Great Basin Naturalist* No. 5 1981, pp. 85-100	<u>Summary:</u> Utah lake receives inflow from many mineral springs within and around the periphery of the lake. As a result, lake water is high in carbonate and sulfate content. This study provided a comprehensive list of all algae collected from the water column through 1978 and descriptions of the major taxa. This paper discussed standing crop of algae in the lake. The data showed that the standing crop (biomass) of the lake was low during spring and early summer and that at that time community diversity was high. Standing crop during the early part of the year was divided relatively evenly among several taxa. As the summer progressed, community diversity decreased and standing crop (biomass) increased. By late summer the standing crop was comprised essentially totally of Aphainzomenon flos-aquae <u>Conclusions:</u> The high diversity of the Utah Lake flora as measured by total species number occurring in the lake coupled with the high late summer biomass suggests that Utah Lake is a rather unique ecosystem. Utah Lake is most similar to some saline eutrophic systems in North America and Australia.
1980	**Winter Phytoplankton Communities of Goshen Bay, Utah Lake, Utah** Rushforth, Samuel R. Grimes, Judith A., Javakul, Adchara, and U.S. Bureau of Reclamation WHAB Phase One Report #28	<u>Summary:</u> Water quality of Utah Lake has been reported to be relatively poor due to elevated levels of TDS, chloride, sulfate and other ions. In addition, the waters are turbid and the lake supports late summer and early fall cyanophyte "blooms." Because of these conditions, Utah Lake has been characterized as a hypereutrophic or saline eutrophic system. Water quality is not uniform throughout the lake. The main body of the lake has been reported to have significantly lower electrical conductivity and concentration of ions than the main bays. In contrast, Goshen Bay is substantially higher in these parameters and can be characterized as a slightly saline system. The increased salinity in Goshen Bay is due to several factors, including runoff from saline playas, evaporative losses and concomitant increases in TDS and the inflow of highly mineralized springs. <u>Conclusions:</u> A total of 21 non-diatom algal species and 159 diatom species were identified during this study. This present study, taken as a single study on its own merits, provides some evidence that the floras are different between inner Goshen Bay and outer Goshen Bay. Overall diversity and density of diatoms in the water column was generally higher in the inner bay samples than outer bay samples. This study, coupled with the study of Grimes and Rushforth (1980) and Whiting et al. (1978) shows a pattern providing strong evidence for the dissimilarity of the inner Goshen Bay algal assemblages from those of the rest of the lake

Year	Title and Author	Summary Information
1980	**An Introduction to the Algal Floras of Utah Lake** Rushforth, Samuel R. Grimes, Judith A., Javakul, Adchara, and U.S. Bureau of Reclamation WHAB Phase One Report #29	Summary: This study examined diatoms in lake sediments, taxonomic and ecological study of diatom assemblages, algal assemblages in the littoral zones and selected other habitats of the lake, seasonal and historical analyses of phytoplankton communities and a study of Goshen Bay, Provo Bay and the main body of the lake. A total of 465 diatoms and 200 nondiatom algal species has been reported from Utah Lake. This number was higher than expected even though past studies indicated that algal diversity was quite high. This elevated diversity is due to a high diversity of niches in the lake. The study indicated that late summer and fall floras were dominated by the nusiance cyanobacterium *Aphanizomenon flos-aquae.* The cyanobacterium *Anabaena spiroides var. crassa* was also important. Both of these organisms are important indicators of diminished water quality and have the Conclusions: Utah Lake appears to be a somewhat unique ecosystem. It is one of the best examples of a non-terminal remnant lake in North America. The lake demonstrates high productivity and high secondary productivity as well. Although the lake is geologically young, it has undergone rapid eutrophication and is now experiencing rapid cultural eutrophication.
1981	**A Study of the Phytoplankton along Established Permanent Transects in Utah Lake, Utah** Rushforth, Samuel R. Grimes, Judith A., Javakul, Adchara, and U.S. Bureau of Reclamation WHAB Phase One Report #30	Summary: A study of Utah Lake biota along predetermined transects was performed. Four transects were established in distinct parts of the lake in order to determine if floras and faunas were homogeneous or diverse throughout the lake at a single point in time. Each transect was sampled quarterly in order to assess seasonal variations as well as locality variations in the lake biota. Samples were collected from each transect on six dates between September, 1978 and July, 1979. The study resulted in the significant finding that summer and fall algal communities in Utah Lake showed higher levels of average similarity than winter and spring communities. This was found to be especially true of nondiatom communities as a result of the large blooms of *Aphanizomenon flos-aquae* that developed in all transects of the lake during summer and fall. Spring and winter nondiatom communities Conclusions: Nondiatom algal communities in Utah Lake demonstrated a higher degree of variability than diatom communities, which were not overwhelmingly dominated by any individual species. During periods when one diatom species increased in importance, other species still remained in significant numbers as well, unlike nondiatom communities where the dominance of one species resulted in the decrease of species of lesser importance. Seasonal differences in Utah Lake nondiatom algal communities tend to be stronger than in diatom communities. Diatom diversity was higher throughout all seasons than nondiatom algal diversity.

Year	Title and Author	Summary Information
1981	**A Study of the Algal Communities from the Littoral Zone of Utah Lake, Utah** Rushforth, Samuel R., and Grimes, Judith A., Squires, Lorin E. U.S. Bureau of Reclamation WHAB Phase One Report #31	<u>Summary:</u> This study performed diversity analysis, community similarity analysis, cluster analysis and importance value analysis in order to delineate the littoral algal assemblages of the lake. This paper is mostly descriptive in nature, providing information about amounts and kinds of algae present in the littoral zone of the lake. <u>Conclusions:</u> According to this study, the assemblage of taxa in Utah Lake was consistent with what would be expected in a highly eutrophic lake corroborating conclusions from other studies of the Utah Lake ecosystem. The littoral zone of Utah Lake was shown to be extremely productive through an analysis of standing crop, though primary productivity
1981	**A Study of Planktonic Floras Collected from Historical Sites on Utah Lake, Utah** Rushforth, Samuel R., Grimes, Judith A., Squires, Lorin E., and Javakul, Adchara U.S. Bureau of Reclamation WHAB Phase One Report #32	<u>Summary:</u> Twelve previousously established historical sites were selected throughout Utah Lake for phytoplankton collection to ensure that algal floras examined represented all parts of the lake. Seven sites were located in the main lake, three sites were in Goshen Bay, and two sites were in Provo Bay. Corroborating the results of previous studies, it was found that during late summer months, diatom communities were less similar to each other than nondiatom algal communities. During this season, the nondiatom flora ws comprised often of nearly unialgal stands of the dominant cyanobacterium, usually *Aphanizomenon flos-aquae* . Conversely, during the spring months, the nondiatom algal flora is less similar than the diatom flora due to the large number of green algae and cyanobacteria present during these months, and their uneven distribution throughout the lake. Diatoms were usually quite dissimilar in different parts of the lake and never become as homogenous as nondiatoms, <u>Conclusions:</u> Due to the high species diversity and elevated productivity characteristic of Utah Lake, it should be considered a strongly eutrophic and highly productive system. A majority of the diatom floras of Utah Lake were comprised of euplanktonic taxa, most of which are centric speceis. A few facultative plankters were also important. The nondiatom algal floras of Utah Lake are dominated by planktonic, bloom forming Cyanophyta. The most important cyanophyte in the system is *Aphanizomenon flos-aquae* . Seasonal changes characterize the floras of Utah Lake, which were dominated by green algae and diatoms in the spring, and by bloom forming cyanobacteria (bluegreen algae) in the fall. According to this study, when all species are taken into account, the planktonic floras of Utah Lake are relatively similar in various parts of the lake. Some diatom species occur in higher

Year	Title and Author	Summary Information
1981	**Site Intensive Study of the Algal Floras of Utah Lake** Rushforth, Samuel R. Grimes, Judith A., Javakul, Adchara, and U.S. Bureau of Reclamation WHAB Phase One Report #33	Summary: Because Utah Lake has a wide variety of habitats with various levels of dissolved salts, substrate types, and depth, a study was conducted to gather comparative data on sites within the lake with different substrate types. Conducted during the field season of 1979, this "site intensive" study investigated phytoplankton samples from 11 established sites throughout the lake and was conducted in conjunction with the Division of Wildlife Resources so that data concerning fish populations could be evaluated for each site. Average similarity for all stands of diatom and nondiatom algal communities was calculated. Diatom communities demonstrated less similarity than nondiatom communities, which were nearly twice as similar to each other as diatom communities. The highest degree of similarity Conclusions: The results of this study indicate that littoral algal communities, and especially diatoms, in Utah Lake are diverse and productive. Significant populations of primary consumers can be sustained by these communities. During the summer and fall months, however, diversity of nondiatom communities decreases. During these months, *Aphanizomenon flos-aquae* , a cyanobacterium, is dominant.
1981	**Littoral Community Qualitative Study** Shiozawa, Dennis K. Barnes, James R. McArthur, J. Vaun Oberndorfer, Reed Y. U.S. Bureau of Reclamation WHAB Phase One Report #34	Summary: This study showed a lake locational effect on the distribution of aquatic communities in Utah Lake. The study attempted to determine what factors were important in distribution of communities beyond expected physical and biological gradients. The best predictors of fish presence or absence were not physical factors alone, but included biological factors as well. The presence of many benthic invertebrates were found to be important in the occurrence of various species of fish. Zooplankton were not important predictors of fish presence or absence despite the fact that zooplankton are often Conclusions: Provo Bay demonstrated important littoral habitat as shown by this study. Goshen Bay also proved to contain important littoral habitat. Shiozawa et al. found that the littoral in both Provo Bay and Goshen Bay were important fish habitats, though due to total amount of littoral habitat present Goshen Bay showed to be somewhat more important than Provo Bay. Goshen Bay supported a very diverse benthic community and generally supported a higher fish frequency than Provo Bay.

Year	Title and Author	Summary Information
1979	**Competitive Displacement as a Factor Influencing Phytoplankton Distribution in Utah Lake, Utah** Squires, Lorin E., Brotherson, Jack D., Whiting, Mark, and Rushforth, Samuel R. *Great Basin Naturalist* Vol. 38 No. 3 1979, pp. 245-252	Summary: The distribution of phytoplankton communities or assemblages in aquatic systems is complex and determined by a variety of factors. In Utah Lake, one factor that seems to be important is competitive exclusion (or displacement). During bloom conditions, often the algal phytoplankton community is comprised nearly entirely of *Aphanizomenon flos-aquae* and *Ceratium hirundinella* . This paper examined the way in which these two species co-exist Conclusions: This study showed that *Aphanizomenon flos-aquae* and *Ceratium hirundinella* tended to co-exist in the lake, but occupy somewhat different microgeograpohical habitats. The reason for this was hypothesized to be that *Aphanizomenon* is easily concentrated by the wind and tended to form "windrows" of filaments creating very high biomass. Since *Ceratium hirundinella* is mobile, it was able to move away from the windrows to a locality less occupied by the cyanobacterium, thus relieving competition. Furthermore, this study demonstrated that algal diversity decreased as the seasons progressed from spring to fall. The reason for this seemed to be a homogenization of environmental conditions with
1997	**State Water Plan: Utah Lake Basin** Utah Board of Water Resources Utah State Water Plan Coordinating Committee	Summary: Section twelve of the 1997 State Water Plan discussed the quality of groundwater and surface water in the Utah Lake Basin. Point source pollution problems were identified as effluent discharges from wastewater treatment facilities and large industrial plants, and nonpoint pollution problems were identified as surface runoff generated from agricultural, municipal, and industrial activities. The primary concern was with phosphorus exceeding standards basin-wide. Eighteen point sources were identified as contributing the greatest Conclusions: High concentrations of phosphorus in Utah Lake are not a direct health threat, but phosphorus is the controlling factor in the eutrophication process of the lake. Nutrient loading determines the size of summer and fall blue-green algae blooms.
1982	**Water Quality, Hydrology and Aquatic Biology of Utah Lake: WHAB phase I Summary** Utah Research Team Eyring Research Institute U.S. Bureau of Reclamation WHAB Phase One Summary	Summary: Algal communities in Utah Lake were shown to reflect the main habitats of the lake. The floras of the shoreline region depend upon the nature of the substrate type. This study identified algal communities according to open water communities, rocky shoreline communities, sand or ooze communities, or epiphytes on emergent vascular plant Conclusions: Utah Lake is a highly productive ecosystem with the majority of algal production occurring as massive cyanobacterial blooms in the late summer and fall. Utah Lake could be considered to be hyper-eutrophic, although the unusually high species diversity in the system perhaps makes a classification of saline-eutrophic a better description of this system. Lake algal diversity was highest in spring and early summer, decreasing with progression of the seasons. Although algal populations fluctuated widely in Utah Lake, algal biomass did not appear to be limiting to other lake biota. While zooplankton and other invertebrates respond to fluctuations in algal biomass other environmental factors appeared

