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Bear River Water Quality: Phosphorus Control and the Impacts of Exchanging Water with Willard Reservoir

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Final Report

to the

Division of Water Resources

Utah Department of Natural Resources

Utah Water Research Laboratory
Utah State University
Logan, Utah

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SUMMARY AND CONCLUSIONS
PART I

Previous studies of Bear River water quality have identified phosphorus as a concern because of its role in supporting algal growth in impoundments. The growth of algae and the eutrophication of proposed reservoirs on the Bear River and its tributaries is the water quality problem that is most likely to limit recreational use and increase the costs of treatment for municipal and industrial uses. To reduce or eliminate eutrophication of the reservoirs, the sources of phosphorus need to be identified and an effective phosphorus management plan designed and implemented.

The present study was designed and conducted to accomplish the following objectives: (1) Identify areas of the watersheds of the streams feeding the proposed Honeyville, Avon, and Mill Creek Reservoirs that are above average in contribution of phosphorus to the streams. (2) Identify and evaluate phosphorus management practices that may be effective in reducing phosphorus loading to the streams. (3) Determine the amount of bioavailable phosphorus carried by the streams that will feed the proposed reservoirs. It was intended that the findings of this study would be useful in formulating a phosphorus management plan for the proposed reservoirs.

Estimates of total phosphorus loaded to the Bear River and its tributaries from municipal and industrial waste waters indicated that less than 20 percent of the phosphorus passing Cutler Dam in the 1985 water year could have been contributed by these point sources. The availability of phosphorus from sewage effluents to algae would be expected to be high, making the relative importance of these sources more important than their total mass contribution may suggest.

Phosphorus predicted to be transported to Cutler Reservoir from cattle feeding and dairying operations in Cache County, Utah, accounted for only 0.6 percent of the phosphorus load passing Cutler Dam in 1985, and the total inputs of phosphorus from cattle feeding and dairying in the Bear River basin below Bear Lake would be expected to account for less than 3 percent of this load.

Monitoring of phosphorus in the Bear River and some of its tributaries during a snow melt and runoff event in February 1986 demonstrated the impact that soil and streambank erosion can have on the phosphorus load of streams. Phosphorus inputs to the Bear River from streams in Franklin County, Idaho caused large increases in Bear River total phosphorus concentrations during this event. Battle Creek, Deep Creek, Fivemile Creek, and Weston Creek carried between 1200 and 1600 mg total phosphorus per liter into the Bear River on February 19, 1986. Total and orthophosphorus concentrations were maintained through the Utah Cache Valley as loads increased with increasing flow during this event. Much of the highly erosive land in Franklin County and Cache County that contributed to the phosphorus load during this event has been or will soon be planted to permanent cover under the conservation reserve program of the 1985 Farm Bill (Public Law 99-198). Evaluation of the impact of this program must await future studies. Streambank erosion is also an important sediment and phosphorus contributing process in this area, but its relative importance has not been determined.

Bear River monitoring data for 1986 showed that with the exception of June 10 and August 13, total and orthophosphorus concentrations did not increase appreciably as the river flowed from the Bear Lake Outlet Canal to the Honeyville Reservoir site. This suggests that during much of the year, phosphorus inputs and losses along the length of the River are approximately balanced, and that decreasing inputs of phosphorus can result in significant decreases in the phosphorus load of the River as it enters the proposed Honeyville Reservoir. The June 10 and August 13 data show appreciable increases in total phosphorus through the Utah Cache Valley area. On June 10, a major part of the increase may have been due to the phosphorus load of the Cub River. Much of the phosphorus in the Cub River seems to come from the Franklin, Idaho, area including Worm Creek. Worm Creek carries the effluent from the Preston, Idaho, waste water treatment plant.

The monitoring data indicate that when total phosphorus is high (i.e., greater than 0.1 mg/L), phosphorus can be removed from the River in Oneida Reservoir.

Relatively rapid changes in flow in the Bear River in response to hydroelectric power generation operations (power peaking) were demonstrated to increase the concentration of total phosphorus in the river. This indicates that power peaking flows may help to move particulate phosphorus downstream.

The highest concentrations of phosphorus in the Logan River were observed during the spring runoff season. The water quality of the Logan River as it enters Cutler Reservoir is affected by the Logan sewage lagoon effluent and by urban runoff.

Phosphorus concentrations in the Little Bear River were highest in April during the spring runoff season, but relatively large increases in total and orthophosphorus concentrations downstream from Hyrum Reservoir suggest that waste water effluents, which enter the stream in this reach, may be important phosphorus sources.

Phosphorus loads to the Avon Reservoir site from the South Fork of the Little Bear River and Davenport Creek are dominated by spring runoff erosion and high flows. Orthophosphorus in the S. F. Little Bear River tends to be a large fraction of total phosphorus, suggesting a high bioavailability of S. F. Little Bear River phosphorus.

Because of higher flows, the Blacksmith Fork River contributes the greatest load of phosphorus to the Mill Creek Reservoir site. Concentrations of total and orthophosphorus tend to be higher in Mill Creek than in the Blacksmith Fork. Spring runoff results in the highest concentrations of phosphorus in all of the streams in this area. The lowest concentrations of total and orthophosphorus observed anywhere during the study were measured in samples from Sheep Creek collected November 1.

Soil erosion control practices that are likely to reduce phosphorus in runoff from land include no-till or low-till agriculture, contour farming, strip cropping, terraces, and diversions of water courses away from fields. Application of these practices to erodible soils with high sediment delivery ratios, along with the establishment of buffer zones or green belts along streams in critical areas, will do much to reduce phosphorus loading to streams.

Streambank erosion may be controlled using low porosity covers, loose material covers, vegetation, and modification of the stream. Careful consideration must be given to the soil properties and hydraulics of streams before bank erosion controls are implemented since the interaction of these and other factors can lead to enhanced erosion or flooding if the correct control strategy is not used. Landslides contribute to problems with streambank erosion in the Bear River and its tributaries. Controls for landslides usually depend on methods of reducing shearing stress and increasing shear resistance in the land mass that is sliding.

Algal available (bioavailable) phosphorus was between 65 and 100 percent of total phosphorus in a Bear River sample taken near Honeyville in September. Toxicity induced in samples from gamma radiation sterilization prevented collection of more bioavailable phosphorus data. The toxicity apparently arises through the formation of hydrogen peroxide from oxygen dissolved in the water. Sparging oxygen from the water with nitrogen and treatment of irradiated samples with peroxidase removes toxicity from the samples. Future studies will be able to determine bioavailable phosphorus as a fraction of total phosphorus using this procedure.

The following conclusions have been reached for Part I of the study:

1. Much of the phosphorus carried by the streams that will feed the proposed reservoirs is derived from runoff and erosion of the land in the watershed.

2. Spring runoff and runoff associated with rainfall and snow melt are major contributors of total phosphorus to these streams.

3. Streambank erosion, enhanced by landsliding in some areas, may be an important source of phosphorus.

4. Soil and streambank erosion in the Battle Creek, Deep Creek, Fivemile Creek, and Weston Creek areas of Franklin County, Idaho can contribute substantially to the phosphorus load of the Bear River during runoff events. Recent placement of much of the highly erodible soils in this area into conservation reserves may reduce the phosphorus producing potential of this area.

5. Soil erosion control practices commonly used in agriculture, combined with streambank erosion control and landslide management techniques, hold considerable promise for substantial reductions in phosphorus control for the Bear River and its tributaries which will feed the proposed reservoirs.

6. Waste water effluents may contribute up to 20 percent of the phosphorus load of the Bear River passing Cutler Dam. The Logan City lagoons alone may account for 10 percent of this load. The actual fate of waste water effluent phosphorus due to chemical

precipitation and biological immobilization/mineralization is not known.

7. Feedlot and dairying contributions of phosphorus in the basin below Bear Lake are likely to contribute less than 3 percent of the phosphorus passing Cutler Dam.

8. Algal available phosphorus in the Bear River at Honeyville may approach 100 percent of total phosphorus at specific times of the year.

SUMMARY AND CONCLUSIONS PART II

Willard Reservoir was found to be a frequently mixed (polymictic) eutrophic water body with spring and early summer algal blooms that were dominated by Aphanizominon sp. Depletion of oxygen in the water column to concentrations approaching 50 percent of saturation in August, despite the lack of thermal stratification, is evidence of a large oxygen demand by the sediments of the reservoir. Chlorophyll a concentrations in the surface waters exceeded 66 µg/L at one location in the reservoir in March, but were less than 2 µg/L at three locations in late August. Light extinction in the water column in March, June, and early August showed two rates, with extinction below approximately 2 m being higher. This may indicate the presence of a sub-surface layer of algae during periods of high algal production. Total dissolved solids and electrical conductivity were essentially equal throughout the reservoir.

Empirical models predicted that exchanging Bear River water for Weber River water would not produce a noticeable change in the algal production and trophic state of the reservoir. The use of Bear River water was predicted to result in an increase in maximum salinity of the reservoir of less than 200 mg/L. This increase in salinity would not be expected to interfere with any anticipated uses of Willard Reservoir water.

PART I
PHOSPHORUS INPUTS TO THE BEAR RIVER BELOW BEAR LAKE

Introduction

The problem of phosphorus in the Bear River

Previous studies of water quality in the Bear River below Bear Lake have identified fecal indicator bacteria (coliform) concentration, biochemical oxygen demand, nitrate-nitrogen, and phosphorus concentrations as water quality problems limiting the use of Bear River water (Sorensen et al. 1986). The most recent study (Sorensen et al. 1986) occasionally found coliform concentrations in excess of 5 x 10^3/100 mL, the standard for raw drinking water supply (Utah Department of Health 1978), but found no reason for concern for other water quality criteria except phosphorus. Both empirical eutrophication estimates (Jones and Lee 1982) and deterministic computer models of algal production in proposed Bear River reservoirs indicated that the reservoirs would experience summertime eutrophic conditions, and that phosphorus loads would be the controlling factor in the eutrophication process.

Phosphorus is probably the nutrient that most commonly limits algal production in lakes and reservoirs. Nitrogen is required by algae and other plants in larger supply than phosphorus, but in most waters, nitrogen fixing cyanobacteria (blue-green algae) are able to supply sufficient nitrogen for themselves and sometimes other algae. In some environments, the lack of iron or molybdenum, both components of the nitrogen fixing enzyme system, may limit nitrogen fixation and, hence, algal productivity. Because of this central role of phosphorus in limiting algal productivity, and hence eutrophication, controlling phosphorus inputs to lakes and reservoirs is frequently used to prevent or reduce eutrophication (Porcella and Bishop 1974).

Natural processes of phosphate mineral weathering, soil erosion, and biological mineralization of phosphorus in organic matter increase the mobility and solubility of phosphorus in the environment, and some soluble and insoluble phosphorus is found in most natural waters. Concentrations of phosphorus in lakes and streams that are conducive to accelerated rates of algal and aquatic plant production are in many cases traceable to watershed use by mankind. This is especially true where wastewaters are released to streams or lakes, and where soil erosion has been accelerated by removal of vegetation and soil disturbance (Porcella and Bishop 1974).

Not all phosphorus that enters a stream, lake, or reservoir is equally available to algae and aquatic plants for growth. As a rule all dissolved orthophosphate phosphorus (PO_4-P) is considered to be "bioavailable", but much of the insoluble (particulate) phosphorus is not. If the particulate phosphorus is organic matter (e.g., manure or sewage solids), microbial mineralization of the phosphorus to PO_4-P can make it bioavailable in a relatively short amount of time (days to weeks). Some inorganic particulate phosphorus may be made available to algae through ion exchange processes and solubilization reactions (e.g., dissolution by organic acids). In general the fraction of total phosphorus in a water that is available to algae for growth is not known. The question of bioavailability of phosphorus in water and sediments has received some research attention and chemically determined indexes or measurements of bioavailable phosphorus have been proposed (Dorich et al. 1984, Wendt and Alberts 1984, Hegemann et al. 1983, Sonzogni et al. 1982, Dorich et al. 1980, Huettl et al. 1979). One such measurement, the NaOH/NaCl extractable phosphorus content, has not proved to be a reliable indicator of bioavailable phosphorus in water samples from the Bear River and its tributaries (Sorensen et al. 1986).

As with most "foreign" materials, phosphorus may enter streams as either an obvious, localized, easily measurable (point) source or from more diffuse and not easily measured (nonpoint) sources. In the Bear River basin, point sources are mostly discharges of wastewater treatment facility effluents, while nonpoint sources arise from natural or man induced erosion of the watershed. Nonpoint sources of phosphorus might also include phosphorus released from sediments and stream bank erosion. Earlier research (Sorensen et al. 1986) suggested that erosion problems, at least in certain areas, were major contributors of phosphorus in the Bear River, but that a clearer understanding of phosphorus loading processes was needed if phosphorus was to be managed.

Toward a phosphorus management plan

Managing phosphorus to prevent or minimize eutrophication in the proposed Bear River basin reservoirs requires a comprehensive approach (Porcella and Bishop 1974). All sources of phosphorus must be considered, and their relative contribution to the problem weighed. Not only should the total mass of phosphorus contributed by any one source in a year's time be considered, but the mass of algal available phosphorus contributed must also be taken into account. Control of those sources having the greatest impact in terms of contributing total bioavailable phosphorus to the reservoir should be ranked highest. A management plan should apply best management practices (BMP) to those sources that will reduce this load in the most cost effective way. The purpose of the research reported here was to make the first step toward developing a phosphorus management plan for the Bear River basin below Bear Lake. Its major objectives were to: (1) identify areas of the watershed or stream reaches which contributed unusual amounts of phosphorus to the streams which will feed the proposed reservoirs, (2) identify and evaluate phosphorus management practices which are applicable to the sub-basin, and (3) determine the algal availability (bioavailability) of phosphorus transported by the Bear River and its tributaries at various points in the river system.

Methods

Sampling

Stream sampling stations established in the beginning of the current study were selected to "isolate" reaches of the stream that might be important in terms of phosphorus loading. Tributary locations, assumptions about soil or bank erosion tendencies, and accessability were considered (Table 1).

Table 1. Regular sampling stations in the Bear River Basin below Bear Lake.

Stream	Sampling Location	Approximate River miles from Corinne, Utah	Corresponding USGS Gauge	Corresponding Utah BWPC Sampling Station
Bear River	Bear Lake Outlet Canal at US-89	205	10059500*	
	West of Georgetown at bridge	192		
	Above Soda Point Reservoir	171	10075000	
	At Grace Dam	156		
	Above Alder Creek at bridge	143		
	Cottonwood Creek near Cleveland, ID at I-34	127		
	Above Oneida Reservoir	126		490630
	Below Oneida Reservoir at I-36	110	10086500*	490620
	Mink Creek near Bear River confluence	110		
	Above Battle Creek at US-91	104	10090500	
	Battle Creek near Bear River confluence	104		
	Deep Creek near Bear River confluence	102		
	Five-mile Creek near Bear River confluence	100		
	Weston Creek near Bear River confluence	91		
	West of Fairview, ID at USGS gauge	90	10092700	490610
	West of Richmond, UT	76		490382
Bear River	Below Cub River	69		490368
	Above Cutler Reservoir west of Benson	55		490326
	Below Cutler Reservoir near Collinston	44	10118000	490198
	West of Deweyville at bridge	28		
	West of Honeyville at bridge	17		490170

Table 1. cont.

Stream	Sampling Location	Approximate River miles from Corinne, Utah	Corresponding USGS Gauge	Corresponding Utah BWPC Sampling Station
Cub River	North of Franklin, ID at bridge	88		
	West of Franklin, ID at bridge	86		490425
	Worm Creek west of Franklin, ID	82		
	High Creek at US-89/91	80		
	North of Richmond at bridge	77		
	South of Richmond at bridge	71		
Logan River	Below Logan Lagoon Effluent	60		490504
Little Bear River	So. Fork below Three-mile Creek at bridge	97		
	So. Fork above Davenport Creek	93		
	Davenport Creek	92		
	Below Hyrum Reservoir	81		490565
	Above Logan River confluence	71		490500
Blacksmith Fork	Mill Creek near Blacksmith Fork confluence	91		
	Sheep Creek near Blacksmith Fork confluence	92		
	Blacksmith Fork above Sheep Creek	92		
	Blacksmith Fork at Anderson Ranch	91		

Unfortunately, insufficient attention was paid to the location of USGS stream flow gages in selecting the Bear Lake Outlet Canal, Georgetown and above Battle Creek stations on the Bear River, since USGS gages are located upstream from these stations and significant differences in flow occur between the gage site and the sample site due to tributary entry or canal withdrawal. A similar error was made at the above Davenport Creek site on the South Fork of the Little Bear River site since the functioning USGS gage is located below the Davenport Creek confluence. Sampling sites were adjusted for the October sampling to correspond with the location of USGS gages.

Samples were collected at nearly all of the sites on February 19, 20, or 21, April 15, May 12 or 13, June 10 or 11, August 13 or 14, and October 31, or November 1, 1986. Samples were collected by submerging a chemically clean and 0.1 N HCl rinsed 0.5 gallon polyethylene container in the stream to a depth of 2 to 4 inches, or by filling a well rinsed polyethylene, 2 gallon bucket suspended by a rope into the stream from a bridge and using the water thus collected to rinse and fill a 0.5 gallon polyethylene bottle. Water samples collected in the bucket were transferred to the bottle quickly to minimize settling of suspended material in the water.

Bottles containing the samples were placed in ice chests with ice and transported to the Utah Water Research Laboratory within 12 h. Samples were stored under refrigeration (5°C) until analyses were complete. All samples were either analyzed or appropriately filtered and preserved within 72 h. All analyses were completed within 7 days.

Analytical procedures

Stream temperature and electrical conductivity (EC) were measured in the field using a Yellow Springs Instruments Conductivity Meter. The temperature accuracy of the meter was checked in an ice bath and with a NBS traceable thermometer. The conductivity measurements were calibrated with a known standard and corrected to 25°C (APHA, 1985).

Orthophosphorus and Total phosphorus samples were analyzed either manually (March, August, and October samples) or with a Technicon AutoanalyzerII (May and June samples) by the ascorbic acid method. Procedures for manual analyses are described in Strickland and Parsons (1972). For both manual and automated procedures, total phosphorus digestions were carried out according to APHA (1985) persulfate digestion protocol. Autoanalyzer methods for orthophosphorus samples and total phosphorus digests are also described in APHA (1985).

Total dissolved solids (TDS) analyses were performed according to APHA (1985) methods.

Stream discharge measurements

Stream discharge at sample locations was estimated by multiplying average velocity by the cross-sectional area. The method is described in detail in Dunne and Leopold (1978) and is recommended where budget and lack of easy access to a current meter prohibits a more detailed flow measurement. Using an average velocity is recognized as less accurate than taking velocity measurements with a current meter at 0.1 and 0.8 of the depth across the stream, but Dunne and Leopold (1978) state this method gives good results when done with care.

The cross-section profile was done once, when a boat, current meter, depth finder, engineer level, stadia rod and three people were available. The level and stadia rod were used to determine the elevation profile of the stream bank, elevation of a reference point on a bridge, and water surface elevation. The elevation profile across the bottom of the stream was found by using a sonar depth finder attached to a boat. The boat was guided across the stream by a cable fastened to both banks. The cross section profile was reported as a distance from the reference point on the bridge. The cross sectional area at the time of a sample measurement is determined by measuring the distance from the reference point to the water surface.

The average velocity was found by floating an orange under the bridge at one or more points. An orange is commonly used (Hynes 1970), because it is conspicuous and travels almost entirely submerged. The average velocities obtained by using the orange was similar to average velocities obtained with the current meter. Use of the current meter is only possible when a boat is used. Use of the boat requires at least two people for each sampling trip and 2 hours per station. Time and personnel are generally not available for this level of data collection.

Estimation of phosphorus bioavailability

Laboratory experiments were conducted in 1986 to determine the algal availability of phosphorus at several locations in the Bear River system. Preliminary studies indicated that autoclaving was not a suitable method for sterilizing Bear River samples for use in algal assays, due to precipitation of phosphorus during autoclaving. Ultraviolet radiation sterilization was also investigated, but the treatments did not kill all native algae and protozoans. Dorich et al. (1985) used gamma radiation to sterilize concentrated suspended sediments from the Black Creek watershed, Indiana, prior to use in algal bio-assays. It was decided that gamma radiation sterilization of our samples would yield the least chemically altered sample from which to estimate phosphorus bioavailability in Bear River waters.

Surface water samples were collected several times during the year from five locations: 1. Bear River above Oneida Reservoir, 2. Bear R. at UT-ID border (USGS gage), 3. South Fork of the Little Bear R. below Davenport Creek, 4. Blacksmith Fork R. above Anderson Ranch, and 5. Bear R. at Honeyville. Samples were stored overnight at 4°C. For the first two sampling periods, 2500 mL aliquots from the Little Bear, Blacksmith Fork, and Bear R. Honeyville sites were filter sterilized. Subsamples from filtered and "whole" water samples were removed for phosphorus analyses and the remaining sample (~ 3 L) transported to a commercial facility (Isomedix (Utah) Inc., Sandy, UT) for radiation sterilization. Samples received a minimum dose of 2.5 Mrad (cobalt-60 source) during an exposure period of approximately 20 hr. Duplicate samples of untreated and gamma-irradiated water were analyzed for orthophosphorus, NaOH extractable phosphorus, and total phosphorus.

Algal bioassays were performed following the EPA AAP protocol (Miller et al. 1978). Aliquots of treated river water (and in some cases, filter sterilized non-irradiated water) were introduced into triplicate bioassay flasks, enriched with N, and P, and inoculated with Selenastrum capricornutum Printz according to the AAP protocol. Two levels of phosphorus additions and a nonenriched control were used in order to verify linearity of algal growth response to the P additions. In vivo fluorescence measurements were made daily after the third day of incubation of the test flasks and continued until the peak in growth occurred. After graphically verifying that the growth response to P additions was linear, bioavailable P concentrations were calculated by solving two simultaneous equations for the relationship between P concentration and relative fluorescence at the time of maximum standing crop for the sample alone and the sample amended with the maximum P concentration:

$$\frac{\text{Bioavailable P}}{\text{Bioavailable P} + 0.03\ \mu\text{g P/L}} = \frac{\text{Max. Fluor. sample}}{\text{Max. Fluor. sample} + \text{P}}$$

The first bioassay produced no growth in any of the gamma-irradiated samples. We used the Microtox test (Microbics Corp., Carlsbad, CA) to evaluate possible toxicity in those samples. We suspected that low concentrations of hydrogen peroxide, produced by ionization of oxygen in the water during the gamma radiation treatment, may have persisted in the samples after irradiation resulting in toxicity to the algae. Despite subsequent efforts to strip samples of oxygen by sparging with N_2 gas prior to irradiation and thus preventing the formation of hydrogen peroxide, toxicity problems were frequent. We performed a preliminary experiment to evaluate the possibility of using the enzyme peroxidase (Type VI, Sigma Chemical Co., St. Louis, MO) to break down peroxide in irradiated samples and eliminate toxicity. After initial success we conducted a more extensive experiment to evaluate the effectiveness of several different peroxidase concentrations and exposure periods on toxicity elimination in both N_2 sparged and non-sparged samples.

Data reduction and statistical procedures

Data were tabulated and reduced using microcomputer software packages (Lotus 123, Lotus Development Corp., Cambridge, MA and Excell, Microsoft Corp., Redmond, WA) and graphics and linear regression analyses were done using Cricket Graph software (Cricket Software, Philadelphia, PA) on Apple Macintosh computers.

Results and Discussion

Phosphorus loads from point sources

Many municipal and industrial wastewaters in the Bear River basin are contained in non-discharging lagoons (total containment) or they are applied to land where care is taken for the water not to run into streams. Principal municipal and industrial wastewater discharges in the Bear River Basin below Bear Lake include the Montpelier, Idaho, lagoons; the Georgetown, Idaho, lagoons; the Soda Springs, Idaho, sewage treatment plant (STP); the Grace, Idaho, STP; the Franklin, Idaho, lagoons; the Del Monte Company lagoons (July and August discharge only) at Franklin, Idaho; the Preston, Idaho, STP; the Logan, Utah, lagoons; White's Trout Farm, Paradise, Utah; E. A. Miller, Inc., Hyrum, Utah; and the Hyrum, Utah, STP. Overflows of the Wellsville, Utah, and Richmond, Utah total containment lagoons have occurred in recent years due to above average sewage flows caused by groundwater infiltration to the sewers in these towns. High groundwater levels have resulted from above average precipitation. Overflow from the Richmond lagoons began about 1979 (Richard Denton, Utah Bureau of Water Pollution Control, personal communication, 1987).

None of the sewage treatment plants or lagoons in the lower Bear River are regulated for phosphorus discharge, and are not required to monitor their effluents for phosphorus concentrations. The Utah Bureau of Water Pollution Control monitors the Richmond lagoon effluent, the Logan lagoon effluent, the Hyrum STP effluent, and White's Trout Farm effluent for total phosphorus concentration approximately monthly. Occasional samples from these sources are also analyzed for orthophosphorus. Using these data, or estimated average phosphorus concentrations in secondary treated effluents (Viessman and Hammer 1985), and actual discharge records for the plants, annual phosphorus loads from the Logan lagoons, the Hyrum STP, White's Trout Farm, and the Preston STP were estimated. These estimates were compared to the estimated 440 Mg (2.6×10^9 m^3 x 0.17 g P/m^3) which flowed past Cutler Dam in the 1985 water year. The results are shown in Table 2.

The relatively large flow from the Logan lagoons combined with high phosphorus concentrations results in the highest phosphorus load from the point sources in the Cache Valley. White's Trout Farm has the highest flow, but low phosphorus concentration in their effluent resulting in a relatively low phosphorus load. The estimated load from the Preston STP is probably artificially high since a relatively high concentration of phosphorus was used to make the estimate. The combined total phosphorus load in 1986 from these point sources was approximately 11 percent of the estimated total phosphorus load transported past Cutler Dam in the 1985 water year (Table 2). The combined phosphorus from all of the STP and lagoon effluents discharged to the Bear River and its tributaries below Bear Lake would probably equal 15 to 20 percent of the phosphorus passing Cutler Dam in the 1985 water year.

Although the phosphorus loads from point sources are less than 20 percent of the Bear River load, the likelihood that a larger fraction of this phosphorus is bioavailable makes this contribution especially worthy of consideration in a phosphorus management plan. Phosphorus in these point sources undoubtedly undergoes biological and chemical reactions after being discharged. Organic phosphorus may be mineralized and soluble mineral phosphorus may react with calcium, iron, and other elements and be precipitated and deposited in the river and reservoir sediments. Phosphorus reaching Cutler Reservoir from the Logan and Hyrum effluents and from non-point sources in the Logan and Little Bear River watersheds may be immobilized by microbial and plant biomass in the marshes in the backwaters of that reservoir. As productivity declines in the fall of the year and plants die, some of this immobilized phosphorus may be released to the water and move downstream. The transport and fate of phosphorus from point sources should be better understood in order to formulate a cost effective phosphorus management plan.

Table 2. Total phosphorus loads from Cache Valley wastewater treatment.

	Facilities				
	Logan Lagoons*	Preston STP	Hyrum STP*	White's Trout Farm*	Totals
Estimated effluent average Total P Concentration (mg/L)	2.2	8**	6.8	0.17	
Total 1986 Flow (10^6 m^3/y)	12.5	1.1	1.1	33	47.7
Estimated Total P discharged in 1986 (Mg)	27.5	9.0	7.5	5.6	49.6
Discharge percent of Total P passing Cutler Dam in 1985 water year+.	6.3	2.0	1.7	1.3	11.3

* Utah Bureau of Water Pollution Control data, March 1980 - September 1987.
** "Average" wastewater treatment plant effluent total phosphorus (Viessman and Hammer 1985).
\+ 440 Mg P/y.