Year	Title and Author	Summary Information
1978	**Environmental Interaction in Summer Algal Communities** Whiting, Mark C. Brotherson, Jack D. Rushforth, Samuel R. *Great Basin Naturalist* Vol. 38, No.1 1978, pp. 31-41	Summary: Phytoplankton samples and environmental data were collected from selected sites in Utah Lake. Environmental continuum theory was employed to describe algal succession and regression analysis was used to discover interactions between algal communities and the environment. Phytoplankton assemblages in June 1974 were characterized by high species diversity. As the lake environment became "stressed" in late summer due to increased turbidity, nutrient levels and pH, species diversity decreased. By August, 1974 the algal flora was comprised of essentially two species, one cyanophyte and Conclusions: Utah Lake in late summer and early fall is characterized by nutrient enrichment, high silt load, increasing total dissolved solids and other environmental stresses. This is also a time when water levels are lowest and water temperature is highest. Under these stresses, species diversity decreases and the biological water quality diminishes
1982	**Utah Lake Water Quality, Hydrology and Aquatic Biology Impact Analysis for the Irrigation and Drainage System - Central Utah Project: WHAB Phase II Summary** Winget, Robert N. et al. Barnes, James R. Merritt, La Vere B. Rushforth, Samuel R. Shiozawa, Dennis K. U.S. Bureau of Reclamation WHAB Phase Two Summary WHAB Phase Two Summary	Summary: Phase I of this study resulted in the finding that algal floras in Utah lake differ between Goshen Bay, the main lake body, and Provo Bay. While floras differed between sites samples from bays and sites sampled from the main lake body, open water floras from different regions of the lake were similar to each other in composition. Phase II studies concluded that algal floras of different substrate types in the littoral zone of the lake were also significantly different from each other. Conclusions: Utah Lake exhibits high algal diversity. Patterns of distribution can be seen in differences between floras from distinct lake locations. This study concluded that differences can also be seen in flora from differing substrate types.

Appendix B
Station Locations Map

Utah Lake TMDL Station Locations

Appendix C

Statistical Analysis

Appendix D

Data Excluded from Analysis

Data Screening

Points Removed Based on Magnitude

Criteria for Removal:

1) For Dissolved Oxygen, samples greater than 20 mg/L were removed.
2) For pH at Stream stations, values less than 4 or greater than 11 mg/L were removed.
3) For pH at Lake stations, values less than 3 or greater than 11 mg/L were removed.
4) For pH at Point discharges, values less than 2 or greater than 12 mg/L were removed.

Constituent	Station	Date	Value	Lake Station	Point Discharge	Stream Station
DO	491737	6/19/1991	77	x		
DO	499479	3/3/1982	21.5			x
DO	499479	1/9/1990	20.1			x
DO	499520	10/4/1991	76			x
DO	499520	3/5/2002	99999			x
pH	499479	9/20/1983	3.2			x
pH	499504	3/20/1990	17.6		x	
pH	499541	1/6/1982	26		x	
pH	499628	11/29/2001	12.67		x	
pH	499649	11/9/1994	12.2		x	
pH	591986	9/22/1992	14			x

Data Screening

Points Removed Based on Distribution

Criteria for Removal:

Monthly mean values and standard deviations were calculated for each station and constituent combination. Data points which were more than three standard deviations away from their respective mean value were removed.

Constituent	Station	Date	Raw Result	Units
Ammonia	499460	5/15/1991	0.3	mg/L
Ammonia	499460	7/11/1990	3	mg/L
Ammonia	499460	2/19/1987	0.5	mg/L
Ammonia	499460	3/29/1988	0.9	mg/L
Ammonia	499460	9/15/1987	1.8	mg/L
Ammonia	499460	4/26/1991	0.3	mg/L
Ammonia	499472	5/7/1993	0.142	mg/L
Ammonia	499479	8/26/1999	0.843	mg/L
Ammonia	499479	7/9/1980	0.4	mg/L
Ammonia	499479	10/27/1983	0.6	mg/L
Ammonia	499479	12/14/1989	0.98	mg/L
Ammonia	499479	3/8/1989	0.9	mg/L
Ammonia	499504	6/25/1992	4.071	mg/L
Ammonia	499504	7/9/1991	7.29	mg/L
Ammonia	499504	8/20/1991	2.06	mg/L
Ammonia	499504	5/6/1992	0.556	mg/L
Ammonia	499504	2/2/1995	8.514	mg/L
Ammonia	499504	1/10/1996	1.51	mg/L
Ammonia	499504	10/14/1998	0.196	mg/L
Ammonia	499504	11/8/1995	0.745	mg/L
Ammonia	499520	10/5/1990	23.0	mg/L
Ammonia	499558	3/13/1997	0.776	mg/L
Ammonia	499558	2/5/1986	1.0	mg/L
Ammonia	499602	3/19/1986	8.5	mg/L
Ammonia	499603	7/10/1991	0.35	mg/L
Ammonia	499610	3/7/1989	0.06	mg/L
Ammonia	499628	2/26/1985	10.1	mg/L
Ammonia	499628	5/21/1985	8.7	mg/L
Ammonia	499651	3/3/1981	0.1	mg/L
Ammonia	499654	8/8/1989	1.47	mg/L
Ammonia	499656	2/11/1988	7.26	mg/L
Ammonia	499656	10/6/1988	0.37	mg/L
Ammonia	499656	1/28/1993	0.374	mg/L
Ammonia	499656	3/19/1998	2.84	mg/L
Ammonia	499657	3/22/1990	0.7	mg/L
Ammonia	499669	2/21/1996	0.079	mg/L
Ammonia	499669	8/19/1999	0.0905	mg/L
Ammonia	499669	3/19/1998	0.64	mg/L
Ammonia	499669	1/22/1997	0.597	mg/L
Ammonia	499669	7/21/1981	0.2	mg/L
Ammonia	499669	4/29/1997	0.15	mg/L
Ca	499479	4/7/1993	180	mg/L

Constituent	Station	Date	Raw Result	Units
Ca	499669	11/28/2001	5.13	mg/L
Cl	499558	5/10/2001	225.	mg/L
Cl	499669	3/22/1993	27.2	mg/L
DO	499460	5/18/1988	18.5	mg/L
DO	499460	3/6/1991	2	mg/L
DO	499460	9/15/1987	14.9	mg/L
DO	499479	7/8/1987	19.3	mg/L
DO	499504	5/9/2000	11.04	mg/L
DO	499504	7/29/2003	11.68	mg/L
DO	499520	10/22/2002	16.10	mg/L
DO	499520	2/11/2003	15.83	mg/L
DO	499525	3/5/2002	9.94	mg/L
DO	499558	10/26/1983	1.0	mg/L
DO	499558	2/26/1991	2.6	mg/L
DO	499622	7/10/2002	4.24	mg/L
DO	499624	7/10/2002	4.30	mg/L
DO	499624	10/13/1998	9.37	mg/L
DO	499646	5/14/1987	0.6	mg/L
DO	499669	3/16/1988	2.0	mg/L
HCO3	499558	10/3/1990	504	mg/L
HCO3	499669	7/29/1997	376	mg/L
K	499558	8/21/1985	7	mg/L
K	499558	5/20/1981	15	mg/L
K	499558	1/7/2003	10.3	mg/L
Kjeldahl	499669	7/10/1991	3.92	mg/L
Mg	499460	4/19/1983	2	mg/L
Mg	499669	4/19/1983	5	mg/L
Na	499558	1/7/2003	112.	mg/L
Na	499558	10/3/1990	160.0	mg/L
Na	499558	9/13/1990	160.0	mg/L
Na	499669	5/20/1981	21.0	mg/L
pH (Field)	499460	5/21/1981	7.4	None
pH (Field)	499504	5/9/2000	8.61	None
pH (Field)	499541	7/21/1983	5.5	None
pH (Field)	499542	8/17/1983	5.7	None
pH (Field)	499602	12/28/1982	2.1	None
pH (Field)	499602	5/9/2000	9.98	None
pH (Field)	499654	7/27/1995	9.8	None
pH (Field)	499669	5/23/1985	6.8	None
pH (Field)	499669	3/8/1989	10.3	None
pH (Lab)	499669	7/10/1991	6.2	None
SC (Field)	499504	12/1/1998	24	umho/cm
SC (Field)	499504	4/10/1996	202	umho/cm
SC (Field)	499504	3/13/1984	307	umho/cm
SC (Field)	499520	8/8/1989	11187	umho/cm
SC (Field)	499541	7/21/1983	129	umho/cm
SC (Field)	499541	5/15/1984	2700	umho/cm
SC (Field)	499544	1/7/1987	9.6	umho/cm
SC (Field)	499544	3/1/2000	403	umho/cm
SC (Field)	499602	10/3/1990	593	umho/cm
SC (Field)	499602	5/9/2000	18	umho/cm

Constituent	Station	Date	Raw Result	Units
SC (Field)	499603	8/31/2000	1718	umho/cm
SC (Field)	499603	7/31/1984	422	umho/cm
SC (Field)	499628	1/17/1984	8856	umho/cm
SC (Field)	499646	9/23/1980	3280	umho/cm
SC (Field)	499646	7/9/1980	115	umho/cm
SC (Field)	499646	3/1/2000	1515	umho/cm
SC (Field)	499656	2/13/1991	377	umho/cm
SC (Field)	499656	7/13/1989	374	umho/cm
SC (Field)	499656	10/30/1984	227	umho/cm
SC (Field)	499656	5/10/2000	328	umho/cm
SC (Field)	499669	7/10/1991	813	umho/cm
SC (Field)	499669	5/8/1991	628	umho/cm
SO4	499610	2/29/2000	222.	mg/L
SO4	499669	2/29/2000	215.	mg/L
TDS	499558	10/3/1990	910	mg/L
TDS	499669	10/10/2001	428.	mg/L
Temp	499472	10/28/1991	6.5	deg C
Temp	499504	7/20/1983	7.0	deg C
Temp	499602	5/5/1992	21.3	deg C
Temp	499649	5/2/1995	5.3	deg C
Temp	499649	7/28/1988	22.6	deg C
Temp	499649	8/4/1992	29.0	deg C
Temp	499656	10/26/1993	11.4	deg C
Temp	499657	7/9/1991	1.67	deg C
Temp	499669	2/23/1995	8.6	deg C
TP	499460	3/17/1988	0.25	mg/L
TP	499460	1/30/1991	0.77	mg/L
TP	499479	2/13/1990	0.322	mg/L
TP	499479	3/31/1987	4.19	mg/L
TP	499479	11/18/1986	0.42	mg/L
TP	499558	3/26/1985	0.95	mg/L
TP	499558	7/16/1986	1.53	mg/L
TP	499558	4/17/1984	3.75	mg/L
TP	499558	2/21/1996	0.45	mg/L
TP	499558	8/19/1999	1.463	mg/L
TP	499558	5/15/1984	7.82	mg/L
TP	499603	3/31/1987	4.49	mg/L
TP	499610	5/15/1984	2.59	mg/L
TP	499610	12/19/1984	1.25	mg/L
TP	499610	4/17/1984	0.83	mg/L
TP	499669	4/27/1982	0.15	mg/L
TP	499669	5/20/1981	4.5	mg/L
TP	499669	9/7/1995	0.71	mg/L
TSS	499460	1/20/1988	180	mg/L
TSS	499460	5/16/1984	292	mg/L
TSS	499460	11/6/1991	130	mg/L
TSS	499460	7/30/1985	400	mg/L
TSS	499460	10/17/1985	336	mg/L
TSS	499460	12/12/1985	340	mg/L
TSS	499479	10/17/1985	350.0	mg/L
TSS	499479	2/13/1990	116.0	mg/L