Table 3. Estimated total phosphorus loads from nonpoint sources in the Bear River Basin.

Nonpoint Source	Mass of P contributed Annually (Mg/y)	Percent of P passing Cutler Dam in the 1985 Water Year*
Feedlots in Cache Valley, UT**	2.5	0.6
Land (Basin total):+	620	141
Forest	47	10.7
Pasture/Crops	550	125
Urban	20	4.5

* 440 Mg P/y
** Estimated load to Cutler Reservoir by Wieneke et al. (1980).
\+ Estimated using the export coefficients of Rast and Lee (1983) and the land use area estimates of UWRL (1974 and 1976).

Phosphorus loads from nonpoint sources

The vast majority of phosphorus entering the Bear River and its tributaries comes from nonpoint sources. The uses of land by man are known to affect the export of nutrients, sediments, and other pollutants with water flowing over or through the land (Anon. 1986, Baker 1985, Myers et al. 1985, Chesters and Schierow 1985, Smart et al. 1985, Sharpley et al. 1982, Wendt and Corey 1980). Table 3 shows estimates of phosphorus contributed to the Bear River and its tributaries by the principal land uses in the basin and by cattle feeding operations in Cache Valley. These estimated phosphorus loads have been compared to the estimated phosphorus transport in the Bear River at Cutler Dam in the 1985 water year.

Confined cattle feeding operations associated with dairying or beef production are often highly visible sources of nonpoint source pollution, and can have considerable impact on stream water quality. Any phosphorus management plan would include incentives for feedlot operators to minimize runoff entering water ways from their facilities since phosphorus from these sources is likely to be largely available for algal growth. In comparison to total phosphorus transport by the Bear River, however, probably less than 1 percent of the Bear River's total annual phosphorus load is contributed by Cache Valley feed lots (Table 3). This estimate of phosphorus contribution to Cutler Reservoir from Cache Valley, Utah, feedlot operations is only one-eighth the phosphorus contribution estimated from urban runoff in the Bear River Basin (Table 3). In other words, total phosphorus contributed by cattle feedlots in all of the Bear River Basin probably does not exceed that contributed by urban runoff and certainly does not exceed the contribution of forested land.

Phosphorus concentrations and loads in the Bear River

Field and laboratory data from the 1986 sampling are tabulated in Appendix A. Data from the Utah Bureau of Water Pollution Control (BWPC) monitoring of the Bear River and its tributaries below Bear Lake from June 1985 to October 1986 are tabulated in Appendix B. Because of budgetary restraints, the BWPC ceased sampling (in July 1985) at several stations that had been established during our previous investigations (Sorensen et al. 1986). The data analyzed and discussed below does not include that collected by the BWPC. BWPC data are presented here primarily to improve accessibility. A more detailed analysis of these data, and data subsequently collected by the BWPC, will be included in future research. An overview of the BWPC data appears to support the conclusions reached here.

Several inches of snow were on the ground in the lower Bear River Basin prior to an increase in temperature and rainfall which began February 18. Because the soil was frozen or near saturation, much of the snow melt and rainfall water ran off of the land, eroding the soil and stream banks. The increased sediment load due to this erosion is reflected by the 2050 mg total suspended solids (TSS) per liter in a Bear River sample collected west of Fairview, Idaho by the BWPC on February 18. By comparison TSS at this site was only 17 mg/L on January 7, 1986 (Appendix B). The increase in TSS from <3 mg/L in the Little Bear River west of Avon on January 7 to 1265 mg/L on February 18, reflects the erosive effects of this meteorological event in the Little Bear River watershed (Appendix B). Solids associated phosphorus and phosphorus dissolved by the water flowing over and through the soil contributed large amounts of phosphorus to the streams.

Figure 1 shows the changes in phosphorus concentrations measured February 19 and 21, 1986, in the Bear River below Oneida Reservoir. Between the I-36 bridge below Oneida Reservoir and the US-91 bridge near Preston, ID, total phosphorus concentration increased 1.7 times, and between the US-91 bridge and the USGS gage near the Utah-Idaho border the concentration increased 2.3 times again. Between the US-91 bridge and the Utah-Idaho boarder USGS gage Battle Creek, Deep Creek, Five Mile Creek and Weston Creek enter the Bear River. February 19 samples showed that Battle Creek carried 1221 mg total phosphorus (TP) per liter, Deep Creek carried 1575 mg TP/L, and Weston Creek carried 1323 mg TP/L into the Bear River (Appendix A). Figure 1 also shows that the total phosphorus load increased nearly four fold between the US-91 bridge near Preston and the gage below Cutler Reservoir on February 21.

Figure 2 is a map of Franklin County, Idaho prepared by the USDA Soil Conservation Service showing areas of highly erosive soils and stream banks. Battle Creek, Deep Creek, Fivemile Creek and Weston Creek all include reaches which have high stream bank erosion. In addition, Battle Creek, Fivemile Creek, and Weston Creek drain areas with highly erodible soils. These sources of soil material undoubtedly explain the very high total phosphorus loads being contributed to this reach of the Bear River during this unusual snow melt and rainfall event. Figure 3 shows the concentrations of total and orthophosphorus in samples of Battle Creek and Weston Creek collected in 1986. Total phosphorus concentrations in Battle Creek were relatively high in the February, April, June, and August samples, while phosphorus concentrations in Weston Creek were relatively low on all sampling dates after February 19. Concentration patterns in samples from Deep Creek and Fivemile Creek were similar to Weston Creek. Stream bank erosion appears to be a major contributor to the sediment and phosphorus load of Battle Creek. Although most runoff events would be expected to be less intense than was observed between February 18 and 22, 1986, the importance of controlling soil and stream bank erosion is demonstrated by these data. Mass transport of total phosphorus past Cutler Dam on February 21, 1986, was in excess of 200 g/s while the average of all other sampling dates was 21 ($\pm$ 16) g/s.

Dissolved orthophosphorus concentrations also increased in response to inputs below Oneida Reservoir during the February 18 to 21 runoff event, but the increase was much less dramatic than for total phosphorus. On February 19, orthophosphorus was 80 percent of total phosphorus below Oneida Reservoir while below Cutler Reservoir on February 21 orthophosphorus was only 35 percent of total phosphorus. This decrease in the fraction of total phosphorus made up by orthophosphorus emphasizes the contribution particulate (sediment) phosphorus makes to the load from land runoff and erosion.

Soils designated as potentially highly erodible by the USDA Soil Conservation Service in Cache County, Utah, are listed according to soils mapping units in Table 4. Many of these soils are relatively steep in hilly or mountainous areas. Some erodible soils (e.g. the Wheelon soils) are cultivated, increasing their potential contribution of sediment and phosphorus to

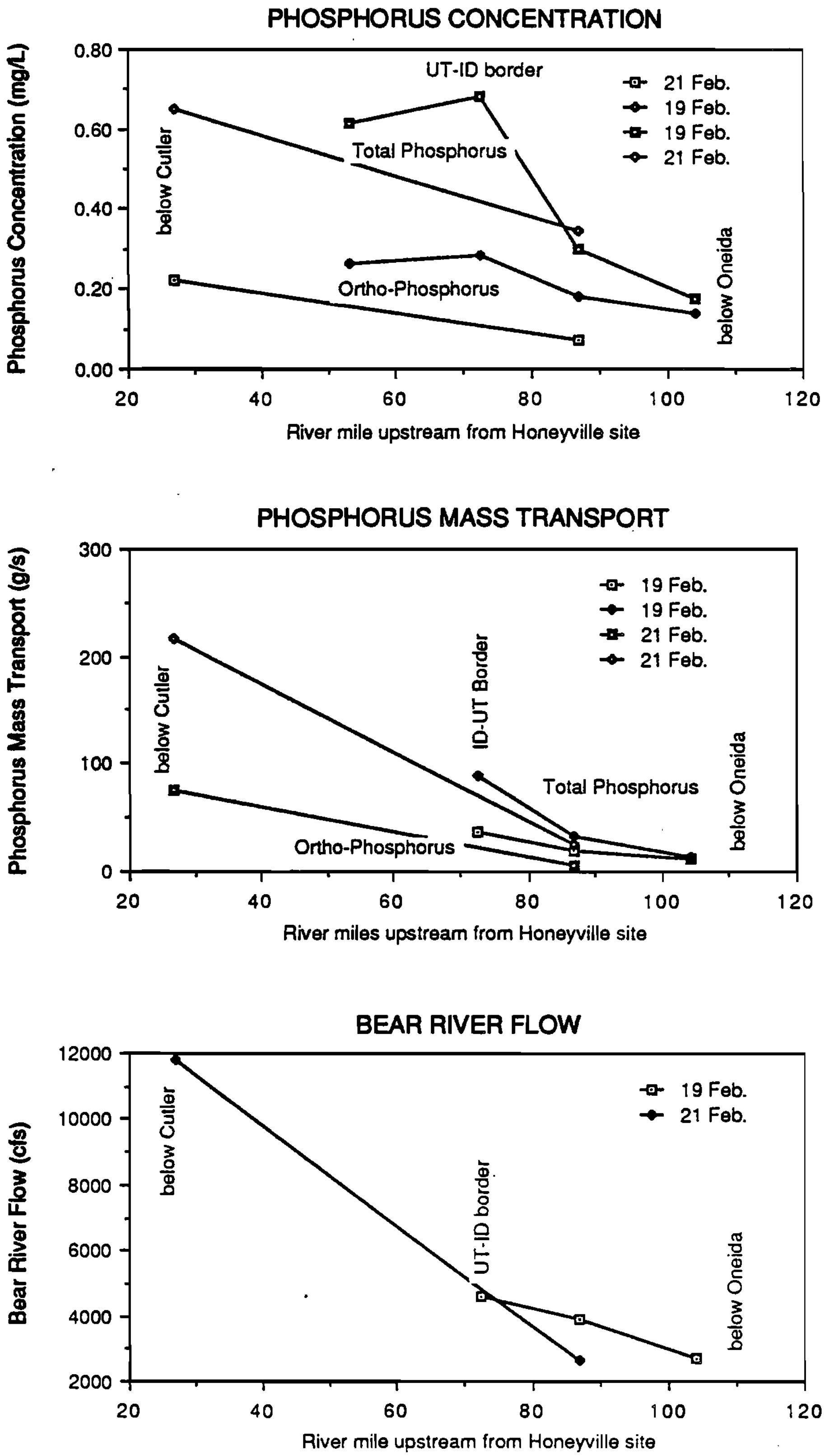


Figure 1. Concentration and mass of ortho and total phosphorus in the Bear River below Oneida Reservoir in February, 1986.

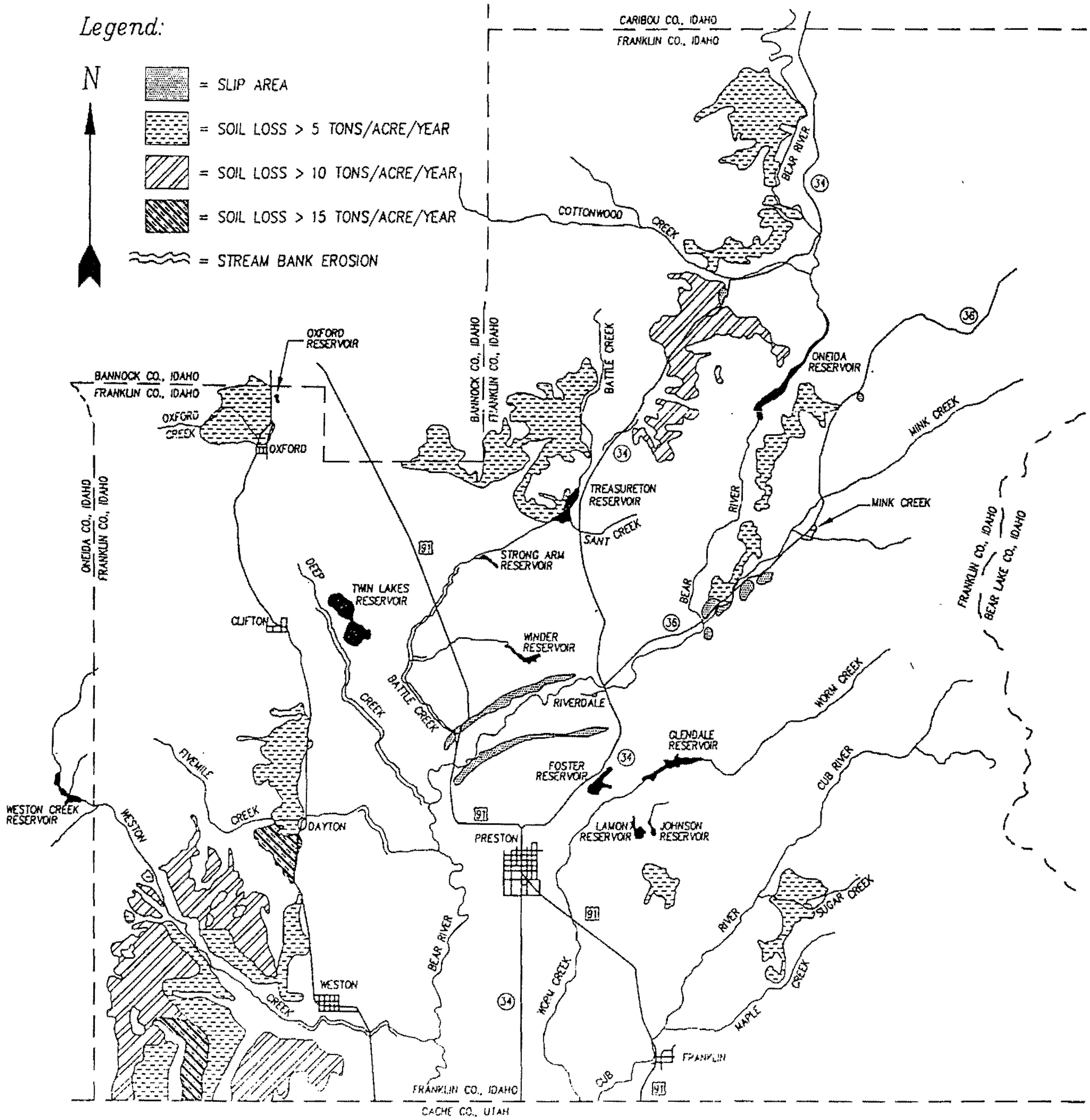
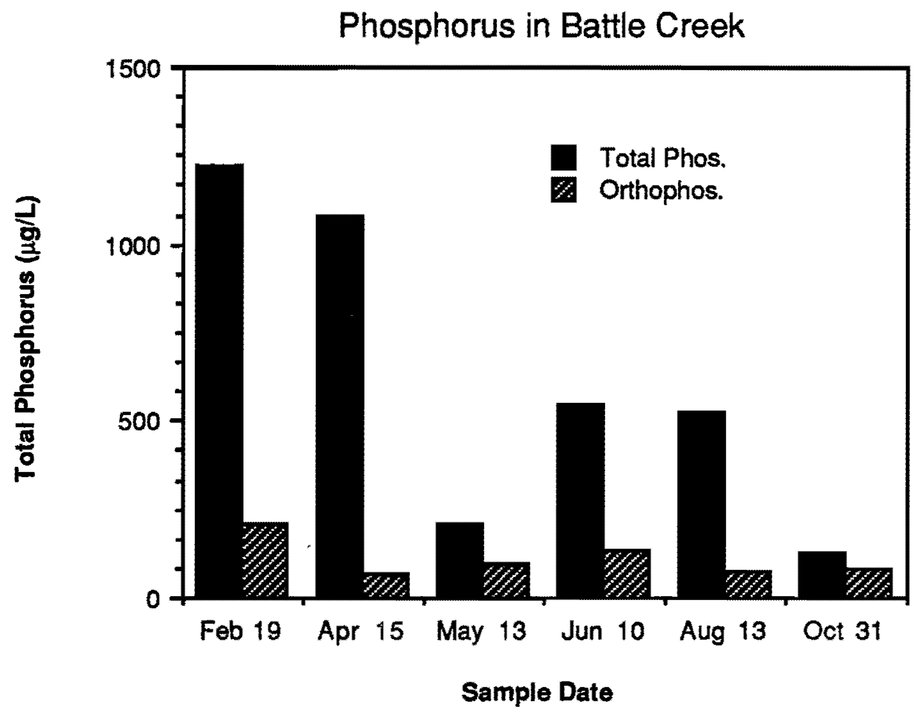


Figure 2. Map of Franklin County, Idaho, showing areas of erosive soils and stream banks (prepared by USDA Soil Conservation Service).



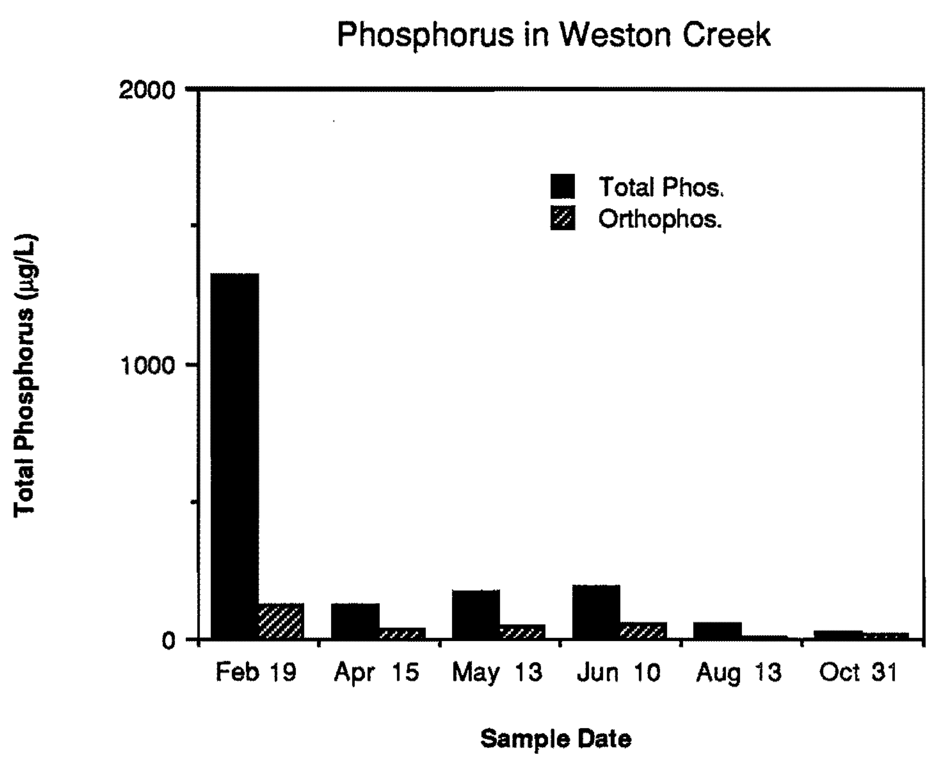


Figure 3. Ortho and total phosphorus concentrations in Battle and Weston Creeks, February - October, 1986.

Table 4. Highly erodible land classes in the Cache Valley area (SCS 1974, SCS personal communication 1987).

Soils Map Symbol	Soil Name
AAG2	Agassiz rocky silt loam, 30-70 percent slopes, eroded.
ABG2	Agassiz-Bradshaw association, eroded.
ADG2	Agassiz-Dateman association, eroded.
AEG2	Agassiz-Elwood association, eroded.
AGG2	Agassiz-Goring association, eroded.
BAF	Barfuss-Leatham association.
BcD	Battle Creek silty clay loam, 8-15 percent slopes.
BGG	Bickmore gravelly silt loam, 30-70 percent slopes.
BKG2	Bickmore-Agassiz association, eroded.
BLG2	Bickmore-Sheep Creek association, eroded.
BSG2	Bradshaw-Agassiz association, eroded.
CSE	Curtis Creek-Goring association, hilly.
CSG	Curtis Creek-Goring association, steep.
DNG	Datwyler-Elzinga-Maughan association.
DPG	Despain-Bickmore asssociation.
EDG	Elwood silt loam, 30-60 percent slopes.
EMG	Elwood-Mult association, steep.
FOG	Foxol rocky loam, 30-60 percent slopes.
HeD	Hiibner gravely clay loam, 10-20 percent slopes.
HeE	Hiibner gravely clay loam, 20-30 percent slopes.
HgE2	Hillfield silt loam, 20-30 percent slopes, eroded.
HhE2	Hillfield-Timpanogos silt loams, 10-30 slopes, eroded.
HKG2	Hoskin cobbly loam, 30-70 percent slopes, eroded.
HLG2	Hoskin-Datwyler association, eroded.
HMG2	Hoskin-Elzinga association, eroded.
HNG	Hoskin-Scave association.
HOG2	Hoskin-Scout association, eroded.
HSG2	Hoskin-Smarts association, eroded.
LMG2	Leatham-Barfuss association, eroded.
LVE	Lucky Star-Hoskin association.
MAG	Maughan-Datwyler association.
MdE2	McMurdie-Hillfield silt loams, 10-30 percent slopes, eroded.
MfE2	Mendon-Colinston complex, 6-30 percent slopes, eroded.
MNG2	Mult-Agassiz association, eroded.
POG2	Picayune-Agassiz association, eroded.
PSG2	Poleline-Agassiz association, eroded.
RCG2	Richmond very stony loam, 30-70 percnt slopes, eroded.
RDG2	Richmond-Middle association, eroded.
REG2	Richmond-Monk association, eroded.
RFG2	Richmond-Nebeker association, eroded.
RGG2	Richmond-Sterling association, eroded.
SAG	St. Marys gravelly very fine sandy loam, 30-60 percent slopes.
SCG	St. Marys-Curtis Creek association.

Table 4. Continued

Soils Map Symbol	Soil Name
SIE	Scave silt loam, 10-30 percent slopes.
SLG	Scout gravelly loam, 40-70 percent slopes, eroded.
SNG2	Sheep Creek cobbly loam, 30-70 percent slopes, eroded.
SOG2	Sheep Creek-Agassiz association, eroded.
SPG2	Sheep Creek-Despain association, eroded.
SRG2	Sheep Creek-Maughan association, eroded.
STG2	Smarts-Hoskin association, eroded.
TrC	Trenton silty clay loam, 4-8 percent slopes.
TrD2	Trenton silty clay loam, 8-20 percent slopes, eroded.
WhE	Wheelon silt loam, 10-30 percent slopes.
WhF2	Wheelon silt loam, 30-50 percent slopes, eroded.
WIE2	Wheelon-Collinston complex, 10 to 30 percent slopes, eroded.
-YHG	Yeates Hollow extremely rocky silt loam, 30-70 percent slopes.

streams. The relative contribution of sediment and phosphorus from any soil to a body of water depends on its erosivity, slope, and distance from the water (Ahuja et al. 1982). For example, in a study of a watershed in northern Wisconsin with slopes less than 12 percent, supporting primarily dairy agriculture, sediment actually transported by streams averaged 26 percent of the estimated soil loss from the watershed (Persson et al. 1983).

Total phosphorus concentrations in the Bear River remained high below the Utah-Idaho border on February 19 and 21 while phosphorus loads increased with increasing flow (Figure 1). Apparently, soil erosion is an important source of phosphorus during runoff events in Cache County, but the relative contribution of specific soils which are above average in erodibility in this area is not clear at present.

Figures 4 and 5 show the concentrations of total and orthophosphorus in samples of the Bear River in April, May, June, August, and November of 1986. With the exception of total phosphorus concentration in samples taken August 13, the similarities between both total and orthophosphorus concentrations in the Bear Lake Outlet Canal and the Honeyville site are remarkable. This does not imply that the phosphorus load below Bear Lake is nil. In fact, phosphorus loads are probably substantial, but it appears that in the absence of runoff the inputs and losses of phosphorus in the Bear River below Bear Lake are approximately equal. Chemical precipitation of phosphate (especially with calcium) in the stream, sedimentation of phosphorus bearing solids, and biological immobilization of phosphorus may be important mechanisms removing phosphorus from the Bear River. During the irrigation season water diverted onto the land would be expected to loose phosphorus through chemical precipitation and sorption in the soil. Water returning to the stream as groundwater would be relatively low in both total and orthophosphorus (Kemp et al. 1978).

In the August 13 samples the concentration of total phosphorus more than doubled between Richmond, and Honeyville, Utah. The relatively high concentration of total phosphorus in the Cub River (Appendix A) and the abrupt increase in phosphorus concentration from the sample taken above the Cub River (west of Richmond) to the sample taken below the Cub suggests that the Cub River was a major contributor to the increase in phosphorus concentration in the Bear River on this date. Phosphorus loads to the Cub River probably included wastewater discharge from the Del Monte lagoons at Franklin, Idaho; Preston, Idaho STP effluent (via Worm Creek); and the Richmond, Utah, lagoon overflow.

Total phosphorus concentration in samples taken above Oneida Reservoir on April 15 and June 10 were similar to the Bear Lake Outlet Canal sample concentration (Figure 4). The relatively large decrease in total phosphorus concentration across Oneida Reservoir suggests that Oneida Reservoir may trap phosphorus (probably associated with larger particles) when the inflowing phosphorus concentration is relatively high. On both of these sample dates the total phosphorus concentration increased through Cache Valley.

Orthophosphorus concentrations were surprisingly uniform along the Bear River from the Bear Lake Outlet canal to Honeyville on each of the sampling dates (Figure 5). Orthophosphorus concentrations were relatively high through most of the river on May 13 and June 10. The three samples collected below Cutler Reservoir were always collected a day after the date shown in the

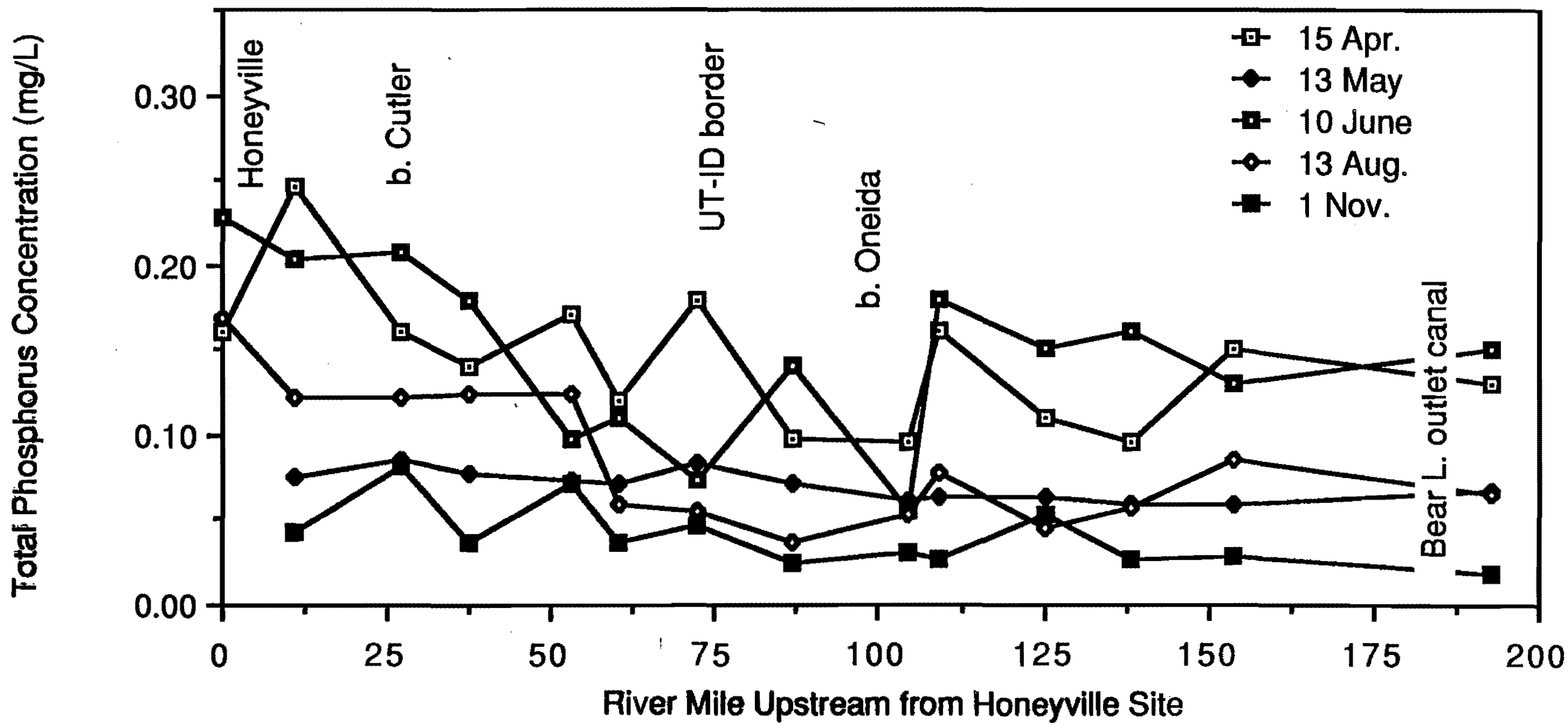


Figure 4. Total phosphorus concentrations vs. river mile in the Bear River from Honeyville to the Bear Lake outlet canal, April - November, 1986.

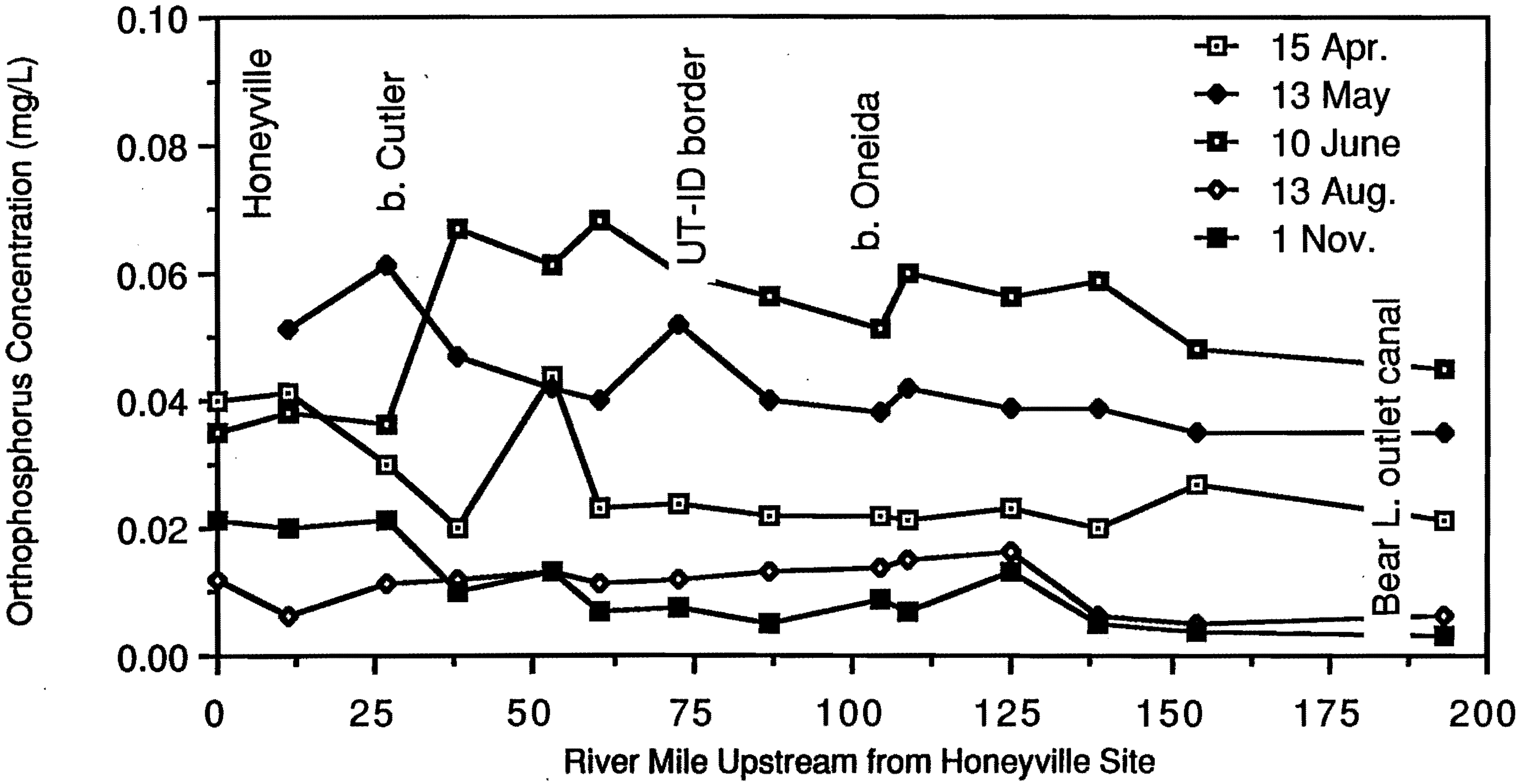


Figure 5. Orthophosphorus concentrations vs. river mile in the Bear River from Honeyville to the Bear Lake outlet canal, April - November, 1986.

legend of Figures 4 and 5. This discontinuity in sampling times may explain the sharp decrease in orthophosphorus concentration below Cutler Reservoir in the June 10 and 11 samples. It is, of course, also possible that orthophosphorus was being removed in Cutler Reservoir.

If surface runoff to the streams occurred during sampling, or perhaps on the day prior to sampling, increased sediment load and dissolved phosphorus would affect the total and orthophosphorus concentration in the sample. Figure 6 shows the average precipitation at the Corinne, Cutler Dam, Logan KVNU, Logan USU, Logan SW Farm, Plymouth, Richmond, Tremonton, Trenton, and Laketown precipitation gages in the lower Bear River Basin for 10 days prior to and including the dates of sampling (NOAA 1986). With the exception of the February samples where the soil was frozen or saturated by snow melt and antecedent rainfall, the occurrence of runoff on the day of sampling (April 15, May 12, June 10, August 13, or October 31) was unlikely.

Soil moisture was probably high due to rainfall each day up to 8 days prior to sampling on April 14 and 15 with an average of nearly 0.5 in falling 2 days prior to sampling, but the average rainfall on April 15 was less than 0.05 in, and it is unlikely that sufficient rainfall intensity occurred to exceed soil infiltration capacity and cause runoff.

On May 12 no measurable rain fell, and no surface runoff could have occurred that day. Rain had fallen each day up to 8 days prior to sampling with an average of more than 0.5 in falling 4 days prior to sampling, but average rainfall on the 3 days prior to sampling was less than 0.15 in. Again rainfall intensities on these 3 days were probably not high enough in most locations to exceed infiltration capacity of the soil.

An average of less than 0.1 in of rain fell on June 10 and October 31, and intensities were probably not high enough to sponsor surface runoff even though small amounts of rain had fallen prior to the sampling dates. Rainfall intensities can be highly variable in an area as large as the lower Bear River Basin, however, and localized runoff events may have occurred on these dates, or any of the dates discussed above, when rain fell.

Total and orthophosphorus would not be expected to be conservative constituents in hard water such as that of the Bear River where chemical precipitation can occur. We, therefore, conclude that in the absence of surface runoff, phosphorus inputs tend to approximately balance phosphorus losses through chemical precipitation with calcium, iron, and other cations; exchange onto clays; and immobilization in biological material along the course of the river. This implies that reductions in the inputs of phosphorus along the river could result in lower concentrations of phosphorus entering the proposed Honeyville Reservoir than are found in the Bear Lake Outlet Canal.

The total and orthophosphorus load of the Bear River at the USGS gauging stations on the sampling dates are shown in Figures 7 and 8. Comparison of these figures with the flows measured at the time of sampling (Figure 9) emphasizes the importance of reducing phosphorus concentrations in order to reduce the phosphorus load to the Honeyville Reservoir. This is, naturally, most important during periods of high flow. The phosphorus loads of the Little Bear and Logan Rivers which enter the Bear through Cutler Reservoir can

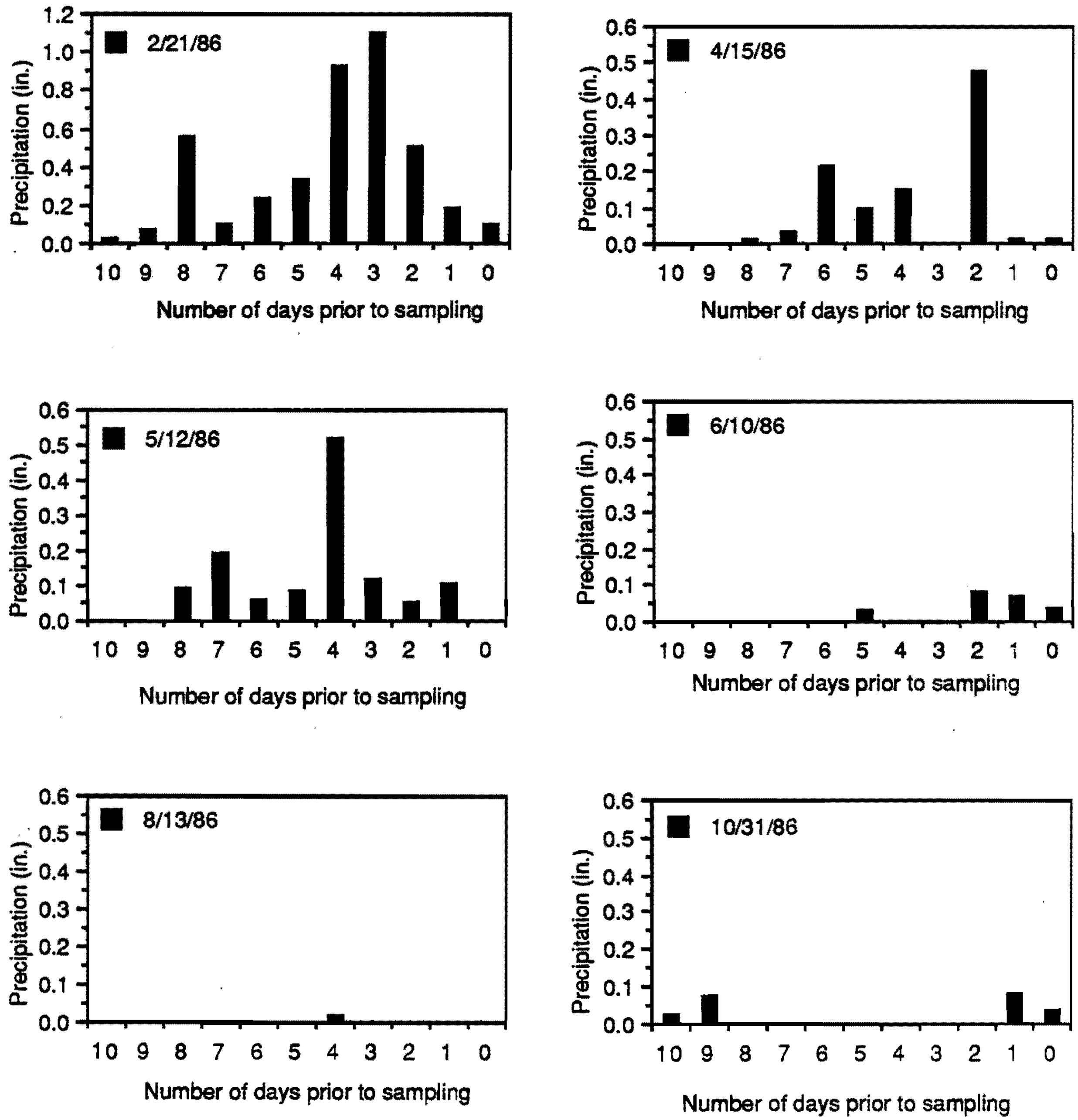


Figure 6. Average precipitation in the lower Bear River Basin 10 days prior to stream sampling.

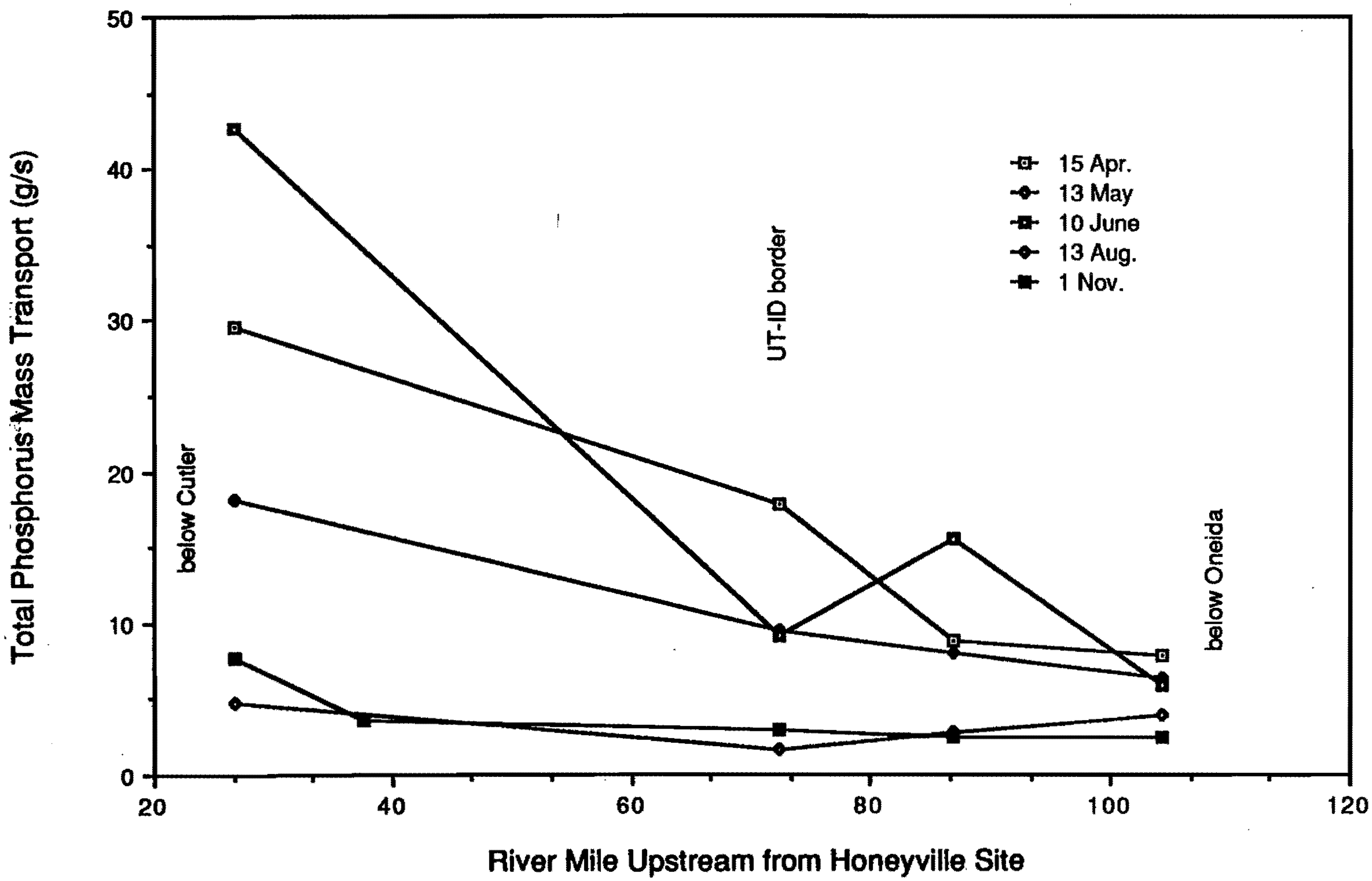


Figure 7. Total phosphorus transport in the Bear River at USGS gaging stations, April - November, 1986.

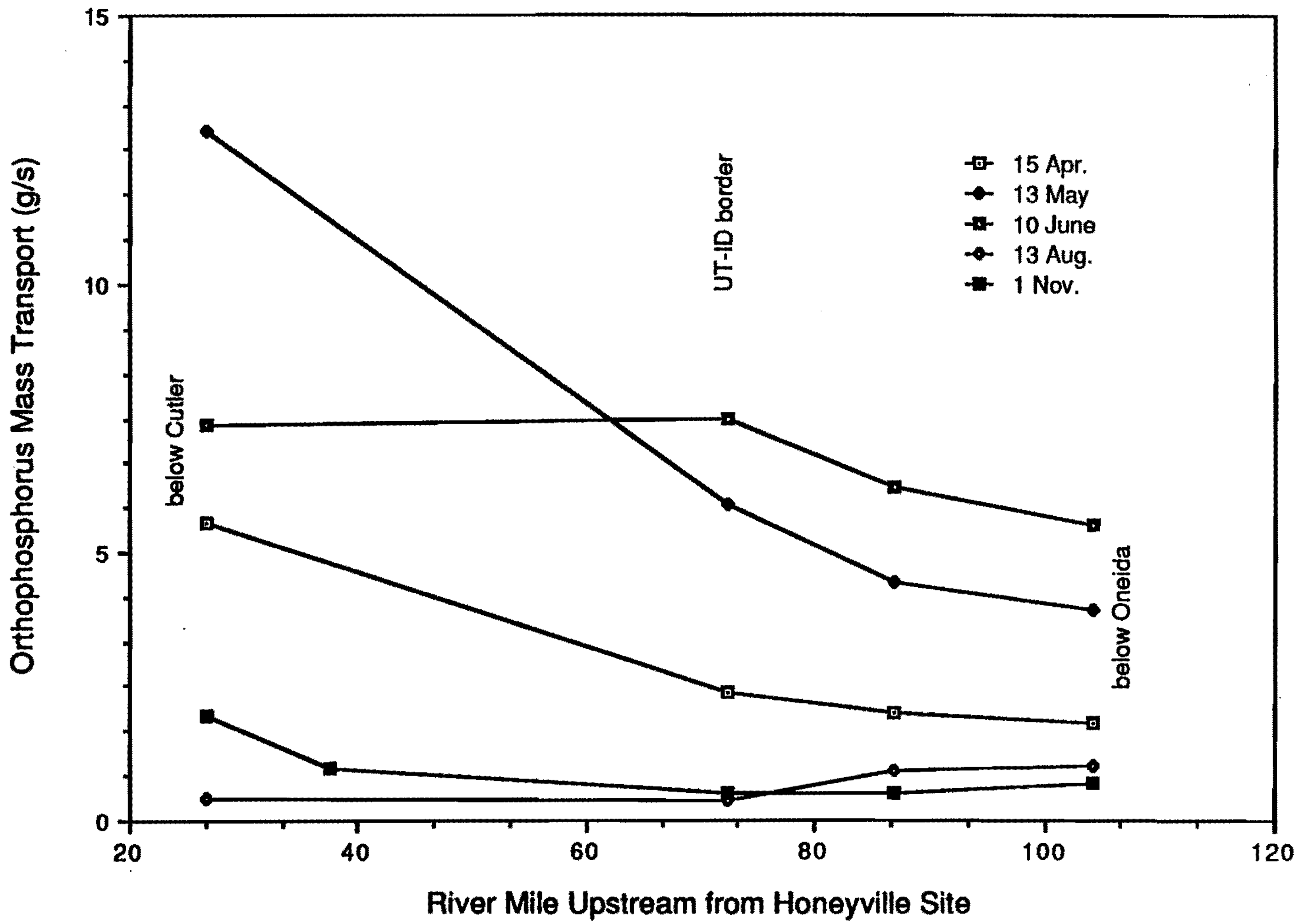


Figure 8. Orthophosphorus transport in the Bear River at USGS gaging stations, April – November, 1986.

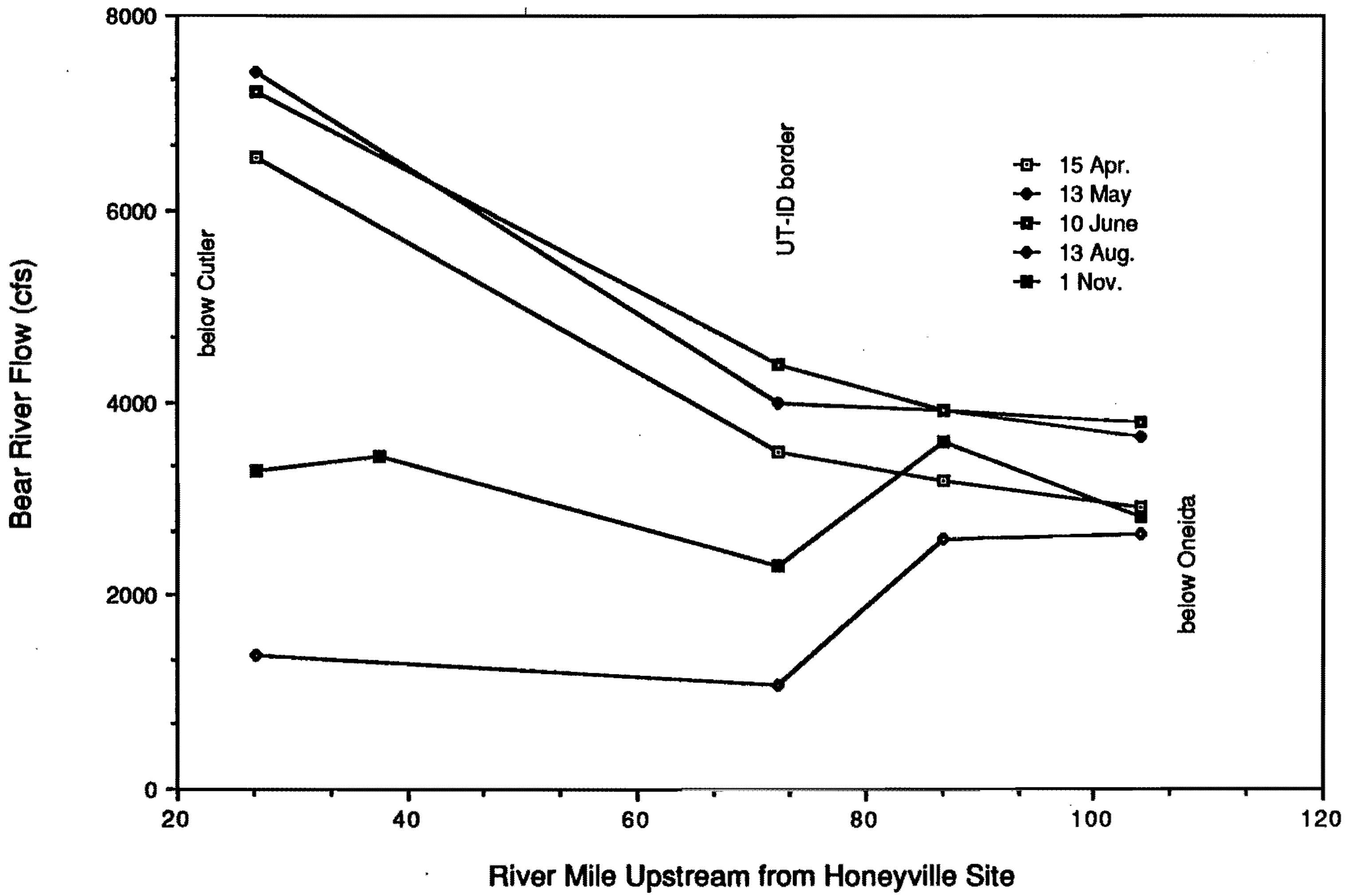


Figure 9. Bear River flow vs. river mile, April - November, 1986.

also make important contributions to the phosphorus load of the Bear below Cutler dam.

In summary, the 1986 monitoring data suggests that the losses and inputs of total and, especially, orthophosphorus in the Bear River from the Bear Lake Outlet Canal to Honeyville are approximately balanced. When total phosphorus concentrations are high in the Bear above Oneida Reservoir, appreciable amounts of the phosphorus can be removed in the reservoir. Below Oneida Reservoir the concentration and load of phosphorus can increase substantially as the river flows through Cache Valley. On August 13, the Cub River appears to have made a major contribution to this increase. Monitoring done during a major runoff event following rainfall and snow melt in February demonstrated the impact soil erosion can have on the total phosphorus load of the Bear River. Tributaries which enter the Bear below Oneida Reservoir in Franklin County, Idaho, and which drain areas with high soil erosion potential and have reaches with high channel erosion, greatly increased the concentration of total phosphorus in the Bear River during this meteorological event.

Potential effects of reservoir power peaking cycles on phosphorus transport

Utah Power and Light Company (UPL) operates hydroelectric power generation plants at Soda Point Reservoir, at Grace and Cove, at Oneida Reservoir, and at Cutler Reservoir on the Bear River. The Grace and Cove power plants use water diverted at Grace Reservoir. The total generating capacity of these plants is 182 megawatts. The plant at Oneida Reservoir is frequently operated in a "power peaking" mode. When electric power consumption on UPL's power grid is at a maximum or when generating capacity of coal fired plants is impaired by equipment failure or maintenance requirements, the 30 megawatt generation capacity at Oneida is brought on line to help meet the demand. The 30 megawatt generation capacity at Cutler Reservoir is also used in this way, but less frequently than that at Oneida (C. B. Burton, Utah Power and Light Company, personal communication, 1986).

Release of water from reservoirs during power peaking cycles can cause river flows to change by as much as 2000 cfs in 1 hour. We hypothesized that increased phosphorus loads could be transported with these hydraulic events as sediments were suspended as a result of the flushing action caused by the high flows. Each power peaking cycle could move particulate phosphorus farther downstream, and could encourage the solubilization of sediment phosphorus, resulting in increased P levels in the reservoirs.

In cooperation with Utah Power and Light Company and the U.S. Geological Survey we sampled for ortho and total phosphorus over a power peaking cycle for both Cutler and Oneida Reservoirs. On December 3, 1986, at 7:00 a.m., Cutler Reservoir was discharging minimal flow (approximately 20 cfs). The flow was increased hourly in increments of 1000 cfs until a maximum of 4000 cfs was reached. Water flow was then decreased back to minimum flow at the same rate. Surface water samples were collected at 30 minute intervals at the USGS gauging station 800 yards downstream from the power plant tail race during the time that the flow rate was changing. After the flow had stabilized at each increment of change, samples were collected approximately 1 foot from the river bottom using a sampler at points approximately 1/3 and 2/3 the distance across the river.

At 9:00 a.m. on December 4, 1986, a power peaking cycle was begun at Oneida Reservoir. Flow was increased hourly in 1000 cfs increments until a maximum of 2800 cfs was reached and then decreased back to minimum flow (40 cfs) in 1000 cfs increments. River sampling was begun at 6:30 p.m. at the USGS Gage Station at the Utah-Idaho border, approximately 32 river miles downstream from the reservoir. A permanently installed sampler, used for suspended sediment monitoring by the USGS, was used to collect water samples at 30 minute intervals from approximately one foot above the river bottom. Surface water samples were collected hourly for the duration of the cycle. On the following evening we intended to collect samples at the Benson Bridge (66.6 miles downstream) but were unable to detect any increased flows.

Total and orthophosphate concentrations changed with flow below both Cutler and Oneida Reservoirs (Figures 10 and 11). The sampling station below Oneida is much farther downstream from the reservoir than is the station below Cutler. This difference is reflected in the magnitude of change in both flow and phosphorus concentration. At the Utah-Idaho border (below Oneida) the flow increased by only 500 cfs and orthophosphorus concentration increased by only approximately 10 µg/L. The water stored in the river channel, marshes, and oxbows below the reservoir evidently produced a dampening effect on the flow rates.