Constituent	Station	Date	Raw Result	Units
TSS	499479	7/29/1992	758.0	mg/L
TSS	499504	5/16/1984	981.0	mg/L
TSS	499504	8/21/1985	64.0	mg/L
TSS	499504	12/7/1994	36.0	mg/L
TSS	499504	10/4/2000	24.	mg/L
TSS	499504	1/22/1997	31.2	mg/L
TSS	499520	5/2/1995	63.0	mg/L
TSS	499525	11/25/1980	97.0	mg/L
TSS	499525	10/30/1984	71.0	mg/L
TSS	499525	7/16/1986	90.0	mg/L
TSS	499544	1/17/1984	151.0	mg/L
TSS	499558	1/17/1984	574.0	mg/L
TSS	499558	7/16/1986	1554.0	mg/L
TSS	499558	3/26/1985	1460.0	mg/L
TSS	499558	5/15/1984	9999.0	mg/L
TSS	499558	4/17/1984	7930.0	mg/L
TSS	499558	8/19/1999	1604.0	mg/L
TSS	499558	9/27/1982	498.0	mg/L
TSS	499602	7/21/1982	55.0	mg/L
TSS	499602	9/23/1980	138.0	mg/L
TSS	499610	5/15/1984	4070.0	mg/L
TSS	499610	3/26/1985	96.0	mg/L
TSS	499610	8/16/1983	186.0	mg/L
TSS	499610	4/17/1984	3690.0	mg/L
TSS	499622	1/5/1999	4.8	mg/L
TSS	499622	3/7/2000	4.4	mg/L
TSS	499622	7/2/1996	5.2	mg/L
TSS	499624	7/14/1999	115.6	mg/L
TSS	499624	1/22/1997	12.0	mg/L
TSS	499646	5/15/1984	36.0	mg/L
TSS	499649	11/1/1988	14.0	mg/L
TSS	499649	1/7/1991	49.0	mg/L
TSS	499649	5/15/1984	41.0	mg/L
TSS	499649	3/5/1991	23.0	mg/L
TSS	499649	9/15/1994	96.0	mg/L
TSS	499651	5/15/1984	58.0	mg/L
TSS	499656	5/16/1984	15.0	mg/L
TSS	499656	6/14/1995	109.0	mg/L
TSS	499656	11/25/1980	17.0	mg/L
TSS	499656	3/13/1997	27.2	mg/L
TSS	499656	10/27/1994	10.0	mg/L
TSS	499657	4/24/1985	241.0	mg/L
TSS	499657	5/16/1984	223.0	mg/L
TSS	499669	3/19/1986	23.0	mg/L
TSS	499669	10/23/1986	39.0	mg/L
TSS	499669	8/8/1989	50.0	mg/L
TSS	499669	7/21/1992	326.0	mg/L
TSS	499669	5/16/1984	496.0	mg/L
Turbidity	499460	6/14/1983	562	NTU
Turbidity	499479	10/17/1985	175.0	NTU
Turbidity	499558	2/15/1984	423.0	NTU

Constituent	Station	Date	Raw Result	Units
Turbidity	499558	1/17/1984	386.0	NTU
Turbidity	499558	7/16/1986	400.0	NTU
Turbidity	499610	4/17/1984	968.0	NTU
Turbidity	499669	10/22/2002	27.2	NTU
Turbidity	499669	7/16/1986	8.0	NTU
Turbidity	499669	5/16/1984	65.0	NTU
Turbidity	499669	4/17/1984	20.2	NTU
Chlor_a	491752	8/14/1990	354.6	ug/L
Chlor_a	491762	8/14/1990	597.5	ug/L
Chlor_a	491731	8/28/1991	210.7	ug/L
Chlor_a	491739	1/22/1991	91.5	ug/L
Chlor_a	491750	1/22/1991	113.8	ug/L

Appendix E

Seasonality Assessment

Seasonality Assessment

Date Range: January 1980 - October 2003
Average monthly concentration based on 5 or more data points per month

List of Tables

Table 1: List of STORET Stations

Station ID	Station Name
491731	UTAH LAKE 0.5 MI W OF GENEVA DISCHARGE #15-A
491734	UTAH LAKE E OF PROVO BOAT HARBOR/6 MI N OF LINCOLN BEACH #08
491737	UTAH LAKE 4 MI NORTH OF PELICAN POINT 5 MI WEST OF GENEVA
491739	UTAH LAKE 4 MI WEST OF PROVO AIRPORT 4 MI NORTH OF LINCOLN P
491750	UTAH LAKE 3 MI WNW OF LINCOLN BEACH
491752	UTAH LAKE 2 MI E OF SARATOGA SPRINGS #12
491762	UTAH LAKE GOSHEN BAY MIDWAY OFF MAIN POINT ON EAST SHORE
491777	UTAH LAKE PROVO BAY OUTSIDE ENTRANCE TO PROVO BAY
499460	JORDAN R AT BLUFFDALE ROAD XING
499472	JORDAN R AT NARROWS - PUMP STATION
499479	JORDAN R AT UTAH L OUTLET U121 XING
499496	AMERICAN FK CK 2.5MI S OF AM FK CITY
499504	TIMPANOGOS WWTP
499512	LINDON DRAIN AT CO RD XING AB UTLAKE
499520	US STEEL GENEVA
499525	OREM WWTP
499541	PAYSON WWTP
499542	BEER CK AB PAYSON WWTP AT U115 XING
499544	SALEM WWTP
499545	BEER CK AB SALEM WWTP
499548	PAYSON CITY POWER PLANT OUTFALL
499558	SPANISH FORK R AB UTAH L (LAKESHORE)
499600	DRY CK @ CR 77 XING AB UTAH LAKE
499602	SPANISH FORK WWTP
499603	DRY CK AB SPANISH FK WWTP
499610	HOBBLE CK AT I-15 BDG 3MI S OF PROVO
499622	SPRINGVILLE FH 001 WEST SIDE DISCHARGE
499624	SPRINGVILLE FH 003 EAST SIDE DISCHARGE
499628	SPRINGVILLE WWTP
499631	SPRING CK BL FISH HATCHERIES AND AB SPRINGVILLE WWTP
499643	PACIFIC STATES COOLING TOWER OUTFALL 001 FORMERLY 003
499646	REILLY TAR AND CHEMICAL
499648	IRONTON CNL AB REILLY TAR & CHEM & BL FISH HATCHERY
499649	W SPRINGVILLE FH
499651	SPRING CK AT DIST. BOX AB SPRINGVILLE HATCHERY
499654	MILL RACE CREEK AT I-15 CROSSING (2 MI S PROVO COURTHOUSE)

Station ID	Station Name
499656	PROVO WWTP
499657	MILLRACE CK AB PROVO WWTP
499669	PROVO R AT U114 XING
591760	BEER CREEK BL SALEM POND SITE #8
591975	SPRING CK AT 400 NORTH
591976	SPRING CK AB CNFL/ BEER CK AT 8400 S
591984	BEER CK AT 4800 WEST AND 8400 SOUTH
591986	BEER CK AB UTAH LAKE

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Bicarbonate (mg/L)
Date Range: January 1980 - October 2003
Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							234					
499460	S	280	276	277	258	261	261	267	259	268	273	288	288
499472	S	288	334	322	265	262	255	243	236	248	257	337	328
499479	S	273	305	275	265	258	250	231	226	228	253	287	317
499504	F		274	262		277		282	285				
499525	F		287	320		246		270					
499541	F			361		353		365	367				
499542	S	442	493	483	489	489		526	497	432	448	460	452
499544	F			449				479	480				
499545	S			328									336
499558	S	297	302	292	270	348	335	332	338	311	300	295	296
499602	F			449		434		450					
499603	S	482	514	480	443	403	387	444	437	439	452	464	472
499610	S	256	246	230	189	211	220	264	268	288	274	287	260
499628	F		287	295		277		295					
499631	S			279		280		284	287			280	281
499648	S		279	280	279	276	275	283	281	282	281	276	280
499651	S	282	282	285	283	287	285	286	285	286	282	284	277
499654	S	268	272	272	263	262	273	277	289	273	263		262
499656	S		234	249		257		270					234
499657	S	277	277	280	274	254	236	249	265	276	282	290	279
499669	S	211	205	208	202	199	177	206	202	216	213	207	211

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.
*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Dissolved Solids (mg/L); based on Specific Conductivity

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L					**1370**							
491731(Bottom)	L					**1377**							
491732(Surface)	L												
491732(Bottom)	L												
491734(Surface)	L												
491734(Bottom)	L												
491737(Surface)	L					**1338**							
491737(Bottom)	L					**1460**							
491739(Surface)	L					**1441**							
491739(Bottom)	L					**1410**							
491750(Surface)	L					**1445**							
491750(Bottom)	L					**1393**							
491752(Surface)	L					**1394**							
491752(Bottom)	L					**1382**							
491762(Surface)	L					**1543**							
491762(Bottom)	L												
491777(Surface)	L					**1340**							
491777(Bottom)	L					**1415**							
499460	S	938	932	830	815	819	830	898	941	727	934	983	948
499472	S	1082	1198	1144	974	834	1096	1056	**1259**	1097	974	**1392**	**1319**
499479	S	1035	1168	1140	925	869	881	1011	959	1138	1031	1074	**1242**
499496	S												
499504	F	669	597	661	639	609	523	571	527	465	616	605	607
499512	S				574	494							
499520	S	919	930	947	963	928	1072	963	955	946	1077	958	1066
499525	F	798	644	710	671	682	562	643	570	669	672	665	671
499526	S												
499541	F	844	920	811	985	765	811	797	811	893	743	882	725
499542	S	661	691	681	710	702	776	754	726	599	590	561	600
499544	F	782	594	700	668	685	623	797	791	758	739	700	675
499545	S		438	480		529		532	446	489		479	403
499548	F												

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499558	S	538	497	497	488	532	546	527	540	472	531	525	518
499600	S	847	785		703	743		739			645		
499602	F	**1254**	1188	**1301**	**1400**	**1283**	1061	**1239**	1174	979	**1206**	**1271**	1163
499603	S	682	725	696	616	550	513	582	571	546	535	618	606
499610	S	362	348	323	290	302	285	399	391	411	370	390	370
499622	F	523		549		504	672				377		
499624	F	1004		588			658	807			795		
499628	F	521	452	445	501	418	467	391	334	432	481	444	422
499631	S		615	616		613		672	624	584		552	545
499643	F	367	526	501	400	266	374	269	323	350	423	399	378
499646	F	726	616	668	709	695	678	842	782	699	745	725	685
499648	S	746	729	716	713	722	728	759	771	713	760	692	716
499649	F	582	576	478	481	585	568	630	551	623	583	535	553
499651	S	633	596	589	534	565	572	631	646	670	639	629	614
499654	S	611	586	596	585	522	558	538	577	543	578	567	574
499656	S	494	500	509	525	503	517	518	499	512	513	505	479
499657	S	404	383	434	380	355	337	358	382	366	405	407	407
499669	S	330	320	320	316	301	282	307	306	312	317	304	302
591760	S												
591975	S												
591976	S			457	414	470							
591984	S	738	739	707	685	840		884	888		635		
591986	S					916							

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.
*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Chloride (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							246					
499460	S	209	199	214	192	172	183	213	219	190	228	213	210
499472	S	220	244	232	211	243	268	287	323	338	289	286	264
499479	S	227	251	255	232	201	203	228	245	268	258	259	289
499542	S	54	62	64	85	71		87	79	51	50	59	51
499558	S	51	58	55	37	51	50	49	51	50	61	61	67
499603	S	58	80	69	54	43	42	44	42	47	39	46	55
499610	S	12	13	11	8	13	9	22	20	17	13	16	15
499648	S		45	44	47	46	50	51	51	50	51	47	48
499651	S	31	36	33	36	32	38	37	38	40	41	39	38
499654	S	55	53	56	56	45	51	47	50		48		57
499657	S	23	23	23	24	17	17	18	24	19	19	22	37
499669	S	16	15	15	15	13	11	14	13	14	13	12	14