The data support the hypothesis that phosphorus released from sediment suspended as a result of power peaking operations contributes to the existing P transport in the river. These "pulses" of P input likely occur regularly in the Bear River system, since both reservoirs go through power peaking cycles, sometimes twice daily. For this experiment, water was released less abruptly than is sometimes done during normal power peaking operations. Faster increases in flow may result in greater increases in P transport.

Phosphorus concentrations in Bear River tributaries

In the Cub River, concentrations of total and orthophosphorus were relatively low in samples collected approximately 1 mile upstream from Franklin, Idaho (at river mile 88) except for the June 10 sample (Figure 12). The relatively high phosphorus concentration above Franklin on this date may have been due to runoff from a locally intense rainfall event in the mountainous watershed of the Cub River. In the April, May and October samples of the Cub River the largest increase in both total and orthophosphorus was observed between Franklin, Idaho, and Richmond, Utah. Worm Creek enters the Cub River in this reach and often carries high concentrations of phosphorus (Figure 13), and is probably responsible for the increase in phosphorus concentration in the Cub River. This would most likely be the case for the April, August, and October sampling dates at least. The most likely source for this phosphorus is the Preston, Idaho, sewage treatment plant effluent, which is discharged to Worm Creek. The large increase in total and orthophosphorus in the Cub River in the Franklin, Idaho, vicinity on August 13 may be due to the discharge from the Del Monte wastewater lagoons at Franklin. Del

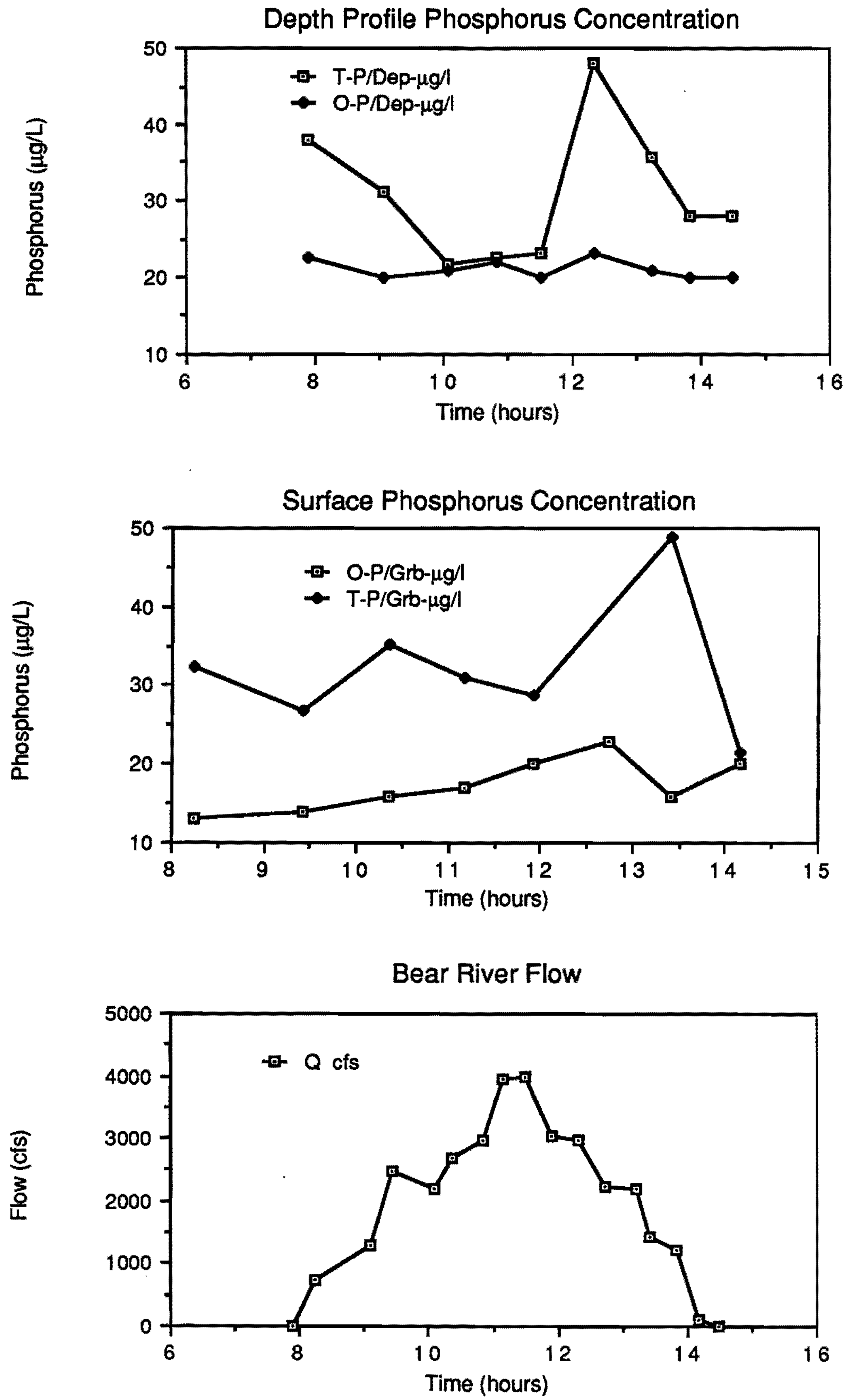


Figure 10. Changes in flow and phosphorus concentrations in the Bear River below Cutler Reservoir during a power peaking operation December 3, 1986.

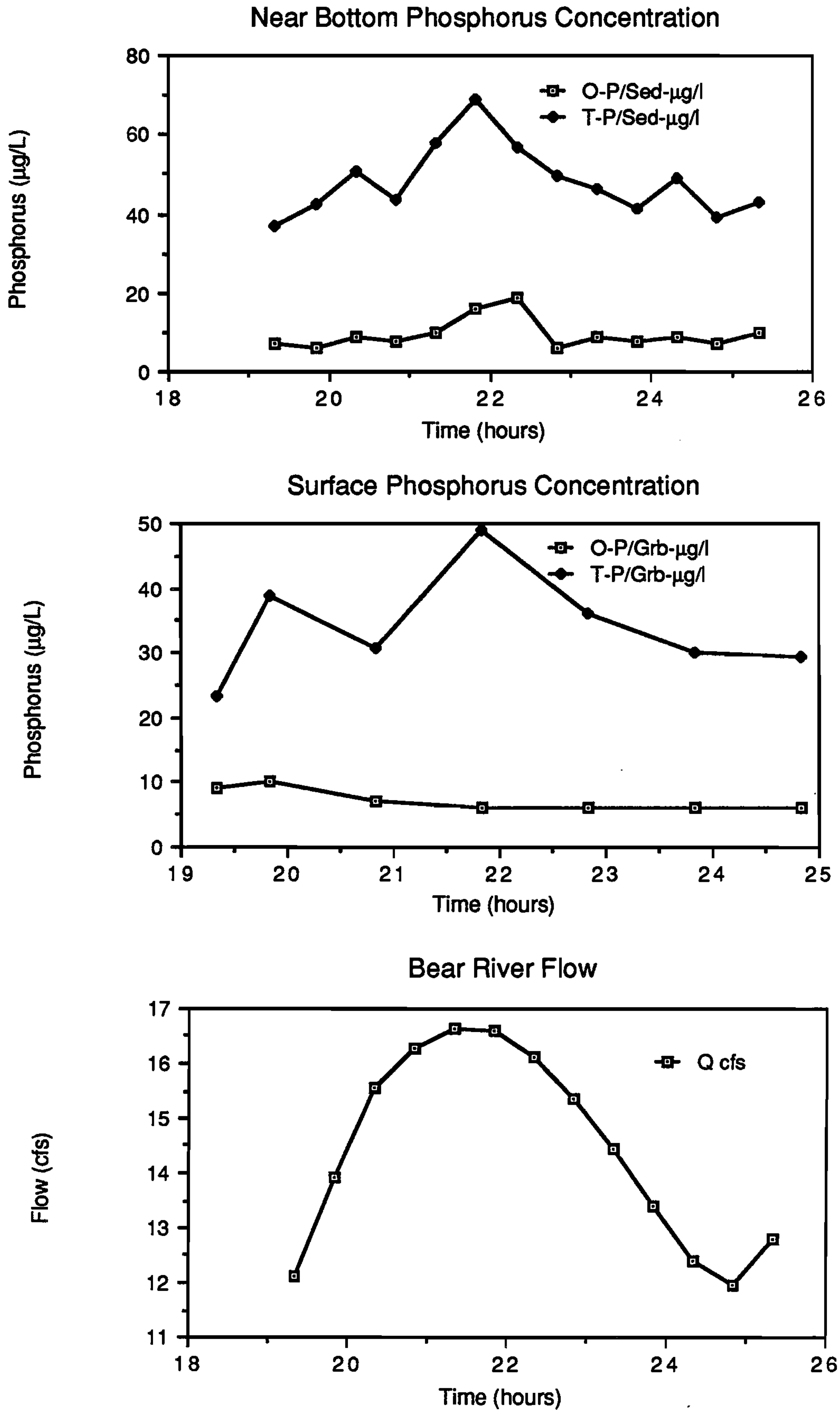


Figure 11. Changes in flow and phosphorus concentrations in the Bear River below Oneida Reservoir during a power peaking operation on December 4, 1986.

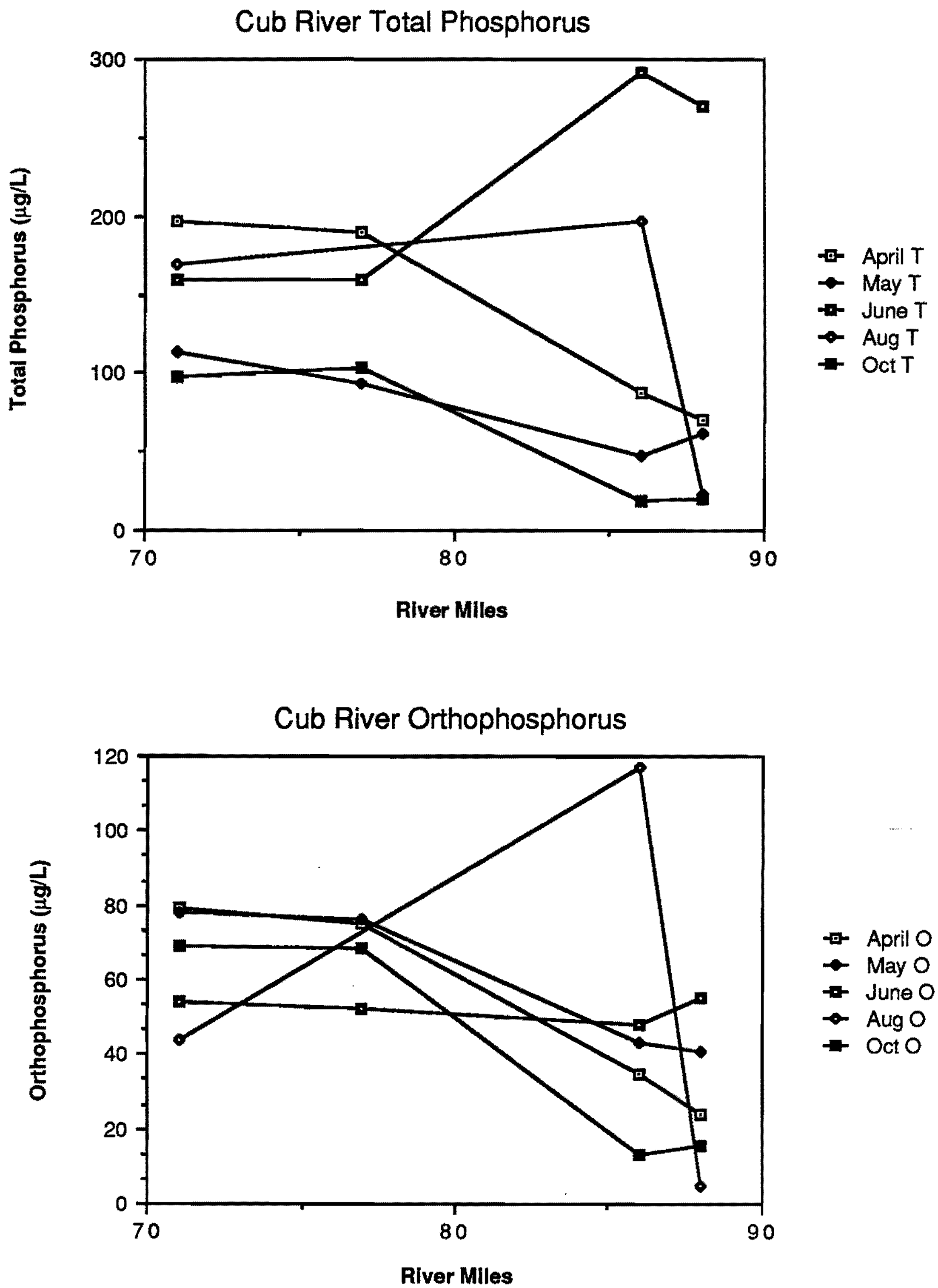


Figure 12. Phosphrus concentrations vs. river mile in the Cub River, April - October, 1986.

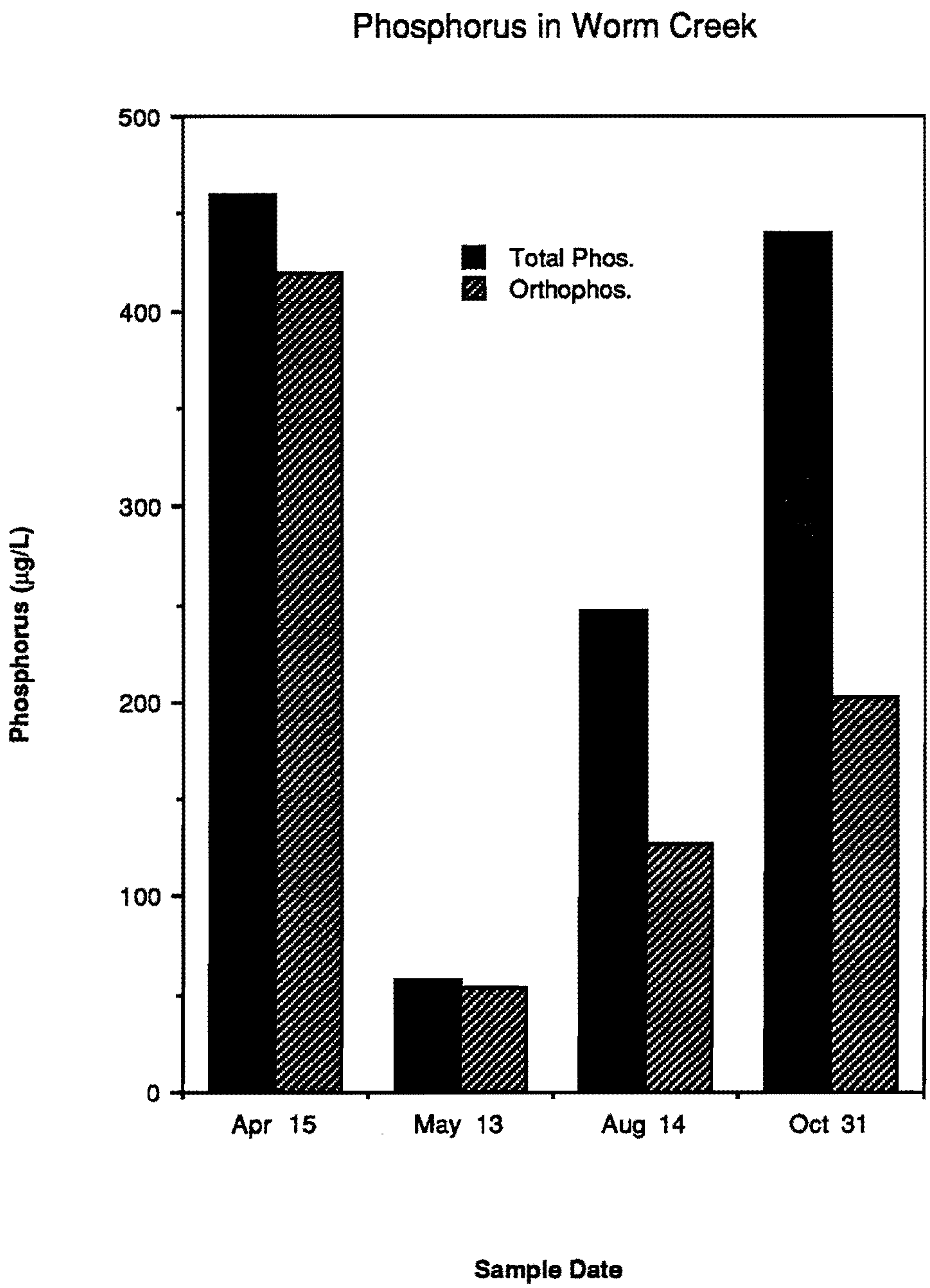


Figure 13. Ortho and total phosphorus concentrations in Worm Creek, April - October, 1986.

Monte discharges from their lagoons in July and August (Bill Smith, Idaho Environmental Services, personal communication, 1987).

Little phosphorus was gained by the Cub River in the Richmond, Utah, area. The effluent from the Richmond lagoons enters the Cub River in this reach, but flows through a small wet land area prior to entering the river. The relatively small flow (<0.3 cfs) and the phosphorus removal in the marsh apparently leads to little gain in phosphorus concentration in the river.

The concentrations of total and orthophosphorus in the Logan River samples taken below the Logan lagoon effluent are shown in Figure 14. The highest concentration was measured in the April 2 sample collected by the BWPC (Appendix B), and is probably associated with spring runoff from the mountains. Part of the phosphorus load borne by the Logan River at this sampling point comes from the Logan City wastewater lagoons. Some urban runoff from the city of Logan may also be an important phosphorus source during times of heavy rainfall or snow melt. Phosphorus entering Cutler Reservoir from the Logan River and the Little Bear River interacts with the sediments and biota of the marsh lands that make up the southern portion of that reservoir. Particulate phosphorus may settle out of the water column, and the dissolved phosphorus and part of the particulate phosphorus is probably immobilized into plant and microbial biomass in the marsh (Simpson et al. 1983, Johnston et al. 1984, and Lowrance et al. 1985). It seems unlikely, therefore, that all of the phosphorus entering the marsh with these streams flows out of Cutler Reservoir. When marsh plants die and decay in the late fall of the year some phosphorus may be released and pass out of the reservoir.

Phosphorus concentrations in the Little Bear River are shown in Figure 15. As with the Logan River, highest concentrations of total phosphorus were observed in the April samples suggesting that spring runoff had a major effect on phosphorus loading during this period. In June and August, total phosphorus concentration in the Little Bear River more than doubled between Hyrum Reservoir and Cutler Reservoir, and in August, orthophosphorus increased four fold in this reach. Hyrum City's wastewater treatment plant, and E.A. Miller & Sons Packing Company wastewater lagoons discharge to waterways that enter Spring Creek, which joins the Little Bear River or Cutler Reservoir below the lowest Little Bear sampling station. The phosphorus load from these sources is, therefore, not reflected in the little Bear River samples. Occasionally, Wellsville City's wastewater lagoons discharge to the Little Bear River within this reach, but the volume of discharge is small (<1 cfs) and it seems unlikely that the resulting increase in phosphorus concentration would be measurable. Nonpoint source contributions of phosphorus could also be important in this lower section of the Little Bear River.

Phosphorus inputs to the Avon Reservoir site

The principal streams that will feed the proposed Avon Reservoir are the South Fork of the Little Bear River and Davenport Creek. Concentrations of total and orthophosphorus in samples of the South Fork of the Little Bear River (S. F. Little Bear River) above Davenport Creek are shown as the most upstream data points in Figure 15 (river mile 93). The highest concentrations of both total and orthophosphorus were observed in the April sample,

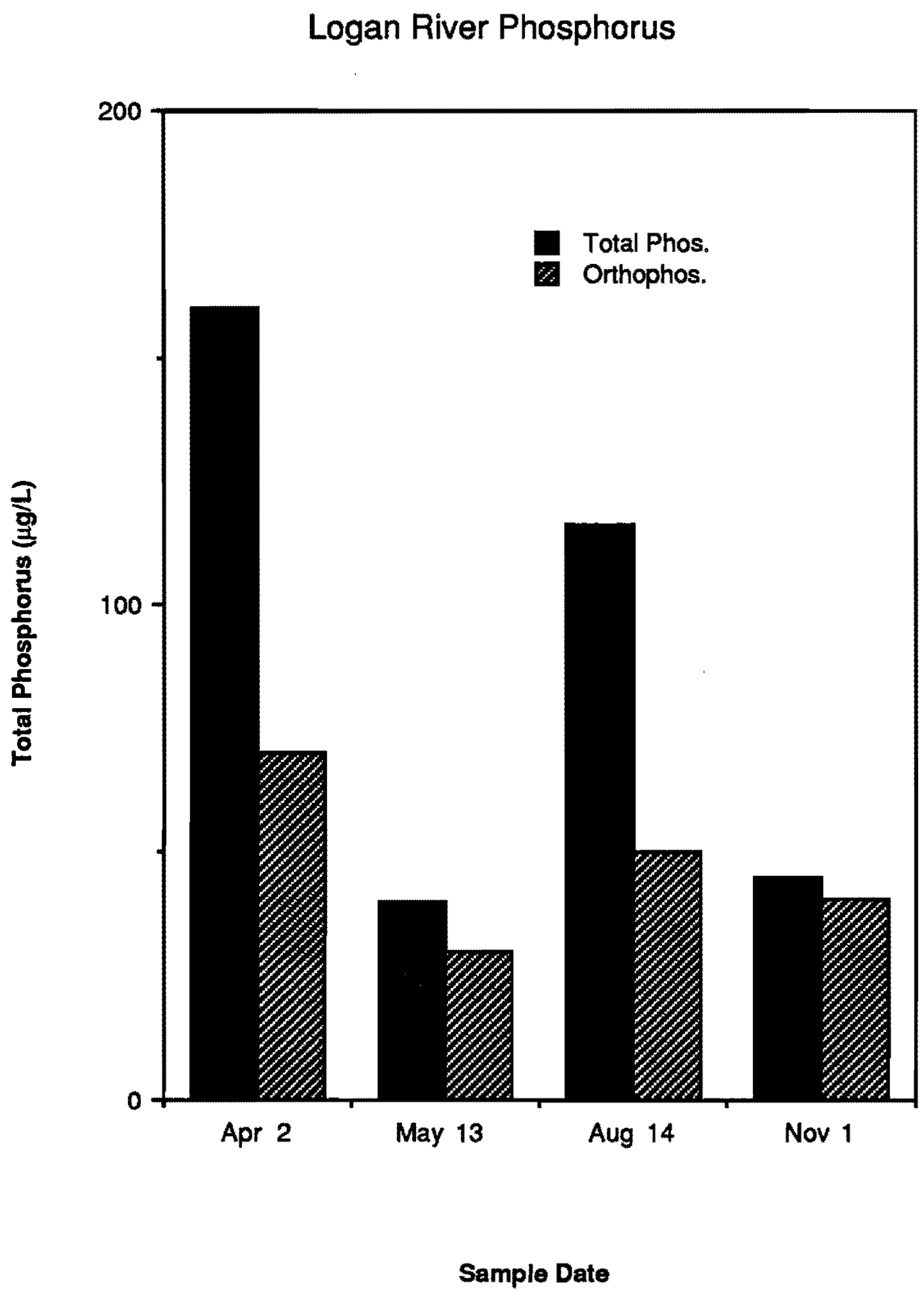
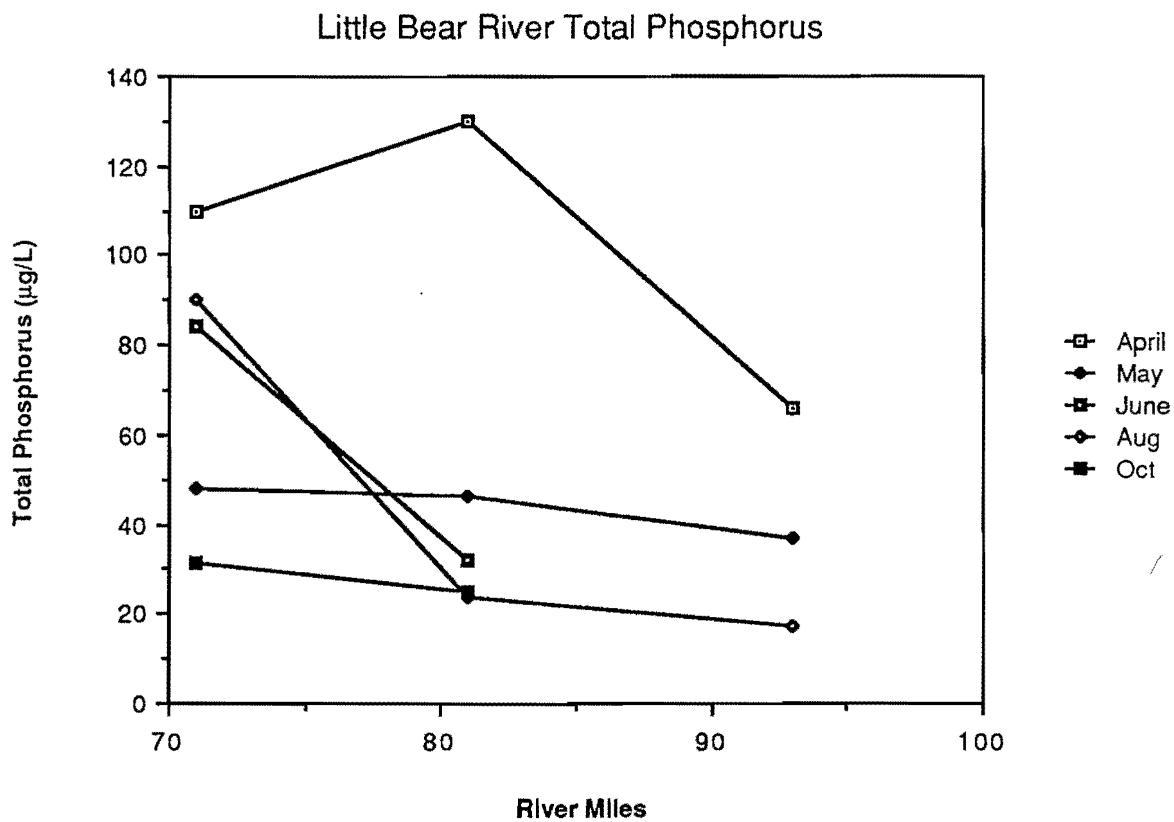


Figure 14. Ortho and total phosphorus concentrations in the Logan River, April - November, 1986.



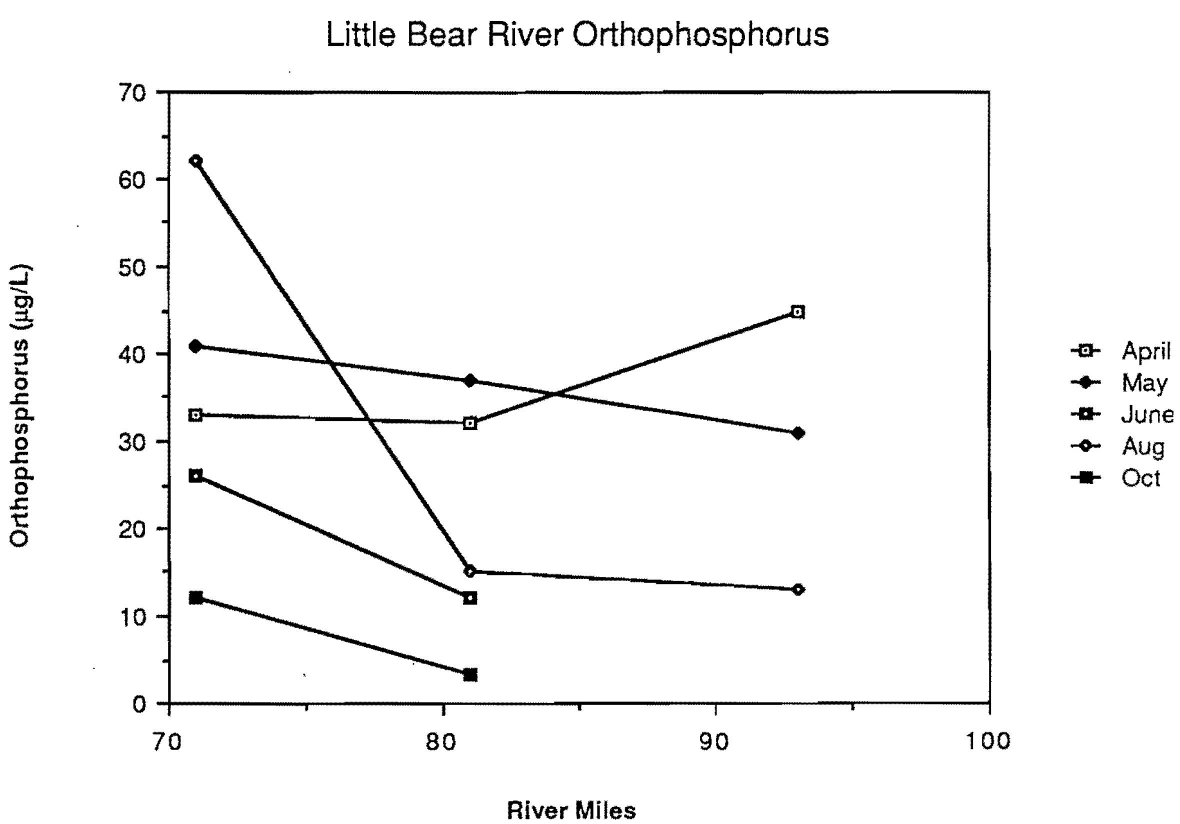


Figure 15. Phosphorus concentration vs. river mile for the Little Bear River.

reflecting the influence of spring runoff on phosphorus transport by this stream. Orthophosphorus remained relatively high in the May sample, but in August both total and orthophosphorus were below 20 ug/L. In the April sample, orthophosphorus was 68 percent of total phosphorus in the S. F. Little Bear River above Davenport Creek. In the May sample this fraction increased to 84 percent, and in August it was 76 percent. These high percentages of orthophosphorus suggest that a very large fraction of S. F. Little Bear River total phosphorus is bioavailable. If in fact the phosphorus is highly bioavailable, the phosphorus may be from a source other than soil erosion, or some soils in the watershed may be high in soluble phosphorus.

The relatively high concentrations of total phosphorus in samples of Davenport Creek collected in February and April (Figure 16) are the result of runoff from snow melt and rainfall. The low concentrations of total and orthophosphorus in the June, August, and November samples indicate that phosphorus control planning for this stream needs to primarily address the spring runoff events and associated soil erosion.

Phosphorus inputs to the Mill Creek Reservoir site

Total and orthophosphorus concentrations in samples from the Blacksmith Fork River above Sheep Creek, Sheep Creek, the Blacksmith Fork River at Anderson Ranch, and Mill Creek are shown in Figure 17. Concentrations of both total and orthophosphorus were consistently higher in Mill Creek than in the other streams on all sampling dates. The other streams consistently carried very low concentrations of phosphorus. Orthophosphorus never exceeded 20 ug/L in the Blacksmith Fork above Sheep Creek, in Sheep Creek or in the Blacksmith Fork at Anderson Ranch including the April samples when runoff was relatively high. The lowest concentrations of phosphorus in any of these streams were observed in Sheep Creek in the October sample. Despite the higher concentrations of phosphorus in Mill Creek, the larger flows of the Blacksmith Fork River make it the largest contributor of phosphorus to the Mill Creek Reservoir site. For example, based on estimated flows at the time of sampling and the concentrations of total phosphorus in the samples taken on February 20, Mill Creek transported 18 mg P/s while the Blacksmith Fork at Anderson Ranch transported 311 mg P/s. Of this 311 mg P/s, Sheep Creek contributed about 10 mg/s (Appendix A). Here again, phosphorus load controls would focus on soil erosion control practices probably including restricted grazing.

Methods of Phosphorus Control

Soil conservation practices

Where phosphorus loads to streams are attributed largely to runoff from the land and soil erosion, best management practices for soil erosion control and nutrient retention are used to control these loads (Miller et al. 1982, Chesters and Schierow 1985, Maas et al. 1985, Baker 1985, Ogg 1986, Gianessi et al. 1986). Estimates of land use in the Bear River Basin applied to average export coefficients show that crop and pasture land in the basin could be expected to contribute up to 89 percent of the total basin export of total phosphorus (Table 3). It seems appropriate, therefore, to emphasize land management practices in a phosphorus control plan. For the streams feeding the proposed Avon and Mill Creek Reservoirs, the watersheds are largely pinyon-juniper, sage brush, or coniferous forest ecosystems used for grazing. For these areas careful management of grazing, protection of wetlands, and stream bank stabilization will likely be required to reduce phosphorus loading. For the crop and pasture lands which influence the Bear River, soil conservation practices, wetland protection, green belt establishment, and stream bank stabilization will probably be required.

Table 5 lists soil conservation practices that could be applied in the Bear River Basin. Most of these practices have already been tried, at least experimentally, in the basin. No-till agriculture is a technology that has been developed since the 1960s and is gaining wide acceptance nationally. In the Bear River Basin, however, relatively small amounts of land are currently under no-till or low-till management practices. In Cache County Utah, for example, no-till land accounted for 0.2 percent of the crop acreage planted in the 1987 calendar year, while all no-till and low-till conservation tillage accounted for 10.1 percent. No-till agriculture has the advantages of reduced fuel consumption, reduced labor requirements, lower dependance on climatic conditions for planting and harvest, improved water retention, more intense land use, and a large reduction (approximately 10 fold) in soil erosion. Disadvantages include more intensive management of fertilizer usage, critical timing of fertilizer application, specialized planting techniques, lower soil temperatures, intense chemical weed control, and increased populations of plant pests (Phillips and Phillips 1984).

Stream bank erosion control

Stream bank erosion has been recognized as an important economic problem in the U. S., and considerable research has gone into its causes and control (Corps of Engineers 1981). A modeling study estimated that 45 percent of the suspended sediment leaving the State of Iowa through its rivers comes from in-stream bank erosion (Odgaard 1984). However, Oalman and Lohnes (1985) found no evidence that stream channel erosion made a significant contribution to the sediment load entering Red Rock Reservoir in Iowa. Major sections of tributaries to the Bear River in Franklin County, Idaho, have been designated as having severe erosion problems (Figure 2), and many other areas of the Bear and its tributaries lose large amounts of soil to stream bank erosion each year. Water quality is impacted by this erosion as well as upland erosion (Stern and Stern 1980). Soluble and bioavailable phosphorus in the soil entering the stream from this source can be important.

Landslides in some areas of the Bear River Basin below Bear Lake contribute to stream bank instability. Soil may be moved into the stream channel as the unstable earth in the slide moves downhill creating a semi-continuous source of erodible material to the stream. Some areas of Franklin County, Idaho, that have shown land sliding are designated as "slip areas" in Figure 2. Increased precipitation in northern Utah and southern Idaho in recent years has increased the frequency of landslides in this area (Anderson et al. 1984).

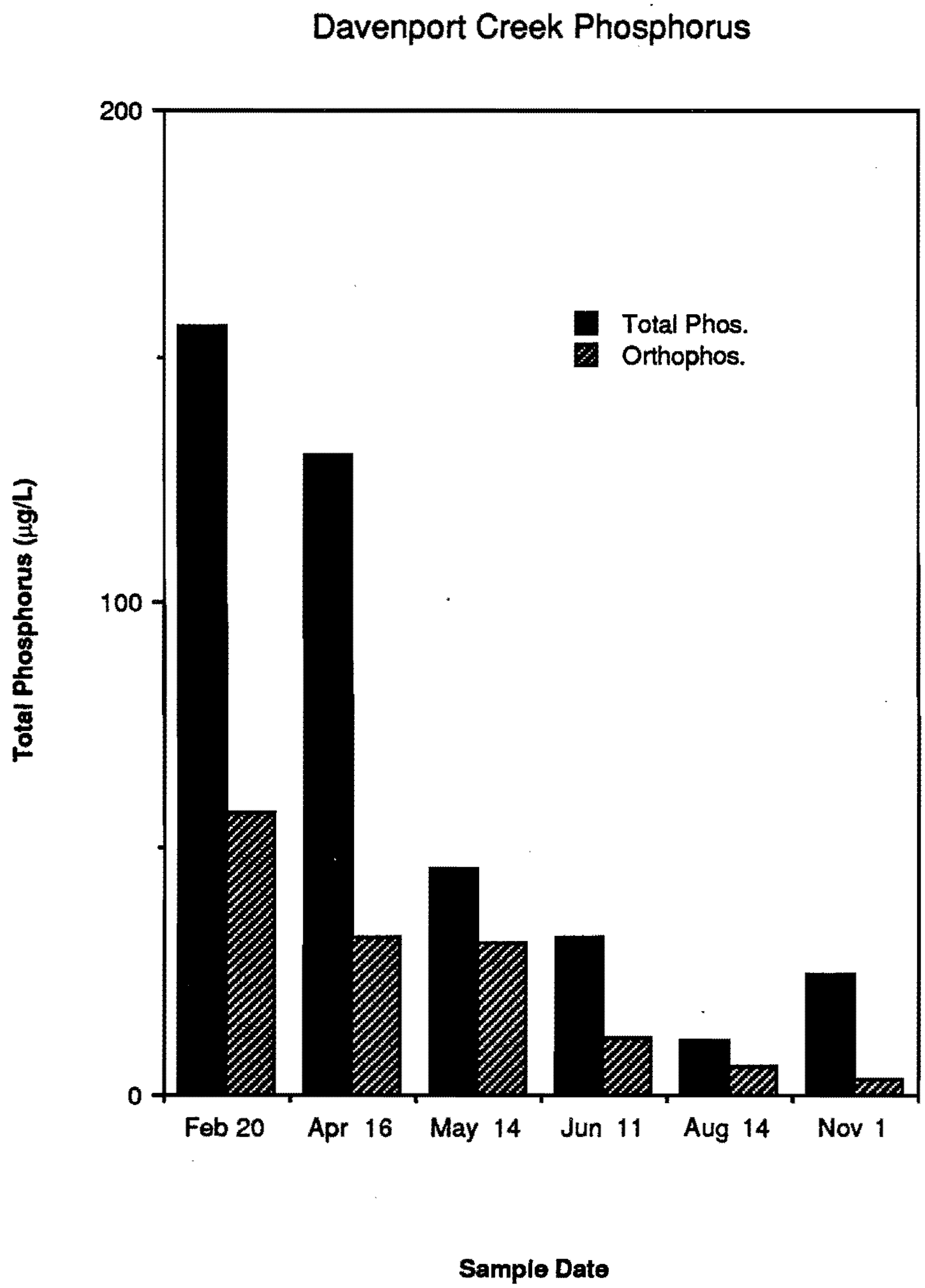


Figure 16. Phosphorus concentration in Davenport Creek from February 20 to November 1, 1986.

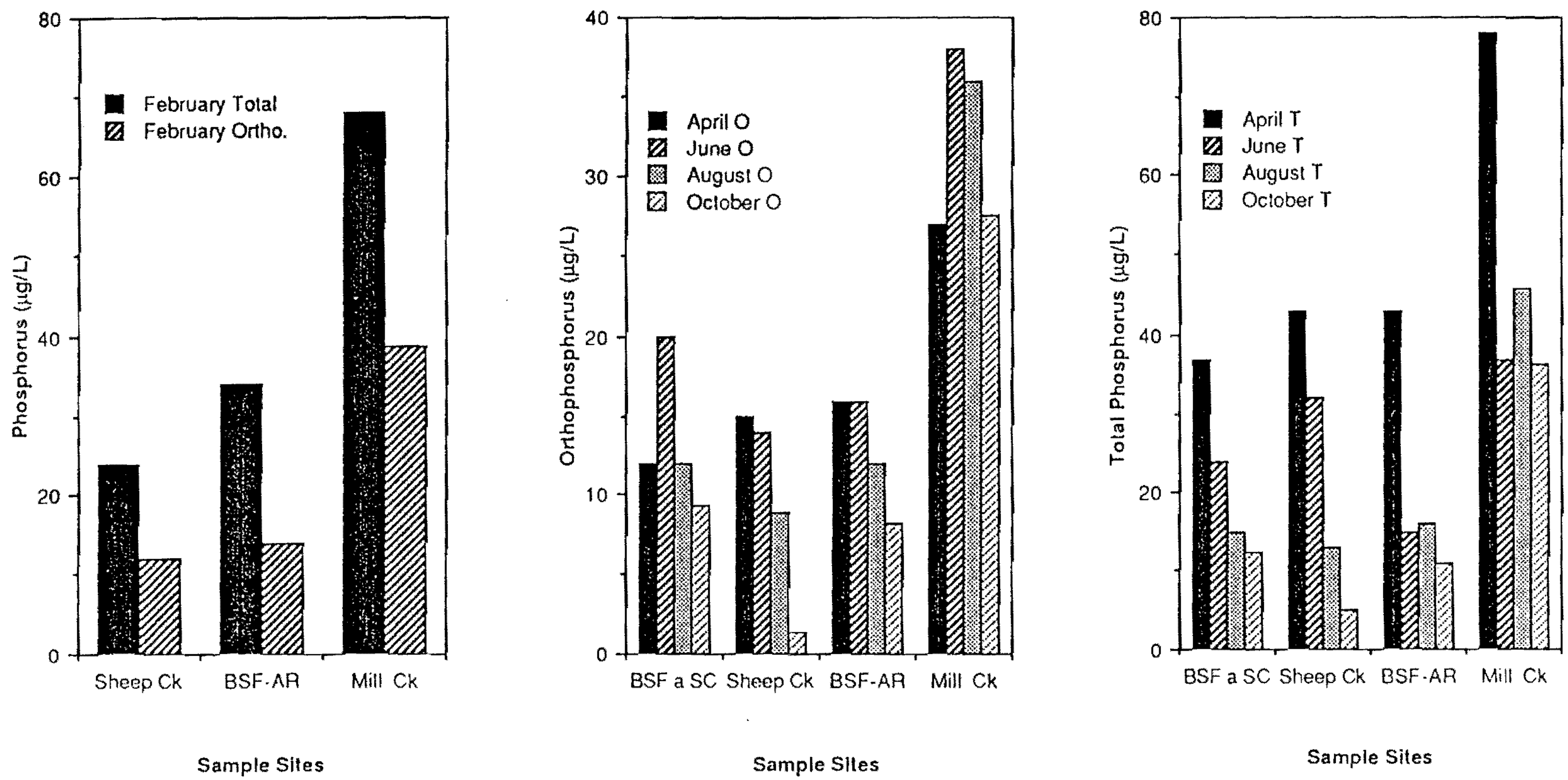


Figure 17. Phosphorus concentrations in Sheep Creek, Mill Creek, and Blacksmith Fork River at Anderson Ranch and at Sheep Creek.

Table 5. Soil conservation practices (Bosworth and Foster 1982).

Soil Conservation Practice	Conservation Principle
No Till or Low Till Conservation Tillage	Minimal soil disturbance; crop residues are left on the soil to reduce erosion.
Contour Farming	Tillage lines (plowing, harrowing, planting)-run across the slope, slow water movement, and reduce erosion.
Strip Cropping	Contour strips of crops alternated with a cover crop (meadow) which intercepts water moving downslope and prevents erosion. More effective than contour farming.
Terraces	Interrupt slope length and provide for drainage or infiltration of runoff water without erosion.
Diversions	Route water courses around fields to prevent erosion.

Methods for stream bank erosion control generally rely on either stream bank surface protection, stabilization of the stream, or modification of the stream (Corps of Engineers 1981). Table 6 lists the types of protection that were evaluated by the Corps of Engineers (1981) in various river basins or regions of the U. S. Costs (in 1981 dollars) for installing these controls ranged from $360 per linear foot of bank line for automobile tire mat to $10 per foot for grass vegetation. In general, stream bank stabilization was not considered cost effective in the demonstration projects conducted in this study (Corps of Engineers 1981). Odgaard and Lee (1984) found that submerged vanes could be designed to eliminate secondary flow and bank scouring on river bends, reducing erosive forces at these locations. Selection of an erosion control method should be done after careful consideration of soil properties and hydraulics of the stream since more than one property of the stream environment usually contributes to stream bank erosion, and misplaced or poorly designed erosion control structures can contribute to flooding or enhance the erosion process.

Methods for the correction and prevention of landslides (Root 1958) that may be applicable to the slide areas affecting the Bear River and its tributaries include:

(1) Excavation, including removal of the head, flattening or benching of the slopes, or removal of all unstable material to reduce shearing stresses.

(2) Reducing shearing stresses and increasing shear resistance through surface and/or subsurface drainage.

(3) Construction of retaining structures such as buttresses at the slide foot, cribs or retaining walls, pilings, and tie-rodding slopes to increase shearing resistance.

Bioavailability of Phosphorus

Due to radiation induced toxicity of the water, bioavailable phoshorus estimates were obtained for only filtered, non-irradiated samples for the first two sampling periods. For the April 21 collection, estimates ranged from 3.6 (Little Bear) to 13.3 µg P/L (Bear R. Honeyville). Bioavailable phosphorus estimates for the May 12 samples were 7.6 (Little Bear) and 26.7 µg/L (Honeyville) (Table 7). Microtox tests performed on the filtered samples collected May 12 indicated toxicity (23 - 31 Microtox units) in the irradiated samples (Table 8). We collected a sample from the Bear River above Oneida Reservoir on June 10 and sparged it with N_2 for 1 hr to strip oxygen from solution hoping to prevent hydrogen peroxide formation through the reactions of singlet oxygen (Foote 1968). Microtox tests indicated no toxicity and a trial bioassay resulted in good growth of *S. capricornutum* in this sample. The next two sets of bioassay samples (23 June and 13 August) were also sparged with N_2 prior to irradiation. Good growth of *S. capricornutum* was exhibited in most samples in each set, but toxicity was evident in the Blacksmith Fork samples collected on both dates and in the Little Bear

Table 6. Streambank protection methods evaluated by the Corps of Engineers (1981).

Types of Streambank Protection

Streambank Surface Protection		
	Low Porosity Cover	
		Surface Soil Stabilization
		Anchored Membrane
		Filled Mats or Bags
	Loose Material Cover (porous)	
	Material	
		Stone Riprap
		Steel-Furnace Slag
		Rubble
		Soil-Cement Blocks
		Gravel
	Placement	
		Composite Revetment
		Reinforced Revetment
		Windrow
		Trench Fill
		Surface Layer
	Manufactured Materials	
		Concrete Blocks
		Filled Bags
	Porous Cover	
		Used Auto Tire Mats
		Gabion Mattress
	Vegetation	
		Grass
		Woody Shrubs
		Trees
		Anchored Trees
Stabilize or Modify Stream		
		Grade Control of Channel Bottom
		Channel Relocation
	Longitudinal Controls	
		Stone/Slag Fill
		Filled Bags or Tubes
		Fence
		Open Frames (Jacks)
		Cribs
		Used Auto Tires on Posts
	Protruding Controls	
		Hard Points
		Board, Wire, etc., Dikes
		Earth- or Gravel-Core Dikes
		Gabion Dikes
		Stone Dikes (including Vanes)

Table 7. Phosphorous data for Bear River water samples treated with gamma radiation and used in algal bioassays in 1986.

		Bear R. above Oneida	Bear R. UT - ID border	Little Bear ab. Avon	Black-smith Fork	Bear R. Honey-ville
21 April 1986	Bioavailable P, µg/L					
	no γ treatment: filtered			3.6	4.9	13.3
	γ treated: filtered			ng	ng	ng
	whole	ng*	ng	ng	ng	ng
12 May	Bioavailable, P, µg/L					
	no γ treatment: filtered			7.6	-	26.7
	γ treated: filtered			ng	ng	ng
	whole	ng	ng	ng	ng	ng
23 June	Bioavailable P, µg/L					
	no γ treatment: filtered					13 (P50)
	γ treated: whole	42	42	2.8	ng	28.7
13 August	Bioavailable P, µg/L					
	no γ treatment: filtered				**NP30	1
	γ treated: whole	22.9	10.6	ng	ng	32.9
15 September	Bioavailable P, µg/L					
	no γ treatment: filtered					
	γ treated: whole		ng	ng	ng	31
	Ortho P, µg/L					
	no γ treatment: whole		17	9	5	20
	γ treated: whole		31	11	<5	42
	NaOH P, µg/L					
	no γ treatment: whole		16	7	<5	17
	γ treated: whole		7	16	6	15

Table 7. Continued

		Bear R. above Oneida	Bear R. UT - ID border	Little Bear ab. Avon	Black-smith Fork	Bear R. Honey-ville
	Total P, µg/L					
	no γ treatment:whole		25	13	9	29
	γ treated:whole		35	14	9	47
1 November	Bioavailable P, µg/L					
	γ treated, whole	ng	ng	ng	ng	ng
	Ortho P, µg/L					
	no γ treatment:whole	<5	<5	<5	7	15
	γ treated: whole	10	10	<5	<5	20
	NaOH P, µg/L					
	no γ treatment:whole	<5	<5	<5	<5	9
	γ treated: whole	5	11	<5	7	8
	Total P, µg/L					
	no γ treatment:whole	35	64	19	11	74
	γ treated, whole	30	62	16	9	74
1 December	Bioavailble P, µg/L					
	no γ treatnment:filtered			**NP30	ng	
	γ treated: whole	4	ng	ng	ng	ng
	Ortho P, µg/L					
	no γ treatment:whole	<5	7	6	8	13
	γ treated:whole	13	12	6	6	23
	γ treated,whole,+perox.	13	12	5	<5	21

Table 7. Continued

	Bear R. above Oneida	Bear R. UT - ID border	Little Bear ab. Avon	Black-smith Fork	Bear R. Honey-ville
NaOH P, µg/L					
no γ treatment:filtered			<5	<5	
no γ treatment:whole	<5	<5	<5	<5	<5
γ treated: whole	<5	<5	<5	<5	<5
Total P, µg/L					
no γ treatment:whole	16	34	18	15	43
γ treated: whole	24	33	15	12	42

* ng = no growth
** some growth occurred in the NP30 treatment

Table 8. Microtox data for Bear River bioassay samples, May-December, 1986. Results are expressed in Microtox units of light reduction.

Collection date and site	No γ treatment filtered	No γ treatment whole	γ treated filtered	γ treated whole	γ treated + peroxidase 450 units/L	γ treated + peroxidase 150 units/L
12 May 1986						
Little Bear R.	2*		24.5*			
Blacksmith Fork R.	0*		31.0*			
Bear R. Honeyville	3*		22.9*			
23 June 1986						
Little Bear R.		0	5.4			
Blacksmith Fork R.		0	18.7			
1 Nov. 1986						
Bear R. ab. Oneida				12.8		
Bear R. UT-ID				6.7		
Little Bear R.				11.8		
Blacksmith Fork R.				17.8	0	
Bear R. Honeyville				13.9		
1 Dec. 1986						
Bear R. ab. Oneida						4.1
Bear R. UT-ID						12.6
Little Bear R.						13.5
Blacksmith Fork R.						13.8
Bear R. Honeyville						12.7

*Microtox tests were performed on 50 percent sample dilutions (1:1). All others were performed on undiluted samples.

sample in August (Table 7). Microtox tests performed on the 23 June Little Bear and Blacksmith Fork samples indicated toxicity in both samples (Table 8).

Apparently, sparging samples with N_2 did not consistently remove sufficient oxygen from solution to prevent hydrogen peroxide formation.

Unfortunately, samples used for phosphorus analyses in samples collected for bioavailability assays in April through August were contaminated with phosphate from membrane filters used in sample preparation and all results are unreliable. It is, therefore, not possible to evaluate what fraction of the total phosphorus in the samples was available to algae. Complete sets of phosphorus data are available for samples collected in September through December. Post irradiation toxicity prevented obtaining bioavailable phosphorus estimates for most of these samples however. In September, bioavailable phosphorus at the Honeyville station was 31 μg/L. Orthophosphorus at this station was 20 μg/L before irradiation and 42 μg/L after irradiation (Table 7). One sample from the November set was selected for an experiment which investigated the use of the enzyme peroxidase to break down peroxide and possibly eliminate toxicity. The sample (Blacksmith Fork R.) was treated with 450 units of peroxidase per liter and allowed to stand at room temperature overnight in the dark. Microtox results changed from 17.8 units to 0 after the enzyme treatment indicating the removal of toxicity in this sample (Table 7). Samples collected on 1 December were treated with 150 units of peroxidase per liter and allowed to stand overnight. Microtox tests indicated that the samples were still toxic (Table 8). Additional peroxidase was added to bring the enzyme concentration up to 450 units activity/L before the algal bioassay was set up, but some toxicity evidently persisted in most (perhaps all) of these samples. A bioavailable phosphorus estimate was obtained at only one site, the Bear R. above Oneida Reservoir (Table 7). Orthophosphorus at this site was $<$ 5 μg/L before radiation treatment and 13 μg/L after treatment. Peroxidase addition did not affect the orthophosphorus concentration (Table 7).

The effects of different concentrations of peroxidase and reaction times on the toxicity of irradiated samples were evaluated in an experiment conducted in mid-December. Water was collected from the Bear R. near Honeyville. One gallon was sparged with nitrogen for 1 hr. A second sample was not sparged. Both samples were irradiated and returned to the laboratory where they were sub-sampled and treated with peroxidase concentrations of 160, 500, 1000, and 2000 units/L. Microtox tests were performed after 2 hr had elapsed and again after 16 hr. The 2000 unit/L treatment reduced toxicity to 1 Microtox unit in the N_2-sparged sample and to 6 in the non-sparged sample after a 16-hr reaction period. Relatively high toxicity levels remained in all other treatments (Table 9). No algal bioassay was set up for this sample. Future bioavailable P research will probably utilize a 2000 unit/L peroxidase treatment for more than 16 h following radiation sterilization of the water samples.

Table 9. Microtox results for a Bear River (Honeyville) water sample 16 December, and treated with gamma radiation followed by peroxidase additions.

Time		Not sparged with N_2 Peroxidase activity (units/L) 0	160	500	1000	2000	Sparged with N_2 Peroxidase activity (units/L) 0	160	500	1000	2000	Microtox Positive Control
4:50 pm	a	21.8					20.7					
	b	20.3					21.0					
	c	20.8					17.7					
	mean	21.0					19.8					
6:45 am	a	29.0	31.0	27.0	30.0	26.0	21.7	21.7	21.4	18.8	18.9	54.7
	b	28.0	27.1	29.0	24.0	26.0	28.7	26.8	25.9	18.7	14.5	68.1
	c	27.1	31.1	32.1	30.1	30.0	26.8	27.7	24.8	23.9	17.6	
	mean	28.0	29.7	29.4	28.0	27.3	25.7	25.4	24.0	20.5	27.0	
	SD	0.95	2.28	2.57	3.49	2.31	3.62	3.23	2.34	2.97	2.26	
8:55 am	a	28.4	30.4	30.4	26.5	5.5	24.6	28.5	17.5	17.6	3.5	78.8
	b	27.4	32.4	28.2	21.4	7.4	29.1	30.1	22.0	7.5	0.52	83.3
	c	27.6	28.4	30.2	22.4	4.7	34.9	32.0	26.0	9.1	-1.0	
	mean	27.8	30.4	29.6	23.4	5.87	29.5	30.2	21.8	11.4	1.34	
	SD	0.53	2.00	1.22	1.39	5.16	1.75	4.25	5.43	1.89		

PART II

THE IMPACTS ON WILLARD RESERVOIR OF EXCHANGING BEAR RIVER WATER FOR WEBER RIVER WATER

Diversion of Bear River Water in Willard Reservoir

A possible method of gaining cost effective beneficial use of Bear River water diverted from the proposed Honeyville Reservoir, or from the river without impoundment, is to use it to replace Weber River water currently diverted through Willard Reservoir. This would make Weber River water available for other uses, and this water could be diverted south to the metropolitan Salt Lake City area. The possibility of capturing high quality Weber River water higher in the watershed for this purpose makes this alternative attractive. The effects of implementing this alternative on the quality of Willard Reservoir water was evaluated as part of the planning process.