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Chlorophyll a, uncorrected for pheophytin (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							12					
491737(Surface)	L							26					
491739(Surface)	L							13					
491750(Surface)	L							22					
491752(Surface)	L							13					

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Dissolved Calcium (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							50					
499460	S	84	84	85	79	69	70	72	65	69	71	87	82
499472	S	110	122	106	87	66	64	58	59	54	63	123	126
499479	S	93	112	108	67	61	63	53	54	51	64	88	111
499542	S	76	78	70	61	61		60	68	68	78	74	76
499558	S	70	74	69	65	66	64	65	55	62	69	70	70
499603	S	84	82	77	80	73	72	77	75	73	80	71	77
499610	S	71	72	63	52	57	58	75	71	66	70	71	70
499648	S		148	146	141	143	160	139	152	136	152	144	142
499651	S	120	112	110	114	109	130	111	122	119	129	122	118
499654	S	103	101	102	98	96	97	95	95	93	92		101
499657	S	82	73	73	73	69	64	66	68	67	76	76	74
499669	S	62	61	62	60	60	54	60	58	60	60	58	59

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Magnesium (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							58					
499460	S	55	54	57	50	48	47	53	54	54	55	59	54
499472	S	58	69	68	57	58	61	63	67	70	67	73	70
499479	S	54	60	60	55	53	54	56	56	60	60	64	68
499542	S	50	55	53	54	49		52	49	44	48	48	46
499558	S	31	31	30	24	34	33	33	33	32	33	31	30
499603	S	49	53	49	42	39	38	45	43	46	46	44	48
499610	S	18	18	17	13	16	14	23	22	25	19	22	19
499648	S		49	49	48	48	49	52	50	54	54	51	48
499651	S	39	42	39	40	38	41	42	40	45	43	43	41
499654	S	34	34	36	33	32	35	31	31	31	30		34
499657	S	24	22	24	22	20	20	20	21	21	23	24	23
499669	S	17	16	17	16	15	13	15	15	15	15	14	16

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Nitrogen, (NO2) + (NO3) as N (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							0.18					
491731(Bottom)	L							0.11					
491737(Surface)	L							0.01					
491737(Bottom)	L							0.03					
491739(Surface)	L							0.04					
491750(Surface)	L							0.01					
491752(Surface)	L							0.06					
499460	S			0.91		0.74					0.94		
499472	S					0.38	1.01						
499479	S					0.41	0.31						
499558	S	0.45	0.39	0.43	0.25	0.24	0.19	0.21					
499610	S			0.82	0.50	0.41		1.41	1.10				
499669	S	0.45	0.58	0.34	0.42	0.26	0.29	0.40	0.28		0.51		0.32

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Oxygen (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							9.9					
491731(Bottom)	L							5.6					
491737(Surface)	L							7.8					
491737(Bottom)	L							6.6					
491739(Surface)	L							7.7					
491739(Bottom)	L							6.4					
491750(Surface)	L							7.8					
491750(Bottom)	L							6.0					
491752(Surface)	L							8.5					
499460	S	11.4	10.7	10.9	10.0	9.1	8.6	8.3	7.7	8.0	9.2	10.7	10.6
499472	S	11.0	11.5	11.3	9.7	7.9	6.6	6.2	6.0	6.7	8.5	10.4	12.5
499479	S	10.4	12.2	9.6	8.5	7.6	7.2	6.8	7.3	7.5	8.0	10.0	11.5
499504	F	6.6	**5.3**	6.1	**5.1**	**5.2**	6.4	**4.8**	**5.5**	**4.7**	**5.3**	**5.2**	**5.4**
499520	S	7.1	6.2	7.1	7.3	6.5	6.1	**4.9**	5.8	**5.1**	**5.4**	5.7	5.9
499525	F	5.8	6.3	5.9	5.8	5.6	**5.3**	**5.3**	**5.1**	**5.2**	**5.3**	5.8	6.0
499541	F	**5.4**	6.3	6.3	5.7	5.6	5.8	**5.0**	**5.0**	**4.9**	**5.3**	**5.2**	6.0
499542	S	9.5	9.1	9.2	8.1	7.5		6.3	5.9	7.6	8.0	8.6	9.5
499544	F	7.9	7.9	8.7	6.8	5.5	**5.3**	**5.3**	**5.4**	5.8	5.8	7.6	7.9
499545	S		10.0	9.8		8.6		12.7	9.3			9.0	9.6
499558	S	11.0	10.4	9.9	8.5	8.4	7.1	6.8	6.8	7.2	9.3	10.1	10.2
499600	S	8.5	8.6		6.9	7.9		6.8			7.4		
499602	F	6.2	6.6	6.2	5.8	6.0	**5.3**	**5.4**	**5.5**	**5.2**	**5.3**	5.6	5.7
499603	S	9.7	9.6	9.0	8.8	8.0	8.9	7.6	6.8	7.6	8.8	9.0	9.5
499610	S	9.2	9.4	9.3	9.3	8.5	8.2	8.5	7.7	7.1	9.0	9.3	9.7
499622	F	6.9	6.8	6.6	7.0	6.5	6.9	7.0	6.6		7.0	7.3	6.9
499624	F	6.9		8.4	7.0	6.9	7.2	7.1	7.0		7.0	6.9	6.9
499628	F	6.9	7.6	7.6	7.0	6.9	6.5	6.8	6.4	6.4	6.7	7.1	7.4
499631	S		7.4	7.5		7.0		7.2	5.8			6.7	6.8
499643	F	5.8	**5.2**	6.0	6.2	6.5	7.3	6.6	**5.2**	5.7	**5.4**	6.2	6.2
499646	F	6.1	6.8	8.4	7.6	7.5	7.5	7.3	7.3	6.2	6.6	7.0	6.3
499648	S	7.5	8.1	7.3	7.8	8.0	8.2	8.1	7.5	7.4	7.6	7.6	7.3
499649	F	6.9	6.7	6.5	6.6	6.5	7.4	7.4	6.5	6.3	7.1	6.8	6.9

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499651	S	6.3	7.1	7.2	7.5	7.6	7.3	7.4	6.3	6.4	6.4	6.5	6.3
499654	S	7.9	8.9	8.4	8.3	8.4	8.1	8.7	7.6	8.9	8.8	7.1	9.3
499656	S	7.6	7.8	7.8	7.7	7.9	8.1	7.7	7.1	6.9	7.2	7.7	7.9
499657	S	9.2	9.4	9.2	9.9	8.9	8.6	8.1	7.7	7.5	8.4	8.5	8.3
499669	S	10.4	11.1	10.9	10.1	9.8	9.4	10.1	9.2	8.4	9.3	10.3	10.7
591984	S	10.6	9.8	9.3	8.0	7.0		**5.2**	6.4		8.4		

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Potassium (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							17.9					
499460	S	14.3	14.5	14.5	15.0	13.3	13.5	15.8	16.0	15.7	15.7	14.5	14.3
499472	S	13.1	15.8	15.6	14.0	16.0	17.6	19.5	21.3	21.8	19.7	16.8	15.9
499479	S	15.8	19.1	18.7	16.4	14.9	15.5	17.2	17.7	18.2	18.1	18.5	20.3
499542	S	9.9	13.3	11.9	10.4	9.0		8.6	10.2	10.2	10.5	11.7	9.1
499558	S	3.6	4.1	3.7	3.1	3.3	3.1	3.8	3.8	4.2	4.2	4.2	3.8
499603	S	8.8	12.1	9.8	8.8	7.4	8.1	7.7	7.0	7.0	6.9	8.2	8.2
499610	S	1.6	1.7	1.4	1.3	1.9	1.7	2.8	2.4	2.8	1.8	2.0	1.9
499648	S		5.7	5.5	5.5	5.4	7.1	5.4	5.7	5.1	5.4	5.2	4.9
499651	S	4.0	3.7	3.7	3.9	3.5	4.5	5.0	4.0	4.1	4.0	3.8	3.7
499654	S	6.2	6.5	6.7	7.1	5.8	6.2	6.3	5.8	6.0	4.9		5.7
499657	S	3.5	3.5	3.3	3.9	3.0	3.9	3.5	3.6	3.6	3.7	4.1	3.2
499669	S	2.4	2.4	2.3	2.5	2.5	2.3	2.6	2.6	2.8	2.6	2.3	2.2

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Sodium (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							188.5					
499460	S	159.1	145.0	154.0	146.1	133.9	128.8	156.3	158.8	151.9	165.4	154.9	160.2
499472	S	156.9	187.0	180.7	162.3	179.5	194.0	211.2	232.3	248.0	228.3	215.0	195.8
499479	S	167.6	175.4	177.2	171.3	158.4	163.3	175.3	186.2	203.2	196.9	184.1	198.0
499542	S	69.9	87.6	93.6	102.8	115.9		147.5	121.1	69.0	66.8	69.3	65.4
499558	S	49.4	54.4	50.8	39.1	66.5	63.5	66.3	69.2	54.2	57.1	55.0	57.4
499603	S	72.1	115.1	91.4	72.9	53.0	75.0	51.4	48.1	48.7	49.2	58.4	69.6
499610	S	12.3	12.0	10.9	8.6	11.4	10.3	19.3	16.6	19.1	13.9	17.7	14.4
499648	S		37.9	36.7	36.9	36.4	41.6	38.5	38.9	38.0	39.3	37.9	37.9
499651	S	28.9	27.9	26.8	28.3	26.4	31.6	31.8	29.3	31.0	30.8	30.3	30.3
499654	S	48.5	45.9	43.6	48.7	38.0	44.0	42.8	41.0	38.4	34.3		45.2
499657	S	20.5	18.4	18.4	20.1	14.7	16.4	16.8	16.5	16.5	19.0	19.3	28.5
499669	S	13.5	12.9	13.3	12.9	12.1	10.3	12.6	11.8	12.9	11.5	11.2	12.5

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Dissolved Total Phosphorus (mg/L)
Date Range: January 1980 - October 2003
Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							0.021					
491731(Bottom)	L							0.022					
491739(Surface)	L							0.024					
491752(Surface)	L							0.020					
499460	S			0.030		0.048	0.027				0.038		
499472	S					0.021	0.036						
499479	S					0.021	0.094						
499558	S	0.015		0.016		0.030	0.029	0.045	0.031		0.019		
499610	S			0.021	0.025	0.027			0.032				
499654	S								0.896				
499669	S	0.026		0.014	0.016	0.021	0.019	0.045	0.027		0.020		

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.
*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Nitrogen, ammonia (NH3) as NH3 (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							0.04					
491731(Bottom)	L							0.03					
491737(Surface)	L							0.03					
491737(Bottom)	L							0.03					
491739(Surface)	L							0.03					
491739(Bottom)	L							0.04					
491750(Surface)	L							0.03					
491750(Bottom)	L							0.03					
491752(Surface)	L							0.03					
499460	S	0.11	0.06	0.10	0.06	0.07	0.32	0.09	0.07	0.10	0.09	0.14	0.09
499472	S	0.18	0.16	0.14	0.05	0.03	0.08	0.06	0.14	0.17	0.06	0.07	0.11
499479	S	0.14	0.19	0.10	0.05	0.07	0.07	0.05	0.04	0.19	0.07	0.18	0.07
499504	F	0.09	0.34	0.13	0.06	0.07	0.10	0.08	0.07	0.17	0.04	0.08	0.07
499520	S	6.32	8.40	6.43	6.43	6.28	4.51	4.49	3.88	4.65	2.48	6.48	6.83
499525	F	11.23	9.67	11.56	12.30	9.60	8.89	8.21	8.64	9.56	9.24	11.86	10.78
499541	F	9.33	9.65	8.45	8.63	4.03	5.46	2.30	1.81	2.42	4.27	5.53	7.23
499542	S	0.56	0.55	0.28	0.19	0.23	0.25	0.17	0.11	0.16	0.16	0.25	0.36
499544	F	5.12	6.94	4.33	3.72	3.04	2.28	2.69	3.44	2.10	2.51	4.45	3.87
499545	S		0.24	0.10		0.08		0.05	0.07	0.06		0.12	0.41
499558	S	0.05	0.06	0.05	0.08	0.12	0.10	0.17	0.11	0.09	0.04	0.05	0.07
499600	S	0.60	0.23		0.44	0.47		0.20			0.13		
499602	F	2.95	3.75	2.12	3.71	2.67	3.07	2.20	2.49	2.29	3.06	2.87	2.43
499603	S	0.24	0.31	0.25	0.19	0.19	0.07	0.08	0.08	0.09	0.10	0.11	0.22
499610	S	0.05	0.09	0.03	0.05	0.05	0.03	0.09	0.05	0.04	0.04	0.03	0.06
499628	F	2.31	1.08	0.87	2.47	0.65	2.12	1.91	1.83	2.19	1.43	2.84	1.71
499631	S		0.16	0.14		0.19		0.15	0.35	0.10		0.06	0.06
499648	S	0.10	0.13	0.10	0.11	0.10	0.04	0.05	0.07	0.06	0.08	0.06	0.08
499651	S	0.03	0.04	0.03	0.03	0.05	0.04	0.05	0.03	0.03	0.03	0.03	0.04
499654	S	0.18	0.26	0.27	0.14	0.17	0.14	0.16	0.09	0.22	0.15	0.36	0.18
499656	S	0.05	0.08	0.06	0.06	0.04	0.04	0.05	0.05	0.08	0.06	0.07	0.05
499657	S	0.14	0.08	0.05	0.05	0.04	0.06	0.06	0.06	0.07	0.07	0.09	0.08
499669	S	0.04	0.03	0.03	0.03	0.04	0.05	0.04	0.03	0.04	0.04	0.04	0.04