Existing Water Quality of Willard Reservoir

Sampling

Understanding the existing limnology and water quality of Willard Reservoir was necessary to make reasonably accurate predictions of how the water quality might change with the introduction of Bear River water. Field measurements and surface water samples were collected from Willard Reservoir at the locations shown in Figure 18 between March 13 and October 23, 1987.

Field measurements of depth, temperature, electrical conductivity, dissolved oxygen, pH, and oxidation/reduction potential (ORP) were made with a Hydrolab Model 8000 at 1 m intervals through the water column. Light extinction (E) was measured with a photometer and a millivolt meter. Water samples were collected by hand at a depth of 6 to 10 inches below the surface. Samples were stored on ice and transported to the laboratory within 10 hours of collection, and were stored at 5 C until analyses were complete. Samples were filtered for chlorophyll a analysis within 24 hours of collection, and filters were stored frozen at -20 C until they were extracted. All nutrient analyses were completed within 7 days of sample collection.

Analytical procedures

Analyses for total and orthophosphorus were conducted as described in Part I above. NO_3+NO_2-N was determined by the automated cadmium reduction procedure, and NH_4-N was determined using the manual phenate technique (APHA 1985).

Chlorophyll a was determined in absolute methanol or 90 percent acetone extracts of the algae trapped on a glass fiber filter (Whatman GF/C) through which approximately 250 mL of sample had been passed. The filter was extracted in 20 mL of solvent. Analysis was done by HPLC on tandem 3 cm long, 4 mm ID (Perkin-Elmer 3X3), C-18 columns. The elution solvent system began with 100

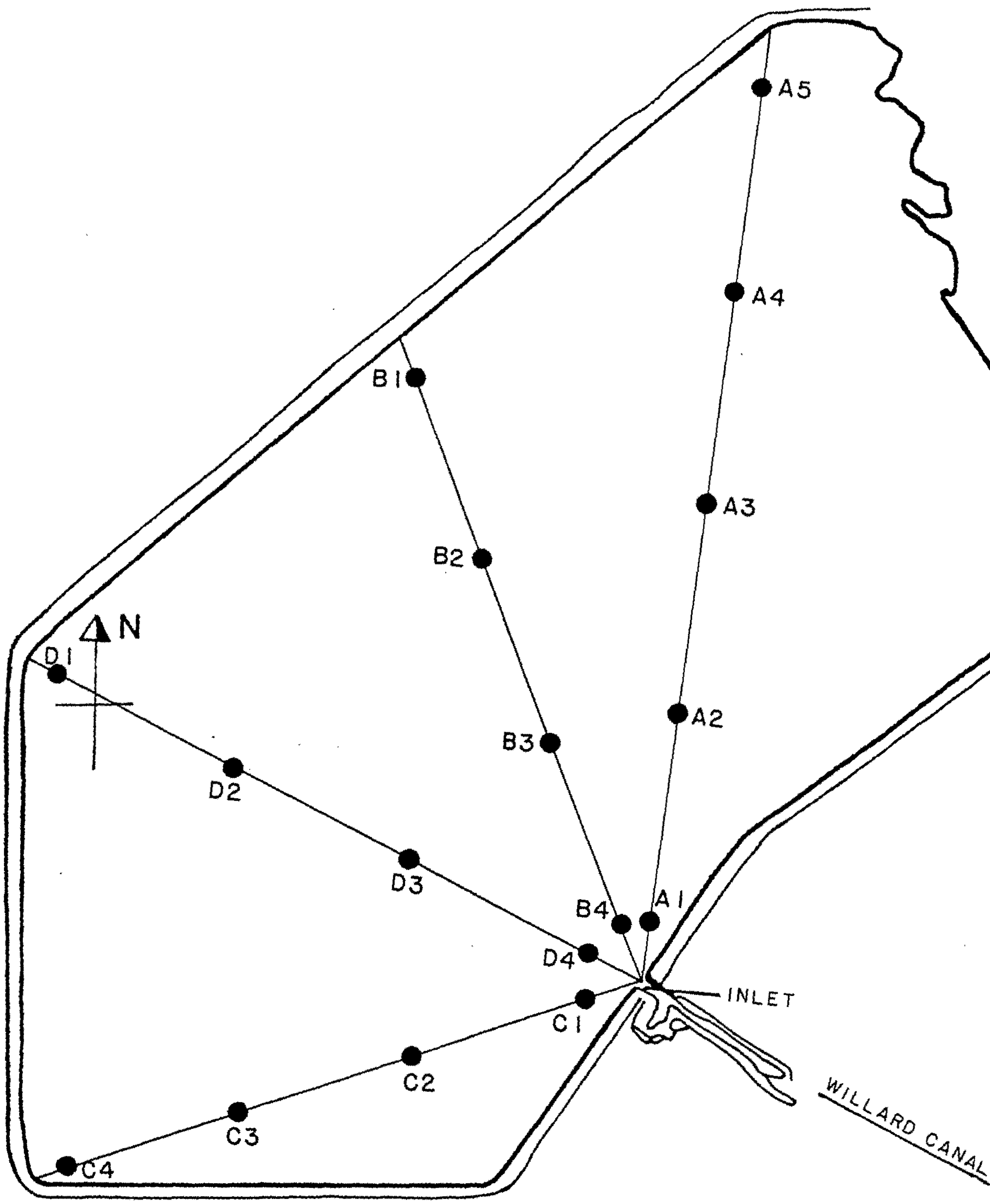


Figure 18. Map of sampling locations on Willard Reservoir.

percent methanol with a 5 minute gradient to a 75:25 methanol:acetone mixture which was maintained for 5 minutes. The solvent was pumped at 1 mL/minute. The detector was a Turner Model 112 fluorometer with output to an integrator.

Results and discussion

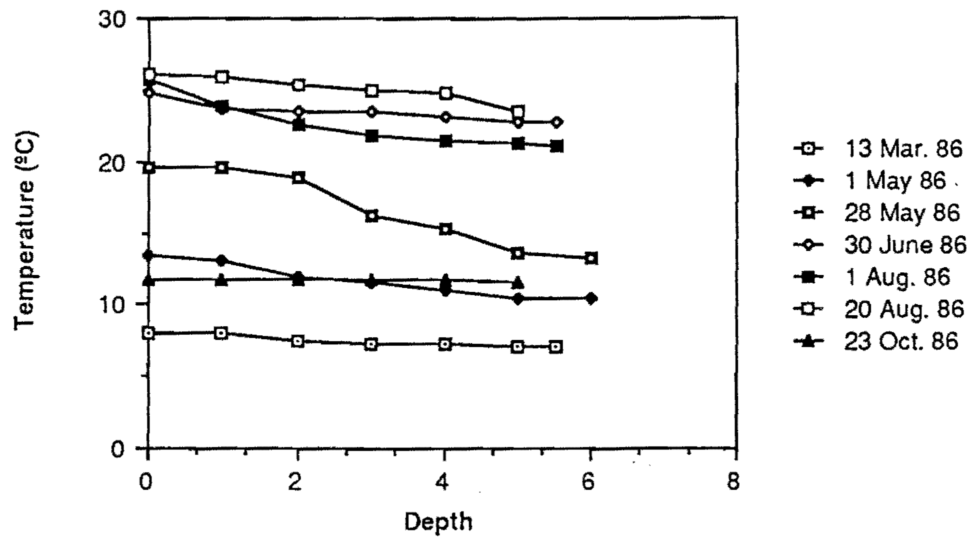
Field measurement data are tabulated in Appendix C. The reservoirs maximum depth was approximately 7 m. At this depth thermal stratification of the water column would not be expected, and was not observed except possibly on May 28 (Figure 19). Despite the general lack of a thermally induced density stratification of the reservoir, considerable oxygen depletion was observed through the water column on May 28, August 1, and August 20. On August 20 the water near the bottom contained only 50 percent of its saturation concentration (Figure 19). On August 1 the surface oxygen concentration was approximately 125 percent of saturation while near the bottom, the oxygen concentration had been depleted to only 60 percent of saturation. Figure 19 presents only data for site B3, but conditions were similar at most sampling locations in the reservoir (Appendix C). The oxygen demand of the organic material in the sediments of the reservoir is probably responsible for this oxygen depletion. These data reflect the highly eutrophic condition of Willard Reservoir brought on by high production of algae.

Salinity (TDS), nutrient, selected light extinction coefficient, and chlorophyll a data for each of the sampling dates are shown in Tables 10 through 16. It is noteworthy that the chlorophyll a concentration in the surface water at site B3 on August 1, when the surface water was super saturated with oxygen and the water near the bottom was only 60 percent of saturation, was only 9 ug/L (Table 14). Total dissolved solids (TDS, salinity) concentrations were, generally, uniform in surface water samples. No evidence of vertical or horizontal differences in salinity were indicated by conductivity data (Appendix C).

The high chlorophyll a concentrations in most of the samples on March 13 through June 30 also reflect the highly eutrophic condition of Willard Reservoir. Chlorophyll a concentrations in the reservoir samples ranged from greater than 66 ug/L at site C1 on March 13 to less than 2 ug/L at three sites on August 20. Most limnologists consider chlorophyll a concentrations higher than 10 ug/L to reflect eutrophic conditions (USEPA, 1979). The potential for improving or contributing to more intense eutrophication of this reservoir by replacing Weber River water with Bear River water seems an important consideration.

Trophic State Analysis

Empirical chlorophyll concentration models were chosen to analyze changes in the trophic state of Willard Reservoir. The models are described in detail in Sorensen, (1986). The decision to utilize the empirical models is based on modeling results given in Sorensen et al. (1986) and chlorophyll sampling of Willard Bay Reservoir presented above. In the previous modeling work on existing and proposed reservoirs in the Bear River Basin, the empirical models satisfactorily predicted trophic status when algal growth was limited by nutrient concentrations. The empirical models did not adequately predict



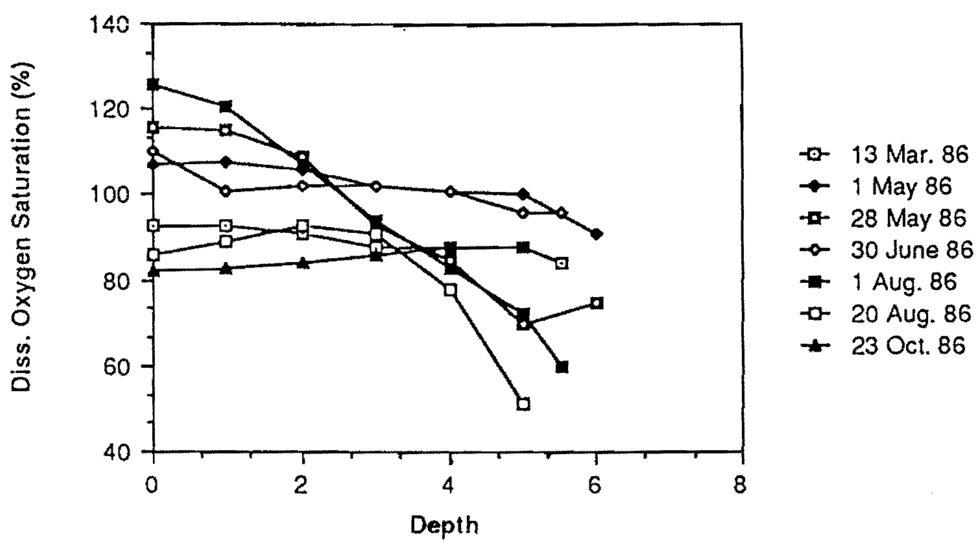


Figure 19. Temperature and dissolved oxygen profiles for sampling site B3 in Willard Reservoir.

Table 10. Willard Reservoir surface water quality, 13 March, 1986.

Site	PO_4-P (µg/L)	Total P (µg/L)	NO_3 + NO_2-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll a (µg/L)
B2	6	70	0.05			21
B3	5	27	0.04		-.161	37
B4	10	33	0.10			67
Inlet	38	83	0.38			24
C1	10	25	0.12			>66
C2	7	33	<.04			
D1	5	30	0.07			47
D2	6	33	0.07			22
D3	7	33	0.06			62
D4	8	42	0.10			83
Canal	38	88	0.39			18

Table 11. Willard Reservoir surface water quality, 1 May, 1986.

Site	PO_4-P (µg/L)	Total P (µg/L)	NO_3 + NO_2-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll a (µg/L)
Inlet	47	214	0.26	<5		47
A1	37	88	0.29	9		27
A2	34	88	0.16	<5		>40
A3	30	84	0.21	<5	-.328	21
A4	35	81	0.14	13		36
B1	28	90	0.22	<5		38
B2	36	90	0.17	13		36
B3	39	96	0.14	<5	-.320	>40
B4	38	88	0.27	9		29
C1	37	84	0.19	54		33
C2	42	110	0.23	22		36
C3	32	98	0.20	132		25
C4	38	81	0.22	9		29
D1	36	84	0.29	18		9
D2	40	90	0.22	136		2
D3	40	94	0.14	18		23
D4	32	90	0.22	9		8
Willow Cr	20	58	0.37	<5		

Table 12. Willard Reservoir water quality data, 28 May,1986.

Site	TDS (mg/L)	PO_4-P (µg/L)	Total P (µg/L)	$NO_3 + NO_2$-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll *a* (µg/L)
Inlet	138	52	150	0.15	31		37
A1	193	39	70	0.14	25		16
A2	255	42	63	0.13	10		29
A3	219	35	74	0.11	18		38
A4	218	36	70	0.12	23		38
A5	170	36	63	0.07	17		>40
B1	301	35	60	0.10	17		28
B2	96	35	41	0.13	18		
B3	278	37	60	0.12	13	-.114	31
B4	254	32	84	0.13	18		24
C1	300	36	74	0.13	18		18
C2	265	30	74	0.09	22		
C3	220	28	65	0.08	24		
C4	257	33	72	0.10	20		12
D1	124	37	65	0.11	18		
D2	135	38	60	0.09	20		24
D3	279	32	77	0.11	29		10
D4	292	30	53	0.05	23		>40
Canal	137	59	290	0.24	23		25

Table 13. Willard Reservoir surface water quality, 30 June, 1986.

Site	TDS (mg/L)	PO_4-P (µg/L)	Total P (µg/L)	$NO_3 + NO_2$-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll *a* (µg/L)
Inlet	292	24	83	0.06	40		33
A1	292	20	63	0.05	32		23
A2	265	16	50	0.06	20		29
A3	287	11	45	0.04	24		23
A4	267	9	49	0.06	28		40
B1	290	18	52	0.05	28		25
B2	292	16	50	0.06	20		19
B3	277	16	59	0.05	24	-.204	21
B4	246	16	52	0.14	28		33
C1	248	18	61	0.06	25		31
C2	262	23	52	0.04	28		36
C3	269	15	44	0.05	21		
D1	252	17	52	0.13	24		17
D2	261	16	50	0.05	16		25
D3	296	16	55	0.03	24		27
D4	232	16	55	0.05	44		
Canal	160	17	63	0.29	20		>40

Table 14. Willard Reservoir surface water quality, 1 August, 1986.

Site	PO_4-P (µg/L)	Total P (µg/L)	$NO_3 + NO_2$-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll a (µg/L)
Inlet	18	62	0.02	<5		7
A2	15	57	0.01	6		5
A4	37	43	0.01	<5		7
B3	12	35	0.01	<5		9
B4	18	41	0.01	<5	-.167	11
C3	15	38	0.02	<5		6
Canal	6	45	0.01	9		

Table 15. Willard Reservoir surface water quality, 20 August, 1986.

Site	TDS (mg/L)	PO_4-P (µg/L)	Total P (µg/L)	$NO_3 + NO_2$-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll a (µg/L)
Inlet	284	12	23	0.02	11		12
A1	328	6	17	0.02	<5		8
A2	302	9	20	0.02	6		10
A3	356	17	25	0.05	31		3
B1	300	27	36	0.05	33		<2
B2	310	8	18	0.03	<5	-.141	<2
B3	256	6	17	0.03	<5		8
C1	350	6	16	0.01	<5		<2
C2	276	8	18	0.03	<5		5
D1	286	16	24	0.03	19		8
D2	318	7	18	0.05	<5		2
D3	308	6	17	0.01	<5		
Canal	234	<5	10	0.01	<5		3

Table 16. Willard Reservoir surface water quality, 23 October, 1986.

Site	TDS (mg/L)	PO_4-P (µg/L)	Total P (µg/L)	$NO_3 + NO_2$-N (mg/L)	NH_3-N (µg/L)	E (m^{-1})	Chlorophyll a (µg/L)
A2	370	43	64		31		
B2	230	43	47		66		
B3	440	42	44		17	-.346	

trophic state when other factors such as temperature, light limitation and depth of mixing limited algal growth. These limitations exist in Cutler Reservoir and Oneida Reservoir resulting in a lower trophic state than predicted by the empirical models.

Favorable algal growth conditions exist in Willard Bay Reservoir. Algal growth is not presently limited by lack of light or depth of mixing. Light could become limiting by self shading at high algal concentrations, but this does not currently prevent eutrophic conditions. Willard Bay Reservoir is shallow, with an average depth of less than 20 feet and is completely mixed, so depth of mixing does not limit algae growth.

Nutrient limitation

From the existing data for Willard Bay Reservoir it is not possible to state that phosphorus is the limiting nutrient. It is possible that other nutrients such as nitrogen or trace nutrients actually limit chlorophyll a production. However, species composition in Willard indicates phosphorus is in greater supply relative to nitrogen. The algal blooms are composed primarily of blue-green algae indicating sufficient nitrogen was not present in the water column for the algae to utilize all the available phosphorus. The blue-green algae can use atmospheric nitrogen and are thus not limited by dissolved nitrogen compounds.

Empirical trophic state models

The empirical trophic state models were applied to Willard Bay Reservoir for 11 different conditions as shown in Table 17.

Existing conditions, where Weber River water is used to fill Willard Bay Reservoir, are given in column 1. An inflow of 155 ac-ft is used to calculate the phosphorus loads. A moderate inflow of 155 ac-ft is slightly larger than the 1974-1983 average of 127 ac-ft. The residence time is calculated on a flow of 155 ac-ft minus evaporation of 33 ac-ft. The monthly distribution of inflow is based on actual inflows used in 1979 when 155 ac-ft was allowed into Willard Bay Reservoir. Phosphorus concentrations and inflows are given in Table 17. The analysis of phosphorus loading from Weber River input is limited to orthophosphorus as only PO_4-P data were provided by the Weber River Basin Water District. Using PO_4-P alone will result in an underestimate of the chlorophyll a concentrations, since a portion of the total phosphorus which is not PO_4-P will also be available to algae. Table 17 Column 1 shows that even with only PO_4-P an average chlorophyll a concentration of 9.9 µg/L and a peak of 16.8 µg/L would be predicted for Willard Bay Reservoir. This concentration is considered to be at the low end of eutrophic conditions. Additional sampling of Weber River water is needed to determine the relationship between total phosphorus and PO_4-P. Chlorophyll a concentrations in excess of 50 µg/L indicate that using PO_4-P concentrations alone would underestimate the trophic status of Willard Bay Reservoir. The underestimate could be because: (1) part of the non PO_4-P total phosphorus is biologically available, and (2) the unique shape and hydrologic operating conditions of Willard Bay Reservoir traps phosphorus making it available for recycle from the sediments.

When average PO_4-P concentrations from the Bear River are used to

Table 17. Summary of results of phosphorus models.

	WR[1] Avg PO_4	BR[2] Avg PO_4	BR, % of Total Phosphorus[3,4]				% of BR inflow		BR, % of Avg. PO_4, 77-83[3,5]		
	84-85	77-83	85	90	80	50	200	50	90	80	50
Approximate Surface Area (ft2)	4E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08	4.3E+08
Approximate Volume (ft3)	7E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09	7.2E+09
Average Depth (ft)	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70
Flow (ft3*y-1)	5E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09	5.3E+09
Hydraulic Residence Time (years)	1.36	1.36	1.36	1.36	1.36	1.36	0.60	3.74	1.36	1.36	1.36
Surface Hydraulic Loading (qs Ft*y-1)	12.31	12.31	12.31	12.31	12.31	12.31	28.02	4.46	12.31	12.31	12.31
Phosphorus Loading (mg)*m-2*y-1)	372.55	257.53	962.62	866.36	770.09	481.31	1925.24	481.31	231.78	206.03	123.77
Average P (mg*m3) (Vollenweider 1975)	27.09	18.72	69.99	62.99	55.99	34.99	103.83	42.37	16.85	14.98	9.36
Average P (mg*m3) (Vollenweider 1976)	45.85	31.69	118.46	106.61	94.77	59.23	127.18	120.59	28.52	25.35	15.85
Average P (mg*m3) (Larson and Mercier 1976)	42.12	29.12	108.83	97.95	87.06	54.41	141.21	74.61	26.20	23.29	14.56
Average P (mg*m3) (Jones and Bachman 1976)	44.30	30.36	114.48	103.03	91.58	57.24	136.45	86.59	27.56	24.50	15.31
Average P (mg*m3) (Kirchner and Dillion 1975)	28.98	20.04	74.89	67.40	59.91	37.45	96.60	49.08	18.03	16.03	10.02
Average P (mg*m3) (Mueller 1982)	26.87	18.58	69.43	62.49	55.55	34.72	95.55	48.70	16.72	14.86	9.29
Jones and Lee (1982)											
Average P (mg*m3)	45.85	31.69	118.46	106.61	94.77	59.23	127.18	120.59	28.52	25.35	15.85
Mean Summer Chlorophyll a (mg*m-3)	9.92	7.38	21.23	19.51	17.75	12.18	22.47	21.53	6.79	6.18	4.24
Mean Summer Secchis Depth (m)	0.50	0.43	0.78	0.74	0.70	0.57	0.81	0.79	0.40	0.38	0.31
Hypolimnetic Oxygen Depletion Rate (g O2*m-2*d-1)	0.50	0.43	0.78	0.74	0.70	0.57	0.81	0.79	0.40	0.38	0.31

[1]WR = Weber River
[2]BR = Bear River
[3]Concentrations given in Sorensen (1986)
[4]Assumes 100% of total P is available
[5]Assumes only ortho P is available

calculate the phosphorus loading, a slightly lower chlorophyll a concentration of 7.38 mg/L is predicted (Table 17). This would seem to indicate a slight improvement over present conditions, changing from eutrophic to mesotrophic-eutrophic.

Column 3 (Table 17) shows that if 85 percent of the total phosphorus in Bear River water is assumed to be available for algae, then the models predict an average chlorophyll a concentration of 21.23 mg/L and a peak of 36 mg/L. Apparently substituting Bear River water for Weber River water will have no noticeable impact on the trophic status of Willard Bay Reservoir. Eutrophic conditions are expected with both Weber River water and Bear River water.

Impact of management options on trophic status of Willard Bay Reservoir

The empirical trophic models were used to analyze the impact of using Bear River water under different flow patterns and with reduced phosphorus loads (Table 17). Reducing total phosphorus Bear River concentration by 50 percent would still result in eutrophic conditions in Willard Bay Reservoir. However, average chlorophyll a concentrations would be reduced from 21.23 mg/L to 12.18 mg/L.

If only PO_4-P is available to the algae then reducing PO_4-P by 20 percent would result in mesotrophic conditions. Varying flow by 200 percent and 50 percent would not change the trophic conditions of Willard Bay Reservoir (Table 17).

Until the relationship between total phosphorus and bioavailable phosphorus is determined it is impossible to predict the trophic status for a given phosphorus reduction. Additional studies would be needed to determine the rate of phosphorus release from Willard Bay Reservoir sediments and phosphorus trapping efficiency.

Salinity Changes Due to Substituting Bear River for Weber River Water

Substituting Bear River water for Weber River water will not increase salinity to levels where the water is unfit for human consumption, recreation, and agricultural purposes.

To determine the change in salinity the same mass balance technique used by the Bureau of Reclamation (personal communication 1986) is used. The Bureau of Reclamation prepared a spreadsheet which calculates a mass balance on the water and salt entering Willard Bay Reservoir. In order for the calculated concentration to agree with observed concentrations it was necessary to add 4500 tons of salt per month to the reservoir. For calculating the impact of Bear River water the only thing changed in the spreadsheet was the Willard Canal TDS concentration. The Weber River TDS concentration was replaced with Bear River TDS concentrations reported in Sorensen et al. (1986).

Figure 20 illustrates measured and predicted TDS in Willard Bay Reservoir. Without adding additional salt the measured TDS is from 250 to 600 mg/L

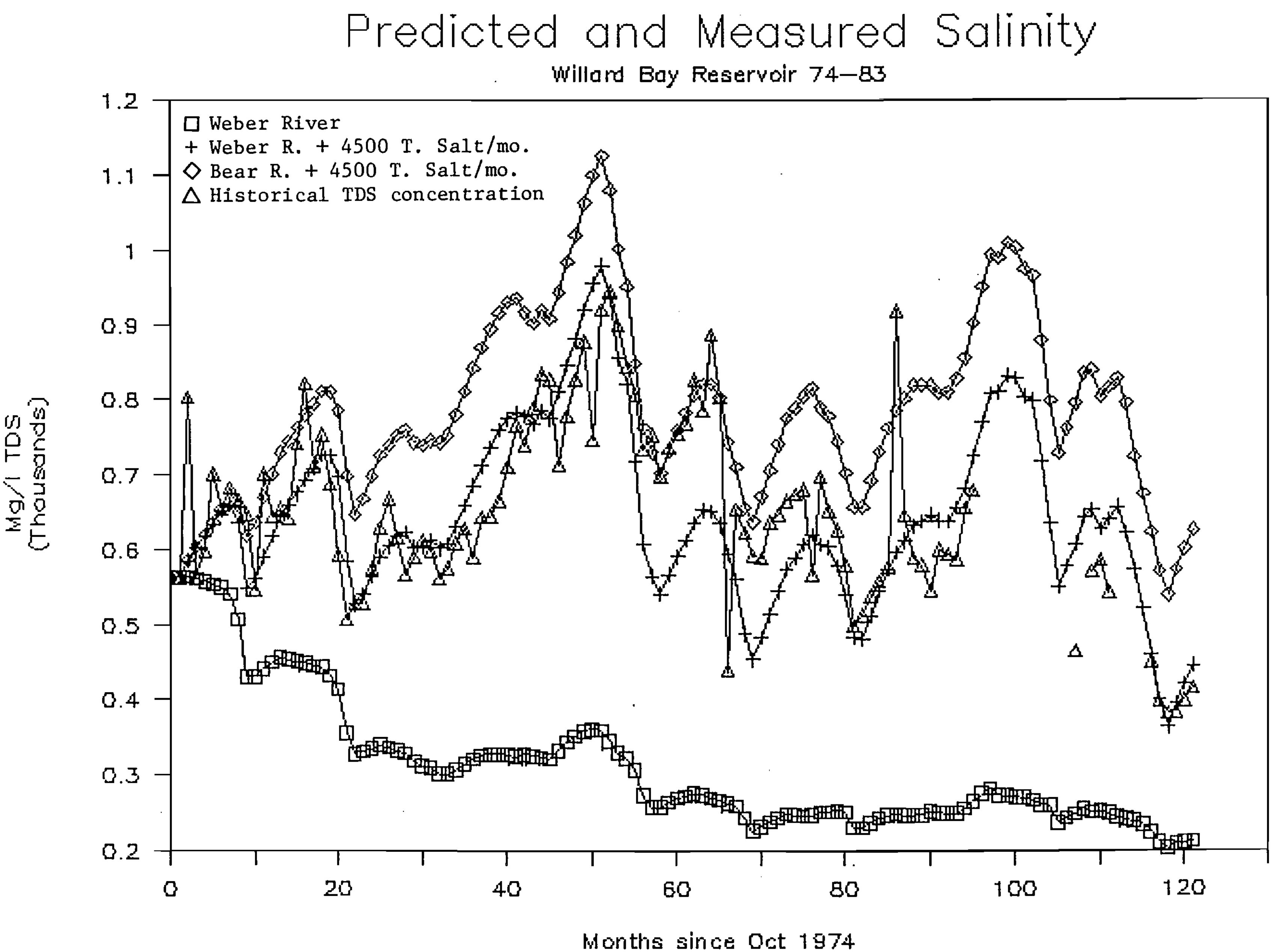


Figure 20. Predicted and measured salinity in Willard Rservoir, 1974-1983.

greater than the predicted (bottom line on Figure 20). This shortage cannot be accounted for by increasing evaporation rates by four times. When 4500 tons of salt are added each month the predicted and measured TDS concentrations are always close. Where this additional salt is coming from is not known. It is not unreasonable to assume saline seeps enter from the bottom of the reservoir. Calculations indicate a minimum flow of only 1.4 cfs would be needed to supply the salt if the TDS concentration of the seep was 19,802 mg/L which was the average TDS concentration of nearby Utah Hot Springs on May 28, 1986. A flow of 1.4 cfs would not be detected in reservoir elevation changes.

Flow and concentrations measured in 1986 are used to check the need for adding 4500 tons/month. These calculations are summarized in Figure 21. This graph illustrates that even over a 7 month period, calculated concentrations based on just inflow concentration would diverge from measured concentrations. By October predicted concentrations (without the additional 4500 tons) are 150 mg/L less than the measured while the difference between predicted with the added 4500 tons/month and the measured is less than 15 mg/L.

Substituting Bear River water for Weber River water resulted in an approximate 100-200 mg/L increase in the end of month calculated TDS concentration. The maximum calculated TDS increased from 935 mg/L with Weber River water to 1125 mg/L with Bear River water.

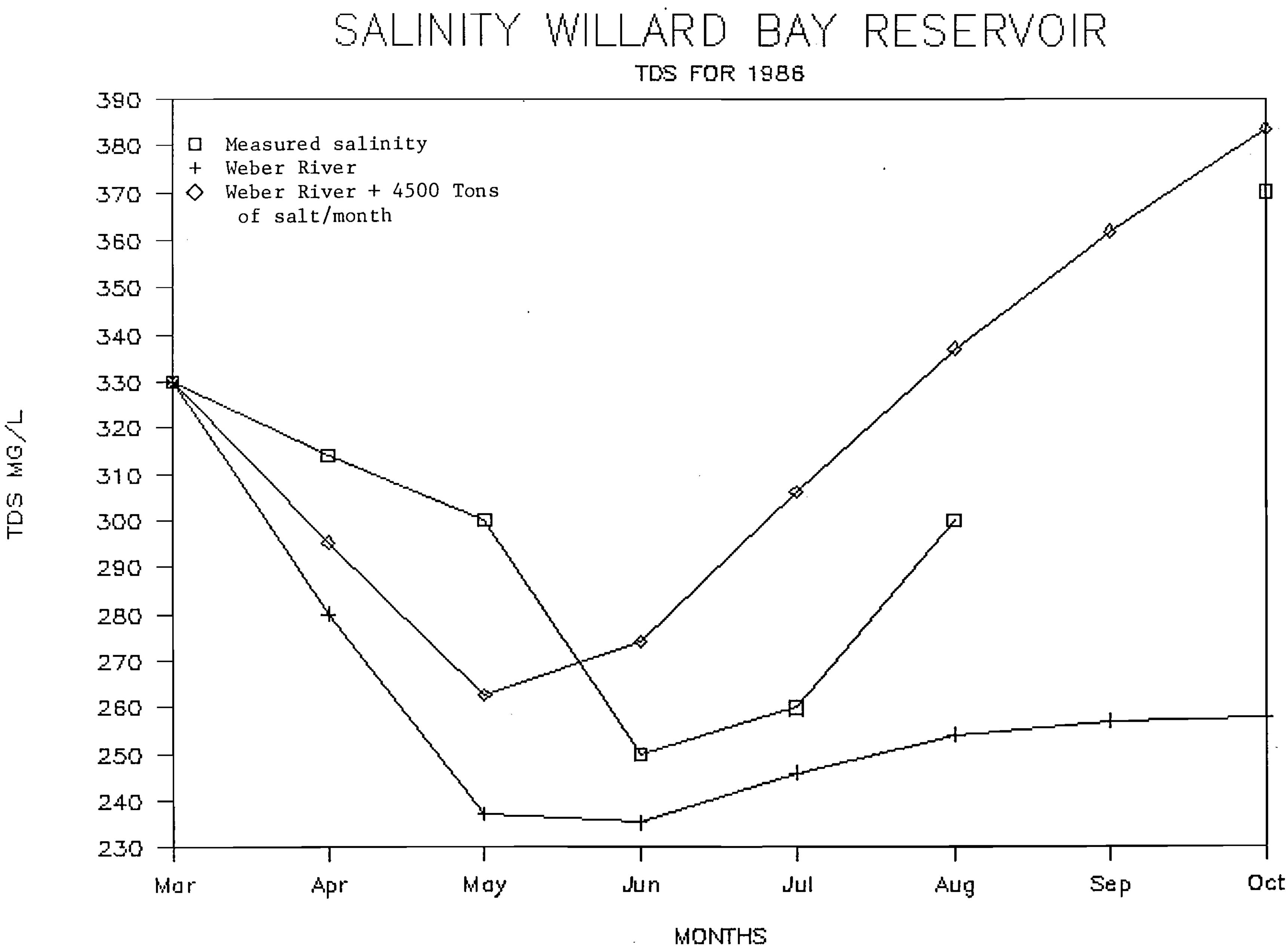


Figure 21. Measured vs. predicted Willard Bay Reservoir salinity with and without salt addition.

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APPENDIX A

FIELD MEASUREMENTS AND PHOSPHORUS DATA FOR

BEAR RIVER SAMPLES COLLECTED

IN 1986

Table A1. Field measurements and phosphorus data for Bear River samples. February, 1986.

Stream	Sample Location	Field Measurements: Flow ft³/s	Field Measurements: Temp °C	Field Measurements: Cond.(25) µ mhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport: Total Phos. mg/s	Phos. Transport: Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89							
	West of Georgetown at Bridge							
	Above Soda Point Reservoir		1.00	519.38	210.00	39.00		
	At Grace Dam				58.00	29.00		
	Above Alder Creek at Bridge							
	Cottonwood Cr. near Cleveland, ID at I-34				385.00	126.00		
	Above Oneida Reservoir		3.00	583.48	176.00	141.00		
	Below Oneida Reservoir at I-36	2670.00	3.00	528.78	176.00	141.00	13308.13	10661.63
	Mink Cr. near Bear R. Confluence							
	Above Battle Cr. at US-91	3923.00	3.00	455.85	301.00	180.00	33440.91	19997.88
	Battle Cr. near Bear R. Confluence		2.50	498.94	1221.00	209.00		
	Deep Cr. near Bear R. Confluence		3.00	619.95	1575.00	156.00		
	Five-mile Cr. near Bear R. Confluence		5.00	518.51				
	Weston Cr. near Bear R. Confluence		3.50	629.70	1323.00	122.00		
	West of Fairview, ID at USGS Gauge	4600.00	3.00	583.48	682.00	285.00	88845.50	37127.52
	West of Richmond, UT		3.00	557.96				
	Below Cub R.				614.00	261.00		
	Above Cutler Reservoir, West of Benson		2.00	486.94	65.00	214.00		
	Below Cutler Reservoir near Collinston		4.00	461.56	648.00	224.00		
	West of Deweyville at Bridge		2.50	461.98	977.00	234.00		
	West of Honeyville		3.50	449.79	644.00	226.00		
Cub R.	North of Franklin, ID at Bridge							
	West of Franklin, ID at Bridge							
	Worm Cr. West of Franklin, ID							
	High Cr. at US-89/91							
	North of Richmond at Bridge							
	South of Richmond at Bridge		2.50	295.67				
Logan R.	Below Logan Lagoon Effluent							
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek		3.50	161.92				
	Davenport Cr.		3.00	237.04	156.00	57.00		
	Below Hyrum Reservoir							
	Above Logan R. Confluence							
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence	9.20	2.00	599.30	68.00	39.00	17.72	10.16
	Sheep Cr. near Blacksmith Fork Confluence	14.40	3.00	765.82	24.00	12.00	9.79	4.89
	Blacksmith Fork above Sheep Cr.							
	Blacksmith Fork at Anderson Ranch	323.00	6.00	488.00	34.00	14.00	311.01	128.06

Table A2. Field measurements and phosphorus data for Bear River samples. April, 1986.

Stream	Sample Location	Field Measurements: Flow ft^3/s	Field Measurements: Temp C	Field Measurements: Cond.(25) µ mhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport: Total Phos. mg/s	Phos. Transport: Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89	1130.00	9.00	152.58	130.00	21.00	4160.21	672.03
	West of Georgetown at Bridge		9.20	158.56	92.00	18.00		
	Above Soda Point Reservoir		8.50	147.71	150.00	27.00		
	At Grace Dam		9.00	161.69	95.00	20.00		
	Above Alder Creek at Bridge		9.20	163.09	110.00	23.00		
	Cottonwood Cr. near Cleveland, ID at I-34		6.50	68.18	66.00	25.00		
	Above Oneida Reservoir		10.00	172.94	160.00	21.00		
	Below Oneida Reservoir at I-36	2910.00	10.00	170.72	95.00	22.00	7829.06	1813.05
	Mink Cr. near Bear R. Confluence		11.00	84.19	130.00	38.00		
	Above Battle Cr. at US-91	3202.00	11.50	155.49	97.00	22.00	8796.02	1994.97
	Battle Cr. near Bear R. Confluence		12.00	399.31	1080.00	70.00		
	Deep Cr. near Bear R. Confluence		10.20	330.80	590.00	46.00		
	Five-mile Cr. near Bear R. Confluence		14.00	239.06	460.00	62.00		
	Weston Cr. near Bear R. Confluence		14.50	334.16	120.00	37.00		
	West of Fairview, ID at USGS Gauge	3502.00	10.50	175.02	180.00	24.00	17851.80	2380.24
	West of Richmond, UT		12.00	176.54	120.00	23.00		
	Below Cub R				170.00	44.00		
	Above Cutler Reservoir, West of Benson		12.00	172.34	140.00	20.00		
	Below Cutler Reservoir near Collinston	6530.00	11.00	159.74	160.00	30.00	29588.74	5547.89
	West of Deweyville at Bridge		11.00	159.74	246.00	41.00		
	West of Honeyville		11.50	157.62	160.00	40.00		
Cub R.	North of Franklin, ID at Bridge		12.00	88.27	70.00	24.00		
	West of Franklin, ID at Bridge		12.00	86.17	87.00	35.00		
	Worm Cr. West of Franklin, ID		13.50	262.47	490.00	420.00		
	High Cr. at US-89/91		11.00	75.55	37.00	19.00		
	North of Richmond at Bridge		11.00	105.77	190.00	75.00		
	South of Richmond at Bridge		9.50	112.35	196.00	79.00		
Logan R.	Below Logan Lagoon Effluent							
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek		6.00	71.56	66.00	45.00		
	Davenport Cr.		7.00	81.68	86.00	45.00		
	Below Hyrum Reservoir				130.00	32.00		
	Above Logan R. Confluence		9.00	111.59	110.00	33.00		
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence		6.00	101.17	78.00	27.00		
	Sheep Cr. near Blacksmith Fork Confluence		6.00	177.67	43.00	15.00		
	Blacksmith Fork above Sheep Cr.		8.00	339.16	37.00	12.00		
	Blacksmith Fork at Anderson Ranch		7.50	203.87	43.00	16.00		

Table A3. Field measurements and phosphorus data for Bear River samples, May, 1986.

Stream	Sample Location	Field Measurements Flow ft³/s	Temp C	Cond.(25) µmhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport Total Phos. mg/s	Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89	1740.00	10.50	150.95	67.00	35.00	3301.55	1724.69
	West of Georgetown at Bridge		10.00	152.99	66.00	42.00		
	Above Soda Point Reservoir		10.00	150.77	60.00	35.00		
	At Grace Dam		9.50	155.05	60.00	39.00		
	Above Alder Creek at Bridge		10.00	155.20	64.00	39.00		
	Cottonwood Cr. near Cleveland, ID at I-34		8.50	76.16	42.00	36.00		
	Above Oneida Reservoir		9.50	166.28	63.00	42.00		
	Below Oneida Reservoir at I-36	3640.00	9.50	161.79	62.00	38.00	6391.26	3917.22
	Mink Cr. near Bear R. Confluence		9.00	91.09	64.00	43.00		
	Above Battle Cr. at US-91	3923.00	9.50	161.79	72.00	40.00	7999.15	4443.97
	Battle Cr. near Bear R. Confluence		9.50	292.11	208.00	97.00		
	Deep Cr. near Bear R. Confluence		12.00	325.76				
	Five-mile Cr. near Bear R. Confluence		12.00	193.35	129.00	65.00		
	Weston Cr. near Bear R. Confluence		12.50	331.79	173.00	51.00		
	West of Fairview, ID at USGS Gauge	4012.00	10.00	164.07	83.00	52.00	9430.45	5908.23
	West of Richmond, UT		12.50	161.75	71.00	40.00		
	Below Cub R		13.20	156.71	73.00	42.00		
	Above Cutler Reservoir, West of Benson		14.00	155.39	77.00	47.00		
	Below Cutler Reservoir near Collinston	7430.00	12.00	151.32	86.00	61.00	18095.91	12835.47
	West of Deweyville at Bridge		12.00	151.32	76.00	51.00		
	West of Honeyville		12.00	151.32				
Cub R.	North of Franklin, ID at Bridge		10.50	91.88	62.00	41.00		
	West of Franklin, ID at Bridge		10.50	87.51	48.00	43.00		
	Worm Cr. West of Franklin, ID		13.50	187.76	57.00	54.00		
	High Cr. at US-89/91		10.00	77.60	30.00	29.00		
	North of Richmond at Bridge		10.50	105.01	94.00	76.00		
	South of Richmond at Bridge		11.00	105.77	113.00	78.00		
Logan R.	Below Logan Lagoon Effluent							
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek		9.00	79.71	37.00	31.00		
	Davenport Cr.		8.00	98.24	46.00	31.00		
	Below Hyrum Reservoir		10.00	93.12	46.00	37.00		
	Above Logan R. Confluence		12.00	86.17	48.00	41.00		
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence		8.00	88.88	37.00	37.00		
	Sheep Cr. near Blacksmith Fork Confluence		6.50	116.87				
	Blacksmith Fork above Sheep Cr.							
	Blacksmith Fork at Anderson Ranch		8.00	119.29				

Table A4. Field measurements and phosphorus data for Bear River samples, June, 1986.

Stream	Sample Location	Field Measurements: Flow ft^3/s	Field Measurements: Temp °C	Field Measurements: Cond.(25) µmhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport: Total Phos. mg/s	Phos. Transport: Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89	2000.00	16.00	137.85	150.00	45.00	8496.00	2548.80
	West of Georgetown at Bridge		16.00	139.74	120.00	45.00		
	Above Soda Point Reservoir		15.00	135.77	130.00	48.00		
	At Grace Dam		17.00	132.37	160.00	59.00		
	Above Alder Creek at Bridge		17.00	139.72	150.00	56.00		
	Cottonwood Cr. near Cleveland, ID at I-34		12.00	79.86	51.00	42.00		
	Above Oneida Reservoir		17.50	141.50	180.00	60.00		
	Below Oneida Reservoir at I-36	3810.00	17.00	143.40	54.00	51.00	5826.56	5502.86
	Mink Cr. near Bear R. Confluence		11.00	79.87	86.00	49.00		
	Above Battle Cr. at US-91	3923.00	18.00	134.25	140.00	56.00	15553.91	6221.56
	Battle Cr. near Bear R. Confluence		20.00	441.14	544.00	136.00		
	Deep Cr. near Bear R. Confluence		19.00	278.83	266.00	68.00		
	Five-mile Cr. near Bear R. Confluence		20.00	254.50	397.00	99.00		
	Weston Cr. near Bear R. Confluence		21.00	363.41	190.00	56.00		
	West of Fairview, ID at USGS Gauge	4402.00	18.00	141.41	73.00	60.00	9100.52	7479.88
	West of Richmond, UT		19.00	142.90	110.00	68.00		
	Below Cub R		19.00	128.96	98.00	61.00		
	Above Cutler Reservoir, West of Benson		18.50	130.70	180.00	67.00		
	Below Cutler Reservoir near Collinston	7230.00	18.00	125.30	208.00	36.00	42588.75	7371.13
	West of Deweyville at Bridge		18.00	125.30	203.00	38.00		
	West of Honeyville		19.00	125.47	228.00	35.00		
Cub R.	North of Franklin, ID at Bridge		12.00	75.66	270.00	55.00		
	West of Franklin, ID at Bridge		13.00	77.75	292.00	48.00		
	Worm Cr. West of Franklin, ID							
	High Cr. at US-89/91		11.00	86.35				
	North of Richmond at Bridge		12.00	84.07	160.00	52.00		
	South of Richmond at Bridge		13.00	83.89	160.00	54.00		
Logan R.	Below Logan Lagoon Effluent							
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek		12.00	84.07				
	Davenport Cr.		9.00	72.87	56.00	17.00		
	Below Hyrum Reservoir		17.00	88.25	32.00	12.00		
	Above Logan R. Confluence		17.00	106.63	84.00	26.00		
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence		11.00	194.28	37.00	38.00		
	Sheep Cr. near Blacksmith Fork Confluence		8.00	219.87	32.00	14.00		
	Blacksmith Fork above Sheep Cr.		10.00	203.98	24.00	20.00		
	Blacksmith Fork at Anderson Ranch		9.00	214.07	15.00	16.00		

Table A5. Field measurements and phosphorus data for Bear River samples, August, 1986.

Stream	Sample Location	Field Measurements Flow ft^3/s	Temp °C	Cond.(25) µmhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport Total Phos. mg/s	Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89	1610.00	20.00	206.99	66.00	6.00	3009.28	273.57
	West of Georgetown at Bridge		20.00	203.60	41.00	5.00		
	Above Soda Point Reservoir		21.00	198.23	85.00	5.00		
	At Grace Dam		20.50	209.27	56.00	6.00		
	Above Alder Creek at Bridge		20.00	212.08	45.00	16.00		
	Cottonwood Cr. near Cleveland, ID at I-34		17.00	84.57	14.00	7.00		
	Above Oneida Reservoir		22.00	217.12	77.00	15.00		
	Below Oneida Reservoir at I-36	2650.00	20.50	227.68	52.00	14.00	3902.50	1050.67
	Mink Cr. near Bear R. Confluence		19.00	116.76	65.00	49.00		
	Above Battle Cr. at US-91	2595.00	22.00	218.73	37.00	13.00	2719.14	955.38
	Battle Cr. near Bear R. Confluence		22.00	611.14	525.00	78.00		
	Deep Cr. near Bear R. Confluence		22.00	418.15	123.00	44.00		
	Five-mile Cr. near Bear R. Confluence		21.50	264.05	133.00	62.00		
	Weston Cr. near Bear R. Confluence		21.50	286.87	54.00	12.00		
	West of Fairview, ID at USGS Gauge	1079.00	21.50	236.34	54.00	12.00	1650.09	366.69
	West of Richmond, UT		22.00	217.12	58.00	11.00		
	Below Cub R		17.00	261.06	124.00	13.00		
	Above Cutler Reservoir, West of Benson		24.50	225.63	124.00	12.00		
	Below Cutler Reservoir near Collinston	1390.00	20.00	254.50	122.00	11.00	4802.51	433.01
	West of Deweyville at Bridge		20.00	1272.51	123.00	6.00		
	West of Honeyville		20.00	254.50	169.00	12.00		
Cub R.	North of Franklin, ID at Bridge		24.00	118.91	23.00	5.00		
	West of Franklin, ID at Bridge		21.50	171.14	197.00	117.00		
	Worm Cr. West of Franklin, ID		24.50	157.94	247.00	128.00		
	High Cr. at US-89/91							
	North of Richmond at Bridge		24.00	129.58				
	South of Richmond at Bridge		24.00	137.50	170.00	44.00		
Logan R.	Below Logan Lagoon Effluent				116.00	50.00		
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek		16.00	120.85	17.00	13.00		
	Davenport Cr.		15.50	114.83	11.00	6.00		
	Below Hyrum Reservoir		17.00	150.76	24.00	15.00		
	Above Logan R. Confluence		18.00	177.20	90.00	62.00		
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence		11.00	127.36	46.00	36.00		
	Sheep Cr. near Blacksmith Fork Confluence		8.50	126.94	125.00	9.00		
	Blacksmith Fork above Sheep Cr.		7.50	101.93	15.00	12.00		
	Blacksmith Fork at Anderson Ranch		10.00	124.16	16.00	12.00		

Table A6 . Field measurements and phosphorus data for Bear River samples, October, 1986.

Stream	Sample Location	Field Measurements Flow ft^3/s	Temp °C	Cond.(25) µmhos/cm	Total Phos. µg/l	Ortho Phos. µg/l	Phos. Transport Total Phos. mg/s	Ortho Phos. mg/s
Bear R.	Bear Lake Outlet Canal @ US-89	1640.00	7.00	192.20	18.20	2.87	845.30	133.30
	West of Georgetown at Bridge							
	Above Soda Point Reservoir	1130.00	6.00	187.54	28.60	4.35	915.25	139.21
	At Grace Dam	1170.00	6.00	202.35	26.00	5.24	861.49	173.62
	Above Alder Creek at Bridge		8.00	203.50	52.70	13.20		
	Cottonwood Cr. near Cleveland, ID at I-34	44.00	7.00	100.90	8.40	3.47	10.47	4.32
	Above Oneida Reservoir	2950.00	7.00	201.81	26.60	7.02	2222.27	586.48
	Below Oneida Reservoir at I-36	2820.00	7.50	203.87	31.20	8.51	2491.71	679.63
	Mink Cr. near Bear R. Confluence	57.43	2.00	96.12	34.50	24.50	56.11	39.85
	Above Battle Cr. at US-91	3597.70	9.00	191.29	24.00	4.95	2445.28	504.34
	Battle Cr. near Bear R. Confluence	29.80	7.50	270.24	128.00	83.10	108.02	70.13
	Deep Cr. near Bear R. Confluence	97.40	7.50	237.06	57.90	30.10	159.71	83.03
	Five-mile Cr. near Bear R. Confluence	92. 0	9.00	232.28	85.30	71.60	222.73	186.96
	Weston Cr. near Bear R. Confluence	176.10	10.00	354.75	29.90	18.30	149.12	91.26
	West of Fairview, ID at USGS Gauge	2303.00	9.00	218.62	45.50	7.61	2967.55	496.33
	West of Richmond, UT		8.00	210.51	35.80	6.72		
	Below Cub R		8.00	196.48	70.90	13.20		
	Above Cutler Reservoir, West of Benson	3457.00	6.00	214.68	37.10	9.98	3632.17	977.06
	Below Cutler Reservoir near Collinston	3290.00	6.00	202.35	82.00	21.20	7640.17	1975.26
	West of Deweyville at Bridge	3741.40	6.00	199.88	42.90	19.80	4545.53	2097.94
	West of Honeyville	3879.00	6.00	202.35		21.20		2328.89
Cub R.	North of Franklin, ID at Bridge		8.00	102.92	19.50	15.30		
	West of Franklin, ID at Bridge	47.00	7.00	108.11	18.20	13.20	24.22	17.57
	Worm Cr. West of Franklin, ID	12.03	8.00	159.06	440.00	202.00	149.90	68.82
	High Cr. at US-89/91							
	North of Richmond at Bridge		8.00	126.31	104.00	68.60		
	South of Richmond at Bridge	218.25	6.00	133.25	97.00	68.90	599.54	425.86
Logan R.	Below Logan Lagoon Effluent		5.00	126.73	44.90	40.80		
Little Bear R.	So. Fork Below Three-mile Cr. at Bridge							
	So. Fork Above Davenport Creek							
	Davenport Cr.		4.00	119.75	7.10	3.17		
	Below Hyrum Reservoir		9.50	134.82	24.70	3.47		
	Above Logan R. Confluence		9.00	152.58	31.20	12.10		
Blacksmith Fork	Mill Cr. near Blacksmith Fork Confluence		6.50	136.35	36.40	27.50		
	Sheep Cr. near Blacksmith Fork Confluence		5.00	116.59	5.15	1.39		
	Blacksmith Fork above Sheep Cr.		6.50	121.74	12.30	9.39		
	Blacksmith Fork at Anderson Ranch	87.40	6.00	123.38	11.00	8.20	27.23	20.30

APPENDIX B

BUREAU OF WATER POLLUTION CONTROL DATA FOR SAMPLES COLLECTED FROM THE BEAR RIVER AND ITS TRIBUTARIES IN 1985 AND 1986

04 June 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	11.0	27	-	-	-	-	9.7	17	3	0.2
Bear R. bl. Oneida res. [490620]	-	-	-	3.0	10	-	-	-	-	1.2	<10	2	0.2
Bear R. W. Fairview, ID [490610]	-	-	-	9.0	37	-	406	260	317.0	12.9	11	2	0.2
Bear R. W. Richmond [490382]	-	-	-	16.0	41	-	374	234	300.0	20.0	13	3	0.4
Bear R. W. Smithfield [490458]	-	-	-	26.0	84	-	350	239	288.0	7.0	15	2	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	21.0	70	-	356	242	268.0	2.3	20	2	0.5
Bear R. bl. Cutler res. [490198]	-	-	-	43.0	103	-	318	226	243.0	3.9	<10	2	0.5
Bear R. near Honeyville [490170]	-	-	-	22.5	77	-	-	-	-	7.2	<10	2	0.5
Cub R. W. of Richmond [490425]	-	-	-	32.5	100	-	-	-	-	1.9	11	3	0.7
Logan R. at Canyon mouth [490520]	-	-	-	1.5	7	-	178	165	188.0	1.0	<10	-	0.1
Logan R. Ab. confl. w/L Bear R. [490504]	-	-	-	4.2	20	-	198	183	241.0	1.8	<10	1	<0.1
L. Bear R. W. Avon [490570]	-	-	-	3.2	17	-	200	1789	207.0	11.0	<10	2	0.1
L. Bear bl. Hyrum res. [490565]	-	-	-	0.8	5	-	-	-	-	4.0	15	1	0.2
L. Bear ab. confl. w/Logan R. [490500]	-	-	-	10.5	37	-	272	218	256.0	4.5	17	1	0.2