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
591984	S	0.68	0.54	0.28	0.36	0.35		0.13			0.32		

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Nitrogen, Kjeldahl (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499460	S	0.64	0.78	0.77	0.70	0.54	2.26	1.00	0.95	0.82	0.78	0.53	0.53
499472	S	0.86	0.69	1.02								0.70	
499479	S	0.83	0.96	1.61	0.76	0.93	1.11	1.05	1.46	1.35	1.17	2.46	0.75
499504	F			1.59	1.38							2.46	
499525	F			18.36								16.40	
499541	F			13.32								9.63	
499542	S	1.20	1.87	1.23	0.99	1.36		1.09	0.72	1.14	0.62	0.97	0.99
499544	F			10.62								10.36	
499558	S	0.56	0.47	0.56	1.44	2.06	0.98	2.47	0.67	0.71	0.38	0.32	0.36
499602	F			4.25	7.38							5.04	
499603	S	1.09	1.38	1.07	1.19	1.22	0.95	0.97	1.31	0.75	0.67	0.65	0.85
499610	S	0.32	0.31	0.30	0.88	0.85	0.54	0.47	0.28	0.53	0.20	0.16	0.34
499628	F											6.07	
499648	S		0.47	0.64	0.32	0.22	0.40	0.32	0.22	0.18	0.20	0.20	0.24
499651	S	0.21	0.18	0.14	0.16	0.23	0.20	0.30	0.17	0.15	0.27	0.14	0.22
499654	S	0.59	1.04	0.97	1.01	1.11		0.86	1.21	1.11	0.70	1.15	0.85
499656	S			0.43		3.51						0.70	
499657	S	0.75	0.32	0.29	0.43	0.36	0.67	0.48	0.61	0.51	0.75	0.31	0.34
499669	S	0.29	0.22	0.23	0.27	0.38	0.41	0.34	0.36	0.35	0.26	0.30	0.16

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

pH (Field) and pH (Lab)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Field/Lab	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	Field	L							8.6					
491731(Bottom)	Field	L							8.4					
491737(Surface)	Field	L							8.3					
491737(Bottom)	Field	L							8.3					
491739(Surface)	Field	L							8.4					
491739(Bottom)	Field	L							8.3					
491750(Surface)	Field	L							8.4					
491750(Bottom)	Field	L							8.3					
491752(Surface)	Field	L							8.5					
499460	Field	S	8.2	8.1	8.3	8.2	8.3	8.2	8.0	8.0	8.0	8.0	8.0	8.2
499472	Field	S	7.6	7.7	8.0	8.0	8.0	8.1	8.2	8.1	8.1	8.1	7.8	7.8
499479	Field	S	7.9	7.7	8.2	8.2	8.2	8.1	8.3	8.4	8.3	8.2	7.9	7.8
499504	Field	F	7.6	7.5	7.5	7.4	7.5	7.7	7.6	7.7	7.5	7.6	7.4	7.6
499520	Field	S	8.0	8.0	8.3	8.1	8.2	8.1	8.0	8.2	7.9	8.0	7.9	8.2
499525	Field	F	7.5	7.3	7.5	7.5	7.4	7.4	7.3	7.4	7.3	7.4	7.1	7.6
499541	Field	F	7.6	7.6	7.7	7.7	7.6	7.7	7.6	7.7	7.6	7.5	7.4	7.6
499542	Field	S	8.1	8.1	8.2	8.2	8.0	8.1	7.8	7.8	7.8	8.1	7.9	7.8
499544	Field	F	7.9	7.9	8.2	8.5	8.3	8.3	8.2	8.0	8.2	8.3	7.9	8.0
499545	Field	S		7.9	8.1		8.2		8.4	8.0	7.8		7.7	7.8
499558	Field	S	8.2	8.2	8.4	8.3	8.1	8.1	8.0	7.9	8.0	8.2	8.0	7.8
499600	Field	S	8.1	8.1		8.1	8.3		8.0			8.0		
499602	Field	F	7.7	7.6	7.8	7.8	7.9	7.7	7.8	7.7	7.7	7.6	7.5	7.8
499603	Field	S	8.2	8.0	8.2	8.3	8.1	8.2	8.1	7.9	7.9	8.2	8.0	7.6
499610	Field	S	8.2	8.0	8.4	8.3	8.3	8.3	8.0	7.8	7.9	8.2	8.0	8.0
499622	Field	F	7.5	7.5	7.6	7.6	7.5	7.5	7.5	7.4		7.5	7.5	7.5
499624	Field	F	7.4		7.6	7.5	7.5	7.4	7.5	7.4		7.5	7.5	7.5
499628	Field	F	7.8	7.8	7.9	7.7	7.8	7.7	7.7	7.7	7.7	7.7	7.5	7.7
499631	Field	S			7.6		7.6		7.6	7.7	7.6		7.4	7.3
499643	Field	F	7.8	7.9	8.0	8.1	8.0	8.1	8.0	7.9	7.8	8.0	7.7	7.7
499646	Field	F	7.8	7.7	7.9	7.8	7.9	7.8	7.7	8.0	7.7	7.7	7.5	7.5
499648	Field	S	7.5	7.6	7.7	7.7	7.8	7.7	7.6	7.7	7.5	7.6	7.3	7.3
499649	Field	F	7.3	7.4	7.5	7.5	7.5	7.6	7.6	7.5	7.4	7.4	7.1	7.5
499651	Field	S	7.5	7.3	7.5	7.4	7.5		7.5	7.6	7.2		7.1	7.3
499654	Field	S	7.8	7.7	7.9	8.1	8.1	8.0	8.1	7.9	7.9	7.9	7.9	7.9
499656	Field	S	7.5	7.3	7.5	7.7	7.6	7.4	7.5	7.7	7.5	7.5	7.4	7.4

Station	Field/Lab	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499657	Field	S	8.0	8.1	8.1	8.2	8.2	8.3	7.9	8.0	8.0	8.0	7.7	7.8
499669	Field	S	8.3	8.4	8.4	8.4	8.5	8.3	8.4	8.3	8.2	8.2	8.2	8.3
591984	Field	S	8.2	8.0	8.1	8.1	8.0		8.0	8.0		8.1		
491731(Surface)	Lab	L							8.2					
499460	Lab	S	8.2	8.1	8.1	8.1	8.1	8.1	8.0	7.9	7.8	8.1	8.1	8.1
499472	Lab	S	7.8	7.9	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	8.0	7.8
499479	Lab	S	7.8	7.7	8.0	8.0	8.1	8.1	7.9	7.9	7.8	8.1	8.0	7.9
499504	Lab	F	7.7	7.6	7.7	7.7	7.9		7.6	7.6	7.9	7.7	7.8	7.7
499520	Lab	S		7.7	7.8	7.9	7.9		7.7	8.2			7.7	
499525	Lab	F	7.5	7.5	7.4	7.4	7.2		7.4	7.0		7.3	7.4	7.5
499541	Lab	F	7.7	7.7	7.7	7.8	7.7		7.9	7.8		7.8	7.8	7.8
499542	Lab	S	8.0	8.0	8.0	8.1	8.1		7.9	8.0	8.2	8.1	8.1	8.1
499544	Lab	F	7.9	7.8	7.7	7.9	7.7		8.0	7.9		8.0	8.0	7.9
499545	Lab	S		8.0	8.1		8.0		8.1	8.0				8.0
499558	Lab	S	8.1	8.1	8.2	8.2	8.1	8.2	8.1	8.1	8.1	8.2	8.2	8.1
499602	Lab	F	7.8	7.9	7.8	7.9	7.7		7.9	7.8	7.9	7.8	7.8	7.8
499603	Lab	S	8.1	8.2	8.2	8.2	8.0	8.1	8.0	8.0	8.2	8.1	8.1	8.1
499610	Lab	S	8.0	8.0	8.1	8.0	8.0	7.9	8.0	8.0	7.9			8.0
499628	Lab	F	7.8	7.8	7.8	7.8	7.7		7.9	7.7	7.8	7.8	7.8	7.9
499631	Lab	S		8.1	7.9		7.9		7.8	7.9			8.0	8.0
499646	Lab	F	7.7	7.8	7.8	7.7	7.7		7.7	7.6	7.8	7.9	7.8	7.6
499648	Lab	S		8.0	7.9		8.0						8.0	
499651	Lab	S		7.9	7.8		7.8						7.9	
499654	Lab	S	7.8	8.0	7.9		7.9			7.9				7.9
499656	Lab	S	7.7	7.8	7.7	7.9	7.9		7.9	7.9		7.9	7.9	7.9
499657	Lab	S	7.9	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.1	8.0	8.0	8.0
499669	Lab	S	8.2	8.2	8.2	8.2	8.2	8.2	8.3	8.2	8.2	8.1	8.4	8.2

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Specific conductivity (umho/cm)
Date Range: January 1980 - October 2003
Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Field/Lab	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	Field	L							1525					
491731(Bottom)	Field	L							1538					
491737(Surface)	Field	L							1437					
491737(Bottom)	Field	L							1638					
491739(Surface)	Field	L							1621					
491739(Bottom)	Field	L							1593					
491750(Surface)	Field	L							1624					
491750(Bottom)	Field	L							1571					
491752(Surface)	Field	L							1543					
499460	Field	S	1451	1442	1287	1222	1278	1264	1365	1456	1112	1418	1498	1466
499472	Field	S	1682	1868	1837	1599	1458	1705	1640	1967	1707	1801	2180	2064
499479	Field	S	1606	1821	1731	1417	1389	1362	1568	1485	1772	1531	1670	1939
499504	Field	F	1051	988	1051	1026	998	902	965	927	872	1005	995	997
499520	Field	S	1420	1462	1380	1532	1467	1646	1485	1433	1476	1653	1442	1670
499525	Field	F	1155	1029	1088	1057	1063	954	1079	965	1051	1054	1048	1053
499541	Field	F	1205	1272	1177	1330	1136	1166	1158	1177	1249	1116	1239	1100
499542	Field	S	1006	1053	1038	1084	1071	1149	1155	1129	906	891	845	907
499544	Field	F	1151	985	1079	1051	1065	990	1177	1159	1130	1114	1079	1057
499545	Field	S		635	716		795		798	667	729		714	591
499558	Field	S	808	761	744	683	813	813	784	825	753	803	788	776
499600	Field	S	1305	1205		1073	1138		1131			981		
499602	Field	F	1567	1509	1608	1696	1593	1386	1554	1496	1324	1524	1582	1487
499603	Field	S	1039	1108	1063	934	828	768	878	861	821	804	937	917
499610	Field	S	526	506	461	388	424	403	586	571	604	535	570	525
499622	Field	F	923		922		906					794		
499624	Field	F	1346		982				1173			1162		
499628	Field	F	921	861	846	904	831	870	807	756	842	886	853	834
499631	Field	S		931	934		929		1024	947	882		832	819
499643	Field	F	786	926	903	814	696	791	699	747	770	835	814	795
499646	Field	F	1102	1004	1050	1086	1075	1060	1204	1151	1078	1118	1101	1065
499648	Field	S	1143	1115	1094	1090	1104	1114	1164	1182	1090	1165	1056	1094
499649	Field	F	975	969	883	886	977	962	1017	948	1011	976	934	950
499651	Field	S	961	901	890	802	852	864	957	982	1021	970	955	930
499654	Field	S	926	895	889	873	777	844	824	873	805	877	855	866
499656	Field	S	738	748	762	782	752	768	776	745	766	769	756	714

Station	Field/Lab	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499657	Field	S	594	560	641	552	514	485	554	558	532	594	609	598
499669	Field	S	474	460	455	453	427	391	432	435	441	449	433	432
591984	Field	S	1130	1112	1059	1096	1327		1365	1416		957		
499460	Lab	S	1486	1368	1493	1301	1293	1337	1466	1450	1425	1440	1535	1447
499472	Lab	S	1643	1887	1787	1565	1572	1639	1702	1865	1927	1845	2144	1955
499479	Lab	S	1573	1683	1575	1549	1404	1475	1489	1536	1623	1577	1724	1906
499542	Lab	S	999	1044	1070	1107	1104		1284	1164	925	944	960	942
499558	Lab	S	795	825	774	625	811	787	819	829	765	855	809	828
499603	Lab	S	1025	1139	1064	936	857	812	907	864	882	890	940	1001
499610	Lab	S	517	506	464	366	434	409	592	567	582	537	584	537
499648	Lab	S		1117	1105	1085	1114		1189	1191	1155	1190	1134	1125
499651	Lab	S	934	923	886	905	880	1010	979	992	1000	1021	976	969
499654	Lab	S	930	894	915	908	806			855		906		901
499657	Lab	S	586	584	588	583	529	489	523	552	548	574	602	636
499669	Lab	S	464	450	469	441	442	382	442	432	450	444	428	443

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Sulfate (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							252					
499460	S	258	238	261	216	193	195	225	214	220	228	286	243
499472	S	344	385	369	307	258	272	277	308	306	315	463	403
499479	S	267	315	315	253	218	222	239	244	269	245	314	355
499542	S	93	95	101	116	120		145	121	80	77	84	85
499558	S	94	102	89	67	93	96	101	100	95	107	105	104
499603	S	99	116	108	84	72	70	74	71	73	70	79	88
499610	S	47	52	44	33	41	30	66	57	53	43	59	55
499648	S		351	337	334	339	368	354	364	343	382	352	355
499651	S	225	239	208	232	203	258	237	252	263	272	260	259
499654	S	186	154	184	169	138	158	134	143	134	181		170
499657	S	56	56	60	60	49	44	43	45	47	52	53	57
499669	S	51	55	53	51	49	40	46	42	44	44	45	46

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Temperature, water (deg C)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							24.4					
491731(Bottom)	L							22.3					
491737(Surface)	L							23.0					
491737(Bottom)	L							22.1					
491739(Surface)	L							23.6					
491739(Bottom)	L							21.4					
491750(Surface)	L							24.1					
491750(Bottom)	L							22.0					
491752(Surface)	L							23.2					
499460	S	3.3	5.5	7.5	12.7	15.1	19.0	20.8	20.9	16.7	13.4	8.0	3.9
499472	S	2.5	4.3	7.3	11.9	15.9	17.6	24.0	22.4	18.3	12.6	10.7	2.3
499479	S	2.4	3.2	6.9	12.7	15.4	18.7	23.6	23.3	17.1	12.1	6.5	2.9
499504	F	8.7	9.1	9.7	12.6	13.9	16.3	19.7	20.1	18.1	16.1	13.0	10.1
499520	S	6.3	7.3	9.8	15.3	17.3	21.3	24.0	24.2	20.3	14.6	9.0	6.0
499525	F	10.5	10.3	11.5	13.6	16.0	19.0	21.3	22.0	20.9	18.4	15.1	12.2
499541	F	8.9	9.4	9.9	12.7	14.7	17.7	19.7	20.2	18.5	16.1	12.6	9.9
499542	S	3.2	5.3	6.4	10.5	13.7	16.5	19.4	19.5	15.0	10.9	5.7	3.7
499544	F	5.4	6.1	8.0	12.7	15.5	19.4	21.9	21.5	18.6	14.1	9.6	6.5
499545	S		7.5	10.4		15.9		20.8	19.4	15.8		9.2	5.6
499558	S	2.3	4.1	6.1	9.1	13.1	16.6	20.2	18.7	15.1	10.1	5.4	3.0
499600	S	6.5	7.8		10.7	13.2		19.7			11.6		
499602	F	9.3	9.4	10.3	12.7	14.4	17.0	19.2	19.4	18.2	15.7	13.1	10.6
499603	S	3.2	5.3	6.6	10.3	13.2	14.9	18.1	17.5	14.0	10.3	6.3	3.1
499610	S	3.5	6.3	7.5	8.9	13.9	13.0	20.1	18.8	14.7	10.2	6.8	4.3
499622	F	13.4	13.9	14.5	14.5	15.8	16.4	15.7	15.4		14.7	14.0	14.5
499624	F	13.7		14.4	14.2	15.0	15.6	15.6	15.3		14.7	14.1	14.5
499628	F	9.7	11.1	12.0	13.8	15.4	18.0	19.4	20.1	18.5	16.8	13.0	11.5
499631	S		13.0	14.3		15.5		17.3	16.8	14.5		13.8	12.3
499643	F	**29.2**	**32.4**	**32.4**	**29.4**	**30.5**	**33.5**	**30.0**	**35.4**	**30.8**	**29.5**	**28.5**	26.0
499646	F	14.4	15.1	17.3	17.2	19.6	20.9	21.5	20.8	19.6	18.7	17.2	15.1
499648	S	11.7	12.2	13.5	14.8	15.9	16.9	18.0	17.6	16.3	15.1	12.3	11.4
499649	F	12.8	13.4	13.9	14.8	15.2	15.8	16.7	16.8	15.9	15.1	14.3	12.7

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499651	S	12.7	13.2	13.8	15.1	15.6	15.9	17.2	16.6	15.5	14.5	13.7	12.6
499654	S	7.1	8.8	10.8	14.0	17.2	20.4	22.4	22.1	19.6	14.6	11.9	7.4
499656	S	11.9	12.0	13.1	14.8	15.5	17.8	19.9	21.0	20.3	18.3	15.6	12.5
499657	S	7.6	8.1	10.2	10.5	13.5	15.0	17.6	19.5	17.0	15.2	12.5	7.3
499669	S	2.5	3.1	5.4	7.4	10.8	12.7	16.5	17.3	14.7	11.3	7.0	3.5
591984	S	4.0	7.4	9.4	10.6	15.1		22.9	21.6		12.4		

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Dissolved Solids (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type	
L = Lake	
S = Stream	
F = Facility or Point Discharge	

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							909.7					
499460	S	958	905	974	828	803	823	913	897	910	915	959	959
499472	S	1110	**1266**	1182	1015	990	1034	1082	1152	**1205**	1182	**1455**	**1321**
499479	S	1009	1140	1139	967	879	914	933	946	1016	1044	1098	**1267**
499520	S	875	917	895	834	879	892	895	801	802	1044	850	1062
499542	S	616	658	659	682	694		807	716	567	579	600	596
499558	S	466	502	463	445	505	523	486	488	485	499	488	507
499603	S	619	741	665	576	523	504	559	530	545	541	573	631
499610	S	301	306	276	243	287	243	361	334	340	318	339	327
499648	S		832	798	793	815		845	857	804	884	844	820
499651	S	636	636	590	618	596	679	647	664	663	708	680	677
499654	S	592	613	596	590	529	553	534	560	541	582	586	594
499657	S	360	363	366	353	323	304	309	330	344	357	379	391
499669	S	281	280	285	285	271	243	269	264	271	268	258	275

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Nitrogen, (NO2) + (NO3) as N (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499460	S	0.85	0.71	0.63		0.81	0.52	0.61			0.59	0.92	
499479	S	0.45						0.35		0.79	0.16	0.34	
499504	F			8.48									
499558	S			3.37				0.41		0.75	0.29	0.51	
499669	S	0.38	0.40	1.72	0.32			0.44		0.45	0.33	0.35	

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Nitrogen, Nitrate (NO3) as NO3 (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type	
L = Lake	
S = Stream	
F = Facility or Point Discharge	

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499460	S	0.82	1.12	0.81		0.69	0.82	0.44		0.68		1.45	
499479	S	0.47	0.27	0.22		0.50	0.57	0.33	0.51			0.56	0.40
499542	S								1.23				
499558	S		0.55	0.43		0.62							
499651	S			1.36									
499669	S			0.47		0.46						0.31	

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Nitrogen, Nitrite (NO2) as NO2 (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499460	S	0.007		0.006		0.011	0.005			0.019		0.019	
499479	S	0.006	0.040	0.010		0.023	0.018	0.005	0.006			0.017	0.008
499542	S								0.007				
499558	S		0.016	0.005		0.005							
499651	S			0.005									
499669	S			0.005		0.014						0.006	

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Phosphorus (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							**0.057**					
491731(Bottom)	L							**0.087**					
491737(Surface)	L							**0.072**					
491737(Bottom)	L							**0.076**					
491739(Surface)	L							**0.080**					
491739(Bottom)	L							**0.064**					
491750(Surface)	L							**0.048**					
491752(Surface)	L							**0.065**					
499460	S	**0.058**	**0.072**	**0.063**	**0.097**	**0.097**	**0.087**	**0.112**	**0.150**	**0.146**	**0.108**	**0.069**	**0.074**
499472	S	**0.081**	**0.096**	**0.082**	**0.070**	**0.121**	**0.130**	**0.168**	**0.168**	**0.212**	**0.111**	**0.075**	**0.053**
499479	S	**0.072**	**0.053**	**0.073**	**0.105**	**0.175**	**0.160**	**0.197**	**0.212**	**0.208**	**0.102**	**0.070**	0.044
499504	F	**4.085**	**4.146**	**4.659**	**4.879**	**4.916**	**3.328**	**3.700**	**3.621**	**4.805**	**4.589**	**4.777**	**4.189**
499525	F	**5.858**	**6.245**	**5.890**	**6.538**	**7.209**	**5.900**	**6.109**	**5.928**		**6.520**	**6.552**	**5.639**
499541	F	**5.985**	**6.233**	**6.149**	**5.839**	**5.223**	**4.955**	**3.863**	**3.702**		**4.610**	**5.601**	**6.154**
499542	S	**0.340**	**0.384**	**0.297**	**0.218**	**0.241**		**0.347**	**0.305**	**0.195**	**0.256**	**0.284**	**0.318**
499544	F	**2.500**	**2.845**	**2.080**	**2.706**	**2.311**	**2.658**	**3.263**	**2.165**		**1.951**	**2.580**	**2.444**
499545	S		**0.068**	**0.072**		**0.092**		**0.081**	**0.154**	**0.092**		**0.101**	**0.082**
499558	S	**0.101**	**0.082**	**0.089**	**0.354**	**0.158**	**0.233**	**0.125**	**0.152**	**0.278**	**0.101**	**0.067**	**0.071**
499602	F	**2.693**	**3.208**	**2.594**	**2.897**	**2.767**	**2.680**	**2.184**	**2.025**	**2.039**	**2.888**	**2.631**	**2.993**
499603	S	**0.229**	**0.297**	**0.194**	**0.157**	**0.199**	**0.269**	**0.245**	**0.168**	**0.141**	**0.170**	**0.211**	**0.258**
499610	S	0.037	**0.061**	**0.057**	**0.063**	**0.061**	**0.086**	**0.132**	**0.109**	**0.109**	0.031	0.034	0.031
499628	F	**2.812**	**3.408**	**3.317**	**2.872**	**3.076**	**2.325**	**1.748**	**1.919**	**2.387**	**2.494**	**3.133**	**2.529**
499631	S		**0.127**	**0.107**		**0.102**		**0.059**	**0.138**	**0.105**		**0.072**	**0.094**
499648	S	**0.080**	**0.073**	**0.069**	**0.079**	**0.073**	**0.064**	**0.081**	**0.050**	**0.088**	**0.073**	**0.053**	**0.068**
499651	S	0.028	0.021	0.034	0.033	**0.073**		**0.059**	0.043	0.041	0.036	0.032	0.036
499654	S	**1.147**	**1.141**	**1.224**	**0.926**	**0.845**	**0.916**	**0.948**	**1.072**	**1.207**	**1.212**	**1.192**	**1.090**
499656	S	**3.592**	**3.642**	**3.434**	**3.478**	**2.991**	**2.441**	**2.240**	**2.391**	**3.166**	**3.123**	**3.850**	**2.976**
499657	S	**0.111**	**0.109**	**0.094**	**0.129**	**0.143**	**0.117**	**0.115**	**0.120**	**0.149**	**0.097**	**0.115**	**0.116**
499669	S	0.039	0.030	0.035	0.031	0.048	0.042	0.042	**0.054**	0.046	0.042	0.038	0.028

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Total Suspended Solids (mg/L)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							35.9					
491737(Surface)	L							68.5					
491739(Surface)	L							30.6					
491750(Surface)	L							53.8					
491752(Surface)	L							50.5					
499460	S	22.0	52.9	51.2	**90.2**	61.5	70.4	85.3	**104.4**	**99.7**	64.5	23.9	28.1
499472	S	33.7	66.2	90.0	51.3	**97.3**	**118.3**	**144.6**	**132.8**	**120.0**	51.2	42.5	39.7
499479	S	16.3	17.3	44.0	69.3	**152.0**	**179.4**	**122.6**	**176.4**	**149.0**	43.8	33.4	14.6
499504	F	3.5	5.6	4.2	3.4	5.4	2.6	4.0	2.6	6.8	1.9	3.4	3.9
499520	S	4.6	4.1	5.5	3.8	2.9	7.7	5.2	7.0	4.7	2.6	1.9	1.6
499525	F	26.0	15.6	18.6	24.5	14.6	14.6	10.5	14.8	14.5	10.5	14.1	23.7
499541	F	11.2	10.4	11.0	9.8	7.6	13.2	9.7	7.0	9.8	7.7	13.4	8.3
499542	S	33.1	39.6	41.9	42.6	51.1	44.1	52.6	34.2	24.2	24.9	27.0	24.1
499544	F	17.2	23.6	20.6	20.8	25.9	21.4	17.0	16.2	18.1	11.9	14.8	15.6
499545	S		9.3	36.9		15.0		13.2	11.5	12.0		28.4	33.3
499558	S	65.6	80.7	**118.1**	**436.1**	**197.8**	**274.6**	**101.1**	**126.3**	68.7	73.4	42.2	**127.1**
499600	S										14.9		
499602	F	12.3	18.2	11.5	16.5	20.3	14.0	12.4	12.3	11.2	9.7	14.3	11.6
499603	S	**96.1**	**93.8**	83.2	**172.3**	**102.9**	58.8	83.1	87.5	75.5	63.2	75.1	**119.6**
499610	S	5.9	8.0	9.3	39.1	24.9	24.5	21.5	8.7	32.0	6.7	7.3	5.3
499622	F	0.0	0.0	0.0	0.0	1.3	0.0	0.0		0.0	1.2	0.0	0.0
499624	F	0.5		1.4	2.5	1.8	0.9	2.6		1.0	0.5	2.8	0.0
499628	F	18.9	10.8	14.7	16.1	15.6	16.0	11.7	8.4	13.3	13.5	12.3	12.1
499631	S		0.6	2.0		0.4		2.5	1.2	3.0		2.0	5.0
499643	F	7.8	13.4	8.7	17.8	17.4	21.4	9.8	16.1	14.6	9.5	7.7	7.1
499646	F	0.0	3.3	1.4	8.7	1.9	0.0	2.4	3.3	1.5	1.9	6.0	1.3
499648	S	4.8	10.8	6.1	4.8	11.4	2.4	8.9	7.0	4.3	6.2	3.7	2.6
499649	F	3.9	4.1	2.3	2.9	2.8	0.8	3.0	1.3	1.4	3.7	1.9	3.5
499651	S	7.6	5.2	3.3	1.3	1.3	1.2	6.7	1.8	4.9		0.4	15.1
499654	S	14.5	16.5	24.3	30.5	32.1	37.8	75.7	32.9	22.2	25.9	26.6	12.9
499656	S	0.9	0.9	1.5	13.3	1.2	0.4	1.1	1.5	0.6	0.4	0.5	2.0
499657	S	7.4	8.6	7.9	20.0	10.1	39.7	17.2	15.2	9.6	6.3	4.4	28.3

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
499669	S	2.4	2.8	4.0	10.0	9.9	8.5	4.2	5.3	8.2	7.7	10.8	2.4
591984	S	20.6			63.5	69.5					44.8		

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.
*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Seasonality Assessment

Type
L = Lake
S = Stream
F = Facility or Point Discharge

Turbidity (NTU)

Date Range: January 1980 - October 2003

Overall average monthly concentration based on monthly averages from 5 or more years

Station	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
491731(Surface)	L							25.4					
499460	S	15.1	24.1	32.5	48.5	33.5	39.5	52.0	53.7	45.8	58.7	21.2	44.2
499472	S	22.6	39.7	52.1	33.3	58.6	76.6	91.1	90.0	73.8	47.7	28.1	21.4
499479	S	12.3	15.8	28.8	53.3	102.5	68.1	84.1	94.6	163.3	50.7	20.7	11.1
499542	S	18.5	17.2	22.9	30.0	21.7		23.7	16.3	16.6	14.1	15.7	15.4
499558	S	15.5	23.0	101.1	137.6	102.0	109.9	44.6	87.6	110.2	36.2	15.3	27.5
499603	S	50.0	38.5	50.3	71.7	36.6	55.9	44.1	28.9	28.0	35.5	43.6	62.5
499610	S	2.7	3.2	7.5	10.2	10.9	20.2	7.2	15.1	17.1	2.9	3.5	3.0
499648	S		3.1	3.5	2.1	5.1	1.5	1.9	1.7	1.5	1.4	1.5	2.2
499651	S	2.5	3.4	2.3	2.4	4.1	1.3	1.0	1.0	1.9	1.2	2.0	4.3
499654	S	9.6	9.3	14.1	14.6	14.0			14.9		12.6		8.3
499657	S	2.3	4.4	5.8	18.9	30.3	45.1	7.9	6.5	5.2	3.5	7.4	8.8
499669	S	1.6	2.5	2.6	3.4	2.7	8.6	1.6	3.9	3.5	3.9	4.4	2.0

*Stations not present in this table had less than five samples in the time period considered. For a list of all stations evaluated see Table 1.

*Average monthly concentrations that exceed state water qualtiy standards or indicators are shown in **red bold** font.

Appendix F
Technical Memorandum 1 Comments Summary

The following table includes comments submitted by Technical Advisory Committee members addressing the Draft Technical Memorandum 1 Utah Lake TMDL Data Evaluation dated October 8, 2004. Many of the comments concerned the general TMDL process, however only comments regarding the Task 1 Memorandum were addressed. We thank everyone involved for their comments, and encourage everyone to resubmit comments specifically concerning future memoranda at the appropriate time.

Source	Heading	No.	Comment	Response
USFWS	Utah Lake Data Analysis	1	We recommend a brief discussion of the individual station data be added to the technical memo, including a review of the assumptions and applicability of merging the data.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.
		2	The current analysis assumes that phosphorus concentrations are evenly distributed throughout the lake--and it may be true--but it is critical to verify this important assumption.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.
		3	The document acknowledges the difficulty with the data, "Infrequent sampling since 1991 prevents an accurate assessment of historical in-lake TP trends (p.35); however, the executive summary claims the data "show significant reductions in tributaries and in-lake concentrations since 1990" (p. iii).	The inconsistency between the sections has been resolved.
	Data Presentation	4	In graphs and in analysis for Utah Lake, please clarify if ALL in-lake data were used or only data from the PRIMARY (i.e. eight) lake stations.	Unless otherwise noted, the time period used was 1980-2003 (as clarified in the Time Period Subsection). The station(s) will be identified. If temporal or spatial subsets are used, it will be so noted on the figure or table.
		5	Specify the period of record in graphs and in analysis, and if necessary, do so for each constituent. For example: Table 5, 8 & 9 show more data than STORET shows between 1990 and 2004 for several parameters.	Unless otherwise noted, the time period used was 1980-2003 (as clarified in the Time Period Subsection). The station(s) will be identified. If temporal or spatial subsets are used, it will be so noted on the figure or table. Also, Table 5 has been updated to include the full time period of the study.
		6	If subsets of data are used in subsequent analyses and figures, clearly indicate which dataset is being used.	Unless otherwise noted, the time period used was 1980-2003 (as clarified in the Time Period Subsection). The station(s) will be identified. If temporal or spatial subsets are used, it will be so noted on the figure or table.
		7	Use appropriate datasets and specify time period in graphs. For example Figure 7 shows monthly average concentrations for TP but does not specify time period. Because TP concentrations have declined since 1980, it would be inappropriate to use all 25 years in calculating monthly average concentrations.	Averaging 25 years of data is appropriate because it gives average historical conditions. Using only recent history would bias the average toward recent conditions.
		8	Consider showing regression coefficients for trend lines in figures (e.g. Figure 8, 9 & 10)	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.
		9	Consider how data are presented. Data in Figure 10 are presented to show seasonal in-lake TP concentrations; however, the data are grouped by month, not season.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed. Also, grouping data by literal seasons (i.e.. summer, winter) would show less data resolution than presenting the monthly averages. Data presented as monthly averages allows the reader to discern variations by month throughout the seasons. The entire seasonality discussion of the report uses this convention.
		10	Table 5 gives the same weight for all sample sizes. Because disparate sample size can have a profound effect on data analysis, if would be beneficial to include sample sizes for TP and TDS within each shaded block (e.g. [2 / 5]).	The purpose of Table 5 is to indicate when stations are sampled without regard to individual constituents.
		11	It is unclear whether sufficient flow data exist, and if flow data are paired with parameters of concern. (Example: Table 8 does not include flow data so it is impossible to determine if sufficient data exist to proceed with development.) Consider adding a summary and discussion on flow data.	Sufficient flow data exist as clarified in the section describing flow data.
		12	In-lake TSS data are presented by month in Figure 55, and the text states that "a definite downward trend can be observed from August to November" (p. 65); however, there is a concern that the decline in TSS over the period of record (Figure 56 shows a dramatic decline in TSS after 1992) might have influenced this conclusion. (i.e. if samples were disproportionately collected in fall months (Sep., Oct., Nov.) after 1992, or disproportionately collected in summer months (Jun., Jul., Aug.) in years prior to 1992, it could have a profound effect on the outcome of the observed trend). To limit potential bias attributable to year of sampling, we recommend that only data after 1992 be included in Figure 55.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.

Source	Heading	No.	Comment	Response
		13	Report comments that "monthly conductivity data were frequently used in order to assess the water quality conditions" (p.10), but does not explain the relationship between SC and TDS or describe how the SC data were used. Please clarify how SC data were used to assess water quality conditions.	The statement was corrected as a TDS/SC correlation was not developed or used in the Task 1 Memorandum.
		14	Consider clarifying the methods used to analyze Chlorophyll A data (p.26). "analyzed like other data", but many different methods were used in the document.	The text was clarified.
	Phosphorus	15	Figure ES-2 shows decline in TP concentrations but this may not be indicative of load based on what the flows are. Perhaps the inclusion of flow and load data was beyond the scope of the technical memo, but these are integral to the development of the TMDL.	Load calculations are beyond the scope of the Task 1 Memorandum.
		16	The seasonality of TP concentrations in tributaries may be a relationship with flows (which is largely seasonal in nature) than influenced by other variables.	The text was clarified.
		17	Is there a strong correlation between TP and TSS at the outlet (since they peak near the same time)? If there is, this may indicate TP concentrations during the peak are related to higher flows leaving the lake which are moving and transporting large sediment loads and/or algae.	Such a correlation may be investigated in the future, but is beyond the scope of the Task 1 Memorandum.
		18	The in-lake DTP "spike in January" (p.40) may be an artifact of small sample size, not actual increase in concentrations. Review data and underlying assumptions before developing a conclusion. Particularly, check for inconsistency in spatial or temporal data collection, and evaluate the small sample size in January relative to other months.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.
	Total Suspended Solids	19	High TSS could inhibit algal growth by reducing light penetration, but are there data verifying this assumption? Is there a statistical relationship between algal populations and TSS? This would be useful to anticipate the consequences of various management actions designed to reduce TSS in Utah Lake.	Light limitation is a potential explaination for this phenomenon. Further investigation may be completed in the future.
		20	It seems likely that common carp are a "significant" source of TSS because they can suspend 5 times its body weight in sediment per day. Consider Utah Lake has roughly 7 million, on average 5 pound carp.	Load calculations are beyond the scope of the Task 1 Memorandum.
	Data Gaps	21	Monitor excluded stations limited in Table 6 for next two years to develop the watershed budget and related loadings. Other facilities and inflows that have not been monitored but contribute flows or loads should also be monitored over the next two years.	Despite the data gaps, we believe sufficient data exist to continue with the study and that an additional two years of data at these stations would not significantly iprove the study.
		22	According to a draft letter by Mr. Keleher, carp have an important role in the re-suspension and cycling of phosphorus. This needs further study.	Data regarding loading/cycling of phosphorus were not considered in the Task 1 Memorandum, and such relationships may be expolred later.
		23	A review of STORET did not reveal any DO data since 1990 for any station that included "Utah Lake" in the description. Are there DO data for Utah Lake? If so, which stations were used? If not, this is a data gap that should be filled during the next two years (etc. sampling specifics).	A review of STORET revealed 19 STORET stations containing "Utah Lake" in the station name having DO data spaning 1978-2004.
	Corrections and Clarifications	24	Table 3 (p.8) lists the endangered June sucker as a nonnative fish of Utah Lake. The June sucker is of course a native fish.	The table title was corrected.
		25	Table 7 shows the Provo River, Spanish Fork River, Benjamin Slough, Mill Race and Geneva Steel Drain as having larger flows than Hobble Creek, yet does not discuss or evaluate data from Benjamin Slough, Mill Race, and Geneva Steel Drain. Please clarify.	A seasonality assessment analysis for all stations was completed and is contained in the appendices. Seasonality plots are only shown for major tributaries where averages for several months were available.
		26	There are discrepancies between Figures 7 & 8. April's average TP concentration for Provo River, (0.34 in Fig 7) is higher than the highest individual point (0.24 in Fig 8).	The reviewer was comparing Spanish Fork averages (0.34mg/L) in Figure 7 and Provo River individual data points in Figure 8. The highest average for Provo River is in August (~0.06 mg/L), which one would expect to be lower than the highest individual value reported (0.24 mg/L on Figure 8).
		27	There are discrepancies between Figures 7 & 8. The average of the averages in Figure 7 for Provo River is roughly 0.15 mg/L, while the text gives averages of 0.08 to 0.04 mg/L.	The reviewer was comparing Spanish Fork averages in Figure 7 and Provo River descriptions in the text. From Figure 7, the average of the averages for Provo River is roughly 0.04, which matches what is displayed in Figure 8. Figure 8 shows the long term trend of TP in the Provo River decreasing from roughly 0.08 mg/L to 0.04 mg/L.
		28	Beneficial uses for Jordan River (described on page 35) should include wildlife.	The text was corrected.
		29	Text on pg. 54 states Calcium concentrations are highest in Hobble Creek, but Figure 39 shows highest concentrations in Mill Race. Please clarify or correct content.	The text was corrected.
		30	Pg. 59 claims Na concentrations are highest in Spanish Fork then states Na concentrations are highest in Mill Race. Figure 47 shows Spanish Fork as the highest. Please correct or clarify.	The text was corrected.

Source	Heading	No.	Comment	Response
		31	Please define "ooze" p.67.	The text was clarified.
		32	Saline-eutrophic (p.67) is not defined. This suggests Utah Lake is salty and may infer that this condition is natural. Please define/clarify	The text was clarified.
		33	Pg. 67 claims "massive cyanobacterial blooms", but there is little supporting data or quantification of the term "massive". We suggest examples of background reference conditions.	The text was clarified.
		34	The memo mentions "unusually high species diversity" but it is unclear whether this reference is to all species, fish species, invertebrate species or other.	The text was clarified.
	Consideration for future data analysis	35	We recommend that loads be calculated from paired data first, and then statistics (e.g. mean) developed for the loads. Calculating statistics and then combining to calculate loads is often easier, especially with large or incomplete datasets, but it may not accurately portray the relationship between flows and concentrations.	Load calculations are beyond the scope of the Task 1 Memorandum.
		36	Consideration for aquatic life in the TMDL should not exclusively focus on Utah Lake; instead the TMDL should also evaluate effects to beneficial uses that extend downstream.	A beneficial use impairment assessment will be completed as a future part of the TMDL process, but it is beyond the scope of the Task 1 Memorandum.
		37	In formulating BMPs for the TMDL, we recommend special consideration be given to the endangered June sucker and to its critical habitat which has been designated as the Provo River at the Confluence with Provo Bay and thence upstream 4.9 miles. Utah Lake is occupied by the June sucker and is also vital in the life history of the species. The June sucker stages in Provo Bay at the mouth of the Provo River prior to upstream spawning. Larvae drift downstream to Provo Bay. Fluctuation in lake levels, loss of aquatic vegetation, nonnative predators, and water quality issues in Provo Bay have altered the larval nursery habitats, contributing to the decline of the June sucker.	The development of BMPs is beyond the scope of the Task 1 Memorandum.
CUWCD		38	Trends shown in the memo may not be significant but could be the result of analyzing inconsistent sampling data over long periods.	The purpose of Task 1 Memo is to take a cursory look at available data to recognize deficiencies. Any spatial or temporal groupings are only used to investigate potential trends or seasonality. If any data are used in the future, further evaluation will be completed.
		39	Stations, parameters, and period of collection used in the 303d listing procedure should be the focus in deriving the TMDL, and future monitoring programs should include critical stations identified in the Technical Memo 1 collecting all parameters associated with the 303d listing.	TMDLs frequently use significantly more data than were used in the listing process. The key listing parameters for Utah Lake are most commonly analyzed for in samples by the Division of Water Quality.
		40	Lake elevation and wind may have the greatest impact on water quality and should be evaluated for correlation to phosphorus and TDS.	Such a correlation may be investigated in the future, but is beyond the scope of the Task 1 Memorandum.
		41	Sediment sampling should be initiated to determine the potential of an internal phosphorus and TDS loading source.	The Department of Water Quality is considering updating its monitoring program to include this typ of data collection.
		42	Add a methodology section for evaluating phosphorus as a listing parameter to eliminate reference to phosphorus as a water quality standard. Refer to it as an indicator related to beneficial use impacts.	The State of Utah has established phosphorus as a listing parameter. Methodology for establishing that parameter is beyond the scope of the Task 1 Memorandum. All references to a phosphorus "standard" will be changed to "indicator".
		43	Is the State's Utah Lake Distribution Plan for water rights taken into account as the Utah Lake levels are modeled? For example: CUP and PRP are not yet under full demand, and changes have been filed to keep Jordan River flow in the lake to develop groundwater rights in areas tributary to the lake. Also, most surrounding cities have not developed all of their water rights, so in the future, inflow to the lake from groundwater will be reduced.	The Task 1 Memorandum looked at historical data and is unaffected by future conditions.
		44	The assumptions to be used to proceed with the TMDL process (p.74) should be listed for stakeholder discussion and evaluation because there are inherent risks associated with assumptions in any data analysis that may be exacerbated in Utah Lake.	Assumptions as they are made in the future will be documented and made available to the Technical Advisory Committee through subsequent comment periods.
UD Wildlife Resources		45	On Table 3 rearrange the list of fish to group related fish closer together generally: Group: black crappie, large mouth bass, small mouth bass, and bluegill; yellow perch and walleye; channel catfish and black bullhead; fathead minnow and carp; rainbow and brown trout.	The content has been changed.
		46	On Table 10 rearrange the list of fish to group related fish closer together generally. The native list is okay, but nonnative group by : fathead minnow and red shiner should follow carp and goldfish; black bullhead, channel catfish; yellow perch and walleye; green sunfish, bluegill, black crappie, largemouth bass, smallmouth bass;	The non-native species are listed in order of introduction, and table organization is clarified in the text.
		47	On Table 10 green sunfish is misspelled and smallmouth bass is listed twice.	The species name has been corrected.

Source	Heading	No.	Comment	Response
		48	One sentence below Table 10, re-order the species list by order of importance (i.e. white bass, black bullhead, and black crappie).	The content has been changed.
Kennecott		49	Identify existing and future potential TDS sources that may result in elevated concentrations conveyed through Jordan River System, as small increases in TDS result in significant cost for treatment for mining process.	The protection of Utah Lake water quality is part of the TMDL process; however, the Utah Lake TMDL study is only considering impairment for two beneficial uses: agriculture and warm water fisheries.
		50	We request that you identify existing and future potential TDS sources that may result in elevated condentrations coveyed through the Jordan River System. Are seasonal increases related to anthropomorphic activity or natural loading? Alternatively, what is the importance of this loading in degrading the Jordan River source considering that Hobble Creek accounts for only 3% of total lake inflow. (Hobble Creek shows a well-defined TDS increase between June and July -- see Figures 22,28,39,41,43,45,47,and 49)	Identification of sources of pollution are beyond the scope of the Task 1 Memorandum.
		51	Should direct precipitation be included as a source in Table 7?	The content has been changed to include precipitation.
		52	A thorough accounting of Utah Lake outflows, similar to the inflow summary in Table 7, would be useful. Current assumptions are 13% of outflow is accommodated by evaporation, evapotranspiration, and direct diversions from the lake.	A full water budget will be presented in the Task 2 Memorandum.
		53	Please clarify the statement "the presence of saline springs or other phenomenon between the Utah Lake outlet and the Narrows requires further investigation". Is this work part of the TMDL process or future water quality study?	Such an investigation is beyond the scope of the Utah Lake TMDL process.
Aqua Engineering		54	The executive summary states the phosphorus limit is 0.25 mg/l, but it is an indicator. Please clarify. There is no national or state standard for phosphorus, but R317-2-14 states "Investigations should be conducted to develop more information where these pollution indicator levels are exceeded".	All references to a phosphorus "standard" have been replaced by "indicator".
		55	The executive summary states "exceedances of state criteria for TP impairing beneficial use 3B". There is currently a study determining how much fish biomass exists in the lake. The TMDL should evaluate the fishery and determine what a healthy fishery would require beyond just phosphorus.	The warm water fishery impairment assessment is beyond the scope of the Task 1 Memorandum, but will be addressed in the future.
		56	Stakeholders should have input on a master paln for Utah Lake, developed to achieve an ultimate acheivable vision of the Lake. This master plan must be finished before the TMDL process can be effective.	A master plan for Utah Lake is beyond the scope of the Task 1 Memorandum.
SUVMWA		57	Add analysis an enhanced study of DO's relationship with TP.	Such a correlation may be investigated in the future, but is beyond the scope of the Task 1 Memorandum.
		58	Correct references to TP as an indicator, not a water quality standard, including references to exceedances of TP as an exceedance of a water quality standard.	All references to a phosphorus "standard" have been replaced by "indicator".
		59	Add a brief analysis of temperature. What is the conclusion? Is temperature a concern?	The TMDL process only address parameters on the 303d list.
		60	We request further analysis on the reasons that the lake is listed for being impaired by TDS and whether the lake may be delisted based on pg. 48 and figure 31 discussion of lake TDS outlet concentrations as typically below the 1200 mg/L standard.	A beneficial use impairment assessment will be completed as a future part of the TMDL process, but it is beyond the scope of the Task 1 Memorandum.
		61	Correct discrepancies between narrative text and stored data table. For example averages in text don't match Table 8-- 499669 reflects TP average as 0.056 mg/L, but text on pg. 31 states between 0.08 and 0.04 when talking about long term trends.	We find no discrepancy between the table data and the text.