04 June 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	<0.1	<0.01	0.41	0.08	0.04	-	-	-	-	-	-	0.13	60.0
Bear R. bl. Oneida res. [490620]	<0.1	<0.01	0.36	0.04	0.01	-	-	-	-	-	-	<0.03	<10.0
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.36	0.06	0.03	45	8	70	34	55	42	0.23	70.0
Bear R. W. Richmond [490382]	<0.1	<0.01	0.43	0.08	0.03	44	8	70	30	56	42	0.34	70.0
Bear R. W. Smithfield [490458]	<0.1	<0.01	0.57	0.13	0.09	37	6	71	27	43	35	0.47	90.0
Bear R. ab. Cutler res. [490326]	<0.1	<0.01	0.65	0.11	0.06	37	7	63	27	43	35	0.44	75.0
Bear R. bl. Cutler res. [490198]	<0.1	<0.01	0.55	0.16	0.12	29	5	57	24	36	24	0.64	95.0
Bear R. near Honeyville [490170]	<0.1	<0.01	0.32	0.28	0.1	-	-	-	-	-	-	0.36	75.0
Cub R. W. of Richmond [490425]	<0.1	<0.01	0.52	0.16	0.12	-	-	-	-	-	-	0.46	70.0
Logan R. at Canyon mouth [490520]	0.1	<0.01	0.09	0.03	0.01	2	<1	53	14	5	11	0.06	10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.3	0.05	0.03	3	1	61	22	4	14	0.16	10.0
L. Bear R. W. Avon [490570]	0.1	0.06	0.3	0.14	0.02	6	1	52	19	6	13	0.13	15.0
L. Bear bl. Hyrum res. [490565]	0.2	<0.01	0.43	0.27	0.01	-	-	-	-	-	-	0.05	<10.0
L. Bear ab. confl. w/Logan R. [490500]	<0.1	<0.01	1.0	0.08	0.07	15	3	66	22	22	16	0.2	30.0

30 July 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	21.8	7.5	7.5	33.0	71	808	484	298	267.0	4.5	12	-	0.5
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	22.8	8.2	6.8	30.0	91	551	472	295	328.0	5.4	<10	-	0.6
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	23.9	8.7	13.5	22.0	24	1510	886	265	260.0	2.8	16	-	0.9
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	21.8	7.5	7.5	55.0	808	372	265	239.0	3.1	<10	-	-	1.1
Logan R. at Canyon mouth [490520]	13.6	7.8	7.8	1.1	8	365	194	186	178.0	0.8	<10	-	0.9
Logan R. Ab. confl. w/L Bear R. [490504]	15.5	7.5	8.6	4.0	12	424	250	221	164.0	0.8	<10	-	0.1
L. Bear R. W. Avon [490570]	17.8	7.3	8.7	2.2	4	440	265	227	196.0	1.4	<10	-	0.3
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	16.5	7.7	7.0	25.0	59	538	328	259	284.0	1.6	<10	-	0.4

30 July 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	<0.1	0.57	0.11	0.1	53	8	57	30	63	34	0.25	60.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	0.06	0.58	0.1	0.13	54	9	63	42	61	53	0.46	80.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.2	<0.01	0.33	0.1	0.03	208	13	54	30	320	28	0.19	40.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	<0.1	<0.01	1.42	0.33	0.21	32	9	55	25	29	5	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.1	0.02	0.03	5	1	48	14	3	8	0.08	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.47	0.06	0.03	6	2	40	16	6	9	0.09	10.0
L. Bear R. W. Avon [490570]	0.1	<0.01	0.38	0.04	0.04	10	3	50	18	5	<5	0.06	15.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.1	<0.01	1.14	0.25	0.19	16	5	61	32	15	18	0.16	40.0

29 August 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	19.7	8.1	6.7	25.0	80	349	478	293	298.0	2.7	<10	-	0.94
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	22.8	8.7	7.3	58.0	133	739	450	273	279.0	2.7	11	-	1.3
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	16.6	8.2	6.1	64.0	125	267	312	262	243.0	2.8	<10	-	1.0
Logan R. at Canyon mouth [490520]	10.5	8.8	9.0	1.1	5	342	194	191	154.0	<0.5	<10	-	0.2
Logan R. Ab. confl. w/L Bear R. [490504]	18.3	8.9	8.7	5.1	24	426	262	227	216.0	0.7	<10	-	0.4
L. Bear R. W. Avon [490570]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	19.7	8.6	8.4	14.0	47	583	262	272	251.0	1.9	12	-	1.0

29 Aug 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	<0.1	0.03	0.35	0.09	0.06	59	9	49	42	68	67	0.44	45.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	<0.1	<0.01	0.18	0.24	0.1	53	8	48	39	64	57	0.66	65.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	<0.1	<0.01	1.24	0.28	0.2	24	7	53	27	21	16	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.15	0.13	0.01	3	1	33	17	3	8	0.03	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.43	0.05	0.02	7	2	53	20	8	17	0.17	<10.0
L. Bear R. W. Avon [490570]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	<0.1	0.01	1.08	0.12	0.12	25	6	63	23	36	14	0.23	35.0

24 Sept 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	14.2	8.2	9.9	11.0	38	834	456	301	300.0	2.4	<10	-	0.2
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	14.7	8.3	7.8	19.0	62	811	446	288	314.0	2.4	<10	-	0.7
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	13.6	8.1	9.2	32.0	59	750	450	273	287.0	2.2	<10	-	0.5
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	13.9	8.0	8.2	53.0	192	471	256	221	214.0	1.4	<10	-	0.7
Logan R. at Canyon mouth [490520]	7.1	8.1	8.9	0.7	<3	366	328	183	200.0	<0.5	<10	-	0.1
Logan R. Ab. confl. w/L Bear R. [490504]	8.9	7.8	8.2	3.5	<3	427	221	214	234.0	<0.5	<10	-	0.2
L. Bear R. W. Avon [490570]	9.3	8.1	8.4	2.5	<3	459	224	226	226.0	0.7	<10	-	0.2
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	12.2	7.9	7.6	18.0	63	515	322	234	200.0	1.4	<10	-	0.4

24 Sept 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.59	0.07	0.08	57	9	52	41	61	64	0.2	45.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	<0.1	<0.01	0.71	<0.01	<0.01	52	8	54	44	61	58	0.26	45.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.69	0.23	0.09	51	8	54	37	59	48	0.32	50.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.1	<0.01	1.17	0.2	0.2	18	5	53	20	13	11	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.2	<0.005	<0.005	4	1	50	18	3	9	<0.03	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	0.01	0.32	0.01	0.01	5	1	57	22	5	16	0.11	<10.0
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.21	0.29	0.04	10	2	60	19	10	12	0.1	20.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	<0.1	<0.01	0.96	0.08	0.1	17	4	54	16	21	13	0.23	45.0

22 Oct 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	7.6	7.8	8.8	13.0	46	789	462	285	302.0	1.9	17	-	0.5
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	8.1	7.8	9.4	12.0	41	823	462	283	292.0	1.8	10	-	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	7.4	8.0	9.1	29.0	81	269	412	257	291.0	1.7	<10	-	0.6
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	6.1	7.7	9.5	1.7	10	387	210	188	180.0	1.5	<10	-	0.3
Logan R. at Canyon mouth [490520]	6.6	7.6	9.8	3.7	<3	376	202	191	193.0	0.5	<10	-	0.3
Logan R. Ab. confl. w/L Bear R. [490504]	6.9	7.8	8.8	19.0	94	418	232	209	221.0	0.7	16	-	0.4
L. Bear R. W. Avon [490570]	5.9	7.8	7.4	8.3	24	470	206	214	220.0	1.4	<10	-	0.3
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	8.1	7.6	5.0	13.0	45	659	356	260	274.0	1.6	<10	-	2.5

22 Oct 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	<0.01	0.54	0.06	0.06	53	7	64	34	62	70	0.23	45.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	0.08	0.76	0.05	0.04	51	7	62	44	61	12	0.21	40.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.66	0.24	0.09	46	6	58	35	57	50	0.41	55.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	<0.1	0.02	0.48	0.04	0.04	9	3	52	12	7	9	-	-
Logan R. at Canyon mouth [490520]	<0.1	0.06	0.16	0.06	0.02	3	1	51	16	4	10	0.09	10.0
Logan R. Ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.33	0.08	0.05	5	1	56	19	6	15	0.52	25.0
L. Bear R. W. Avon [490570]	0.1	0.05	0.24	0.05	0.03	9	2	56	20	11	12	0.25	30.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	1.9	<0.01	0.11	0.44	0.44	20	5	68	25	24	25	0.23	25.0

19 Nov 1985

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	1.6	7.1	8.5	12.0	27	770	374	278	350.0	2.0	<10	-	1.7
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	1.2	7.2	8.9	28.0	88	809	446	282	380.0	2.0	<10	-	0.9
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	1.4	7.4	10.0	8.8	25	706	360	259	270.0	2.3	12	-	0.6
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.9	7.3	10.6	5.1	14	509	268	241	280.0	2.4	<10	-	0.5
Logan R. at Canyon mouth [490520]	2.5	7.6	9.3	0.3	<3	368	166	191	190.0	<0.2	<10	-	2.4
Logan R. Ab. confl. w/L Bear R. [490504]	2.2	7.3	8.4	2.7	<3	415	192	208	230.0	0.6	<10	-	0.5
L. Bear R. W. Avon [490570]	1.3	7.4	9.0	1.2	<3	448	216	218	230.0	1.4	<10	-	1.7
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	2.4	7.3	6.6	4.5	<3	526	266	232	290.0	1.3	<10	-	1.7

19 Nov 1985 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	0.09	0.73	0.05	0.04	42	7	70	43	49	60	0.27	50.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	<0.1	0.08	1.0	0.1	0.03	52	8	72	50	59	65	0.49	75.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.2	0.08	0.86	0.27	0.12	42	7	66	26	49	45	0.15	25.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	<0.1	0.03	1.7	0.11	0.11	21	5	57	33	17	14	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.15	0.05	<0.005	3	1	51	16	3	11	<0.03	10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.31	0.02	0.009	5	1	57	21	6	15	0.09	15.0
L. Bear R. W. Avon [490570]	0.1	<0.01	0.26	0.23	0.02	9	2	54	22	12	11	0.05	<10.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	<0.1	0.01	0.9	0.05	0.03	17	4	70	28	23	14	0.1	20.0

07 Jan 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	-.3	8.2	11.4	7.0	17	833	474	298	345.0	1.9	10	-	0.4
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	-.1	8.2	10.4	6.6	14	823	494	295	329.0	1.7	<10	-	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	-.2	8.2	11.3	5.0	17	778	432	283	340.0	1.8	<10	-	0.6
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	-1.2	8.3	11.1	13.0	36	486	274	231	229.0	1.0	<10	-	0.6
Logan R. at Canyon mouth [490520]	1.6	8.3	11.2	0.4	<3	375	198	193	186.0	<0.2	<10	-	0.3
Logan R. Ab. confl. w/L Bear R. [490504]	1.0	8.3	12.1	2.0	<3	421	218	209	175.0	0.2	<10	-	0.4
L. Bear R. W. Avon [490570]	0.5	8.4	11.7	2.1	<3	438	258	218	220.0	0.8	<10	-	0.6
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	2.8	8.1	9.7	10.0	25	664	368	293	320.0	1.5	<10	-	2.9

07 Jan 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.81	0.04	0.04	56	9	68	43	59	67	0.14	25.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	<0.01	1.03	0.06	0.04	54	10	67	39	59	64	0.13	25.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.92	0.19	0.06	44	7	68	41	52	54	0.12	25.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.1	<0.01	1.77	0.13	0.13	22	6	58	21	20	12	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.23	0.02	0.005	4	2	43	19	4	10	<0.03	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.41	0.03	<0.005	6	1	42	18	6	17	0.05	10.0
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.35	0.02	0.02	10	2	54	20	12	13	0.07	10.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	2.0	<0.01	1.8	0.49	0.5	26	5	72	35	29	42	0.12	30.0

18 Feb 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	2.9	-	-	475.0	2050	484	308	200	210.0	4.3	<10	-	2.5
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	1.6	-	-	104.0	76	561	336	198	210.0	5.9	18	-	2.2
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	2.2	-	-	300.0	740	539	326	188	200.0	4.9	34	-	2.9
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	1.4	-	-	270.0	675	321	204	134	120.0	7.5	10	-	3.7
Logan R. at Canyon mouth [490520]	4.9	-	-	13.0	42	353	176	168	160.0	1.6	<10	-	0.6
Logan R. Ab. confl. w/L Bear R. [490504]	3.9	-	-	180.0	784	297	144	139	150.0	3.6	10	-	3.3
L. Bear R. W. Avon [490570]	3.1	-	-	200.0	1265	148	120	77	77.0	4.6	<10	-	2.8
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	4.9	-	-	210.0	598	342	196	162	175.0	3.8	10	-	2.7

18 Feb 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.5	0.27	1.3	1.42	1.0	36	9	43	27	37	45	9.9	847.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	1.2	0.07	1.53	0.48	0.46	40	11	45	24	41	46	1.67	112.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.8	0.11	1.61	0.84	0.67	34	8	41	24	37	40	2.55	360.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	1.3	0.65	2.87	0.92	0.89	20	11	28	12	13	13	-	-
Logan R. at Canyon mouth [490520]	0.1	0.01	0.41	0.08	0.05	10	3	41	14	13	8	0.26	30.0
Logan R. Ab. confl. w/L Bear R. [490504]	0.3	0.06	0.68	0.59	0.37	8	3	39	14	12	11	4.38	215.0
L. Bear R. W. Avon [490570]	0.6	0.04	0.28	0.91	0.6	4	2	21	6	2	6	5.9	411.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.5	0.09	1.14	0.73	0.66	11	6	44	16	11	11	3.69	180.0

02 April 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	8.0	8.0	8.9	52.0	161	613	380	227	255.0	3.8	13	-	0.7
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	7.2	8.1	9.1	34.0	67	597	326	216	260.0	3.6	20	-	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	7.7	8.0	9.9	53.0	146	561	338	211	240.0	3.9	10	-	1.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	4.9	8.0	9.0	85.0	225	361	184	172	165.0	3.2	20	-	0.7
Logan R. at Canyon mouth [490520]	5.5	8.2	8.9	8.0	21	336	202	178	190.0	2.0	12	-	0.4
Logan R. Ab. confl. w/L Bear R. [490504]	3.2	8.2	9.7	26.0	61	363	190	175	190.0	2.3	<10	-	0.4
L. Bear R. W. Avon [490570]	4.6	8.2	9.2	29.0	100	294	162	147	147.0	2.9	17	-	0.5
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	4.4	8.0	10.4	29.0	76	410	216	186	200.0	6.7	27	-	1.2

02 April 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	0.1	0.03	0.54	0.17	0.17	38	5	56	28	41	58	0.77	94.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	0.03	0.5	0.13	0.11	35	5	60	28	42	52	0.46	52.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	0.04	0.39	0.21	0.16	29	4	57	24	33	43	0.59	78.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.2	0.13	0.92	0.3	0.3	11	3	44	14	10	9	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.24	0.06	0.07	5	1	53	15	5	7	0.18	12.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.31	0.16	0.07	5	1	53	15	6	9	0.38	25.0
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.21	0.12	0.09	5	1	40	11	5	7	0.65	40.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.2	0.04	0.63	6.0	6.0	9	2	50	19	12	9	0.5	41.0

13 May 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	11.9	8.2	8.8	36.0	98	547	292	219	250.0	3.5	22	-	0.2
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	12.8	8.2	8.9	30.0	53	536	298	214	236.0	4.4	<10	-	0.3
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	12.4	8.1	8.3	43.0	113	522	338	211	230.0	3.5	11	-	0.5
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	10.9	8.1	8.1	34.0	94	352	258	173	170.0	2.2	<10	-	0.2
Logan R. at Canyon mouth [490520]	6.8	7.4	10.5	2.9	10	351	178	186	191.0	1.0	<10	-	0.1
Logan R. Ab. confl. w/L Bear R. [490504]	10.9	8.3	9.1	8.8	33	358	186	191	190.0	1.4	<10	-	0.1
L. Bear R. W. Avon [490570]	12.1	8.3	7.8	11.0	43	350	186	177	183.0	2.1	<10	-	0.1
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	13.2	8.3	10.0	18.0	50	373	222	180	185.0	2.5	11	-	0.2

13 May 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	0.44	0.11	0.09	25	4	63	24	29	39	0.67	<70.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	<0.01	0.49	0.09	0.07	27	4	56	23	30	38	0.61	60.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	0.05	0.51	0.14	0.11	25	3	55	22	30	32	0.83	70.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.1	0.06	0.81	0.14	0.13	11	2	46	14	9	20	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.17	0.02	0.01	3	0	53	14	3	19	0.1	<10.0
Logan R. Ab. confl. w/L. Bear R. [490504]	<0.1	<0.01	0.26	0.04	0.03	4	1	50	16	5	21	0.22	15.0
L. Bear R. W. Avon [490570]	0.1	<0.01	0.16	0.05	0.03	7	1	51	14	6	19	0.34	25.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.1	0.01	0.48	0.08	0.05	9	2	49	15	11	20	0.43	30.0

09 June, 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	-	-	-	-	-	-	-	-	-	-	-	-	-
Logan R. at Canyon mouth [490520]	-	-	-	-	-	-	-	-	-	-	-	-	-
Logan R. Ab. confl. w/L Bear R. [490504]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear R. W. Avon [490570]	12.9	7.8	7.3	3.8	15	443	254	227	210.0	1.9	<10	-	<0.1
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	-	-	-	-	-	-	-	-	-	-	-	-	-

09 June, 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	-	-	-	-	-	-	-	-	-	-	-	-	-
Logan R. at Canyon mouth [490520]	-	-	-	-	-	-	-	-	-	-	-	-	-
Logan R. Ab. confl. w/L Bear R. [490504]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.25	0.06	0.06	14	3	51	20	15	14	0.16	30.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	-	-	-	-	-	-	-	-	-	-	-	-	-

24 June 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	22.3	7.8	6.5	3.6	78	550	306	234	248.0	0.7	22	-	0.4
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	-	-	-	33.0	64	-	302	231	232.0	6.5	27	-	1.1
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	22.1	7.9	6.9	52.0	121	504	286	226	227.0	4.4	24	-	1.5
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	14.8	8.1	8.3	36.0	132	312	172	167	161.0	2.1	22	-	0.6
Logan R. at Canyon mouth [490520]	10.7	8.4	9.2	4.0	20	300	150	162	160.0	1.0	19	-	0.3
Logan R. Ab. confl. w/L Bear R. [490504]	12.8	8.3	9.2	4.0	22	343	184	175	175.0	1.3	10	-	0.9
L. Bear R. W. Avon [490570]	16.5	8.3	8.6	5.4	31	346	196	180	183.0	2.2	22	-	0.7
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	18.2	7.7	7.3	50.0	225	525	292	241	240.0	3.0	17	-	1.1

24 June 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	<0.01	5.0	15.0	0.12	26	4	60	22	29	70	0.52	70.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	0.01	0.17	0.17	0.11	25	5	56	22	27	30	0.57	85.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	<0.01	0.19	0.22	0.14	23	4	57	21	27	22	0.87	95.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.1	<0.01	0.28	0.16	0.14	6	2	46	11	5	<5	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.02	0.04	0.03	2	0	44	12	2	<10	0.09	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.14	0.06	0.04	3	1	47	14	3	<10	0.14	15.0
L. Bear R. W. Avon [490570]	0.1	0.01	0.23	0.06	0.04	5	1	46	17	6	10	0.22	20.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.1	<0.01	1.28	0.15	0.11	17	4	62	21	25	<10	68.0	100.0

05 August 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	22.2	8.5	8.4	12.0	37	713	400	262	265.0	4.1	22	-	0.7
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	23.8	8.5	7.8	40.0	115	695	404	259	280.0	5.4	11	-	1.3
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	23.9	8.4	8.2	71.0	145	643	392	252	265.0	3.2	16	-	0.9
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	22.5	8.5	9.2	25.0	<3	550	332	249	235.0	4.1	16	-	1.0
Logan R. at Canyon mouth [490520]	10.0	8.2	8.6	-	73	334	206	193	190.0	0.9	<10	-	0.3
Logan R. Ab. confl. w/L Bear R. [490504]	16.0	8.5	8.2	3.5	24	436	230	209	205.0	1.7	13	-	0.1
L. Bear R. W. Avon [490570]	18.8	8.4	8.4	1.5	5	465	268	232	225.0	1.9	16	-	0.2
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-		
L. Bear ab. confl. w/Logan R. [490500]	19.6	8.2	8.2	16.0	54	555	326	246	255.0	2.1	16	-	0.7

05 August 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	0.01	0.33	0.06	0.04	39	7	53	32	47	50	0.2	<35.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	<0.1	0.01	0.28	0.17	0.1	38	6	58	32	44	51	0.4	75.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	<0.1	0.02	0.24	0.2	0.13	38	6	58	29	44	41	0.65	110.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	<0.1	0.02	1.17	0.16	0.13	24	5	55	23	26	14	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.04	0.2	0.03	0.02	3	1	47	17	2	13	0.09	15.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.35	0.03	0.02	4	1	50	19	4	13	0.13	20.0
L. Bear R. W. Avon [490570]	<0.1	0.01	0.25	0.04	0.03	10	2	55	21	10	11	0.08	25.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	<0.1	0.04	1.31	0.11	0.1	19	5	66	22	29	14	0.03	<10.0

09 Sept 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (μmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	16.9	8.0	7.2	23.0	62	682	396	259	300.0	3.4	<10	-	1.5
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	17.3	8.1	6.8	35.0	84	681	382	260	300.0	4.1	<10	-	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	17.8	7.9	6.3	85.0	225	678	368	252	287.0	3.1	<10	-	0.2
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	16.3	7.8	6.4	81.0	222	429	222	201	202.0	3.2	<10	-	0.1
Logan R. at Canyon mouth [490520]	10.8	7.7	9.3	0.6	<3	386	192	196	188.0	0.5	<10	-	0.1
Logan R. Ab. confl. w/L Bear R. [490504]	12.6	7.9	7.4	2.7	15	418	204	213	231.0	1.3	<10	-	0.1
L. Bear R. W. Avon [490570]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	14.2	7.7	8.1	11.0	36	554	308	239	225.0	2.2	<10	-	0.1

09 Sept 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	0.04	0.71	0.15	0.14	41	6	53	40	45	60	0.49	60.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	0.1	0.05	0.49	0.17	0.16	-	-	54	40	44	58	0.99	90.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.2	0.01	0.46	0.23	0.04	41	6	54	37	47	49	1.54	145.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.1	0.02	0.98	0.29	0.34	19	5	50	19	14	14	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.2	0.02	0.03	3	<1	41	21	3	19	0.06	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	0.1	<0.01	0.27	0.08	0.04	5	1	58	21	5	16	0.09	15.0
L. Bear R. W. Avon [490570]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	0.1	0.025	1.38	0.09	0.07	22	5	54	22	31	15	0.33	40.0

21 Oct 1986

Station	Temp (C)	pH	D.O. (mg/l)	Turb (NTU)	TSS (mg/l)	Field Sp. Cond. (µmhos/cm)	TDS @180C	T. Alk. as $CaCO_3$ (mg/l)	T. Hard as $CaCO_3$ (mg/l)	TOC (mg/l)	COD (mg/l)	BOD_5 (mg/l)	TKN (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	9.6	8.3	8.6	15.0	43	623	450	268	306.7	5.0	17	-	0.1
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	8.6	8.3	8.6	25.0	73	662	400	270	305.0	2.5	<10	-	0.4
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	10.0	8.1	8.6	20.0	55	600	398	254	284.9	2.2	26	-	0.5
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	10.1	8.3	8.0	20.0	58	421	251	218	213.6	2.2	15	-	0.5
Logan R. at Canyon mouth [490520]	8.6	8.5	8.8	0.5	<3	372	256	206	217.0	2.9	11	-	0.5
Logan R. Ab. confl. w/L Bear R. [490504]	8.5	8.3	8.7	2.0	16	396	282	218	240.0	3.2	<10	-	1.1
L. Bear R. W. Avon [490570]	9.9	8.2	8.1	1.0	<3	405	248	219	223.0	1.4	<10	-	<0.1
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	10.4	8.0	8.5	10.0	27	344	268	247	257.6	7.6	<10	-	0.3

21 Oct 1986 cont.

Station	NH_4-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TP (mg/l)	PO_4-P (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Chloride (mg/l)	SO_4 (mg/l)	T. Fe (mg/l)	T. Mn (mg/l)
Bear R. ab. Oneida res. [490630]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Oneida res. [490620]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Fairview, ID [490610]	<0.1	0.02	0.4	0.17	0.13	39	5	52	43	45	64	0.22	20.0
Bear R. W. Richmond [490382]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. W. Smithfield [490458]	<0.1	0.09	0.4	0.17	0.15	39	5	53	42	45	64	0.34	45.0
Bear R. ab. Cutler res. [490326]	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear R. bl. Cutler res. [490198]	0.1	0.04	0.45	0.21	0.06	35	5	54	36	44	53	0.6	40.0
Bear R. near Honeyville [490170]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cub R. W. of Richmond [490425]	0.07	0.01	1.06	0.31	0.23	14	4	51	21	13	11	-	-
Logan R. at Canyon mouth [490520]	<0.1	<0.01	0.23	0.02	0.008	3	1	51	21	4	17	0.03	<10.0
Logan R. Ab. confl. w/L Bear R. [490504]	<0.1	<0.01	0.26	0.04	0.01	4	1	58	22	5	15	0.08	10.0
L. Bear R. W. Avon [490570]	<0.1	<0.01	0.14	0.02	<0.005	7	1	51	23	11	11	0.05	<10.0
L. Bear bl. Hyrum res. [490565]	-	-	-	-	-	-	-	-	-	-	-	-	-
L. Bear ab. confl. w/Logan R. [490500]	<0.1	0.05	1.06	0.18	0.17	14	4	62	25	20	13	0.13	20.0

APPENDIX C

WILLARD RESERVOIR FIELD DATA

Table C1 . Willard Reservoir field data, 13 March, 1986.

Site	Depth (m)	T (C)	EC, µmhos/ cm at 25°C	D.O. (mg/L)
B1	0.0	9.0	628	9.0
	1.0	7.5	644	9.2
	2.0	7.0	661	9.2
	3.0	7.0	661	8.9
	4.0	7.0	653	9.0
	5.0	6.9	663	8.6
	6.0	7.0	636	8.0
	7.0	7.0	636	
B2	0.0	8.0	668	9.0
	1.0	8.0	660	9.0
	2.0	7.5	661	9.0
	3.0	7.3	664	9.0
	4.0	7.2	666	8.9
	5.0	7.2	669	8.8
	6.0	7.2	674	8.8
B3	0.0	8.0	612	9.1
	1.0	8.0	620	9.1
	2.0	7.5	632	9.0
	3.0	7.2	633	8.8
	4.0	7.2	636	8.8
	5.0	7.1	643	8.8
	5.5	7.0	661	8.4

Site	Depth (m)	T (C)	EC, µ mhos/ cm at 25°C	D.O. (mg/L)
Inlet	0.0	6.0	377	9.0
	1.0	5.8	378	9.0
	2.0	5.8	378	9.0
	2.5	5.8	384	9.9
C1	0.0	8.2	601	8.8
	1.0	7.5	612	9.0
	2.0	7.0	623	8.8
	3.0	7.0	628	8.8
	4.0	6.9	630	8.7
	5.0	6.9	633	8.7
	5.5	6.9	636	8.2
C2	0.0	9.0	654	8.7
	1.0	8.2	657	8.8
	2.0	7.5	648	8.8
	3.0	7.2	651	8.4
	4.0	7.2	651	8.4
	5.0	7.1	653	8.3
	5.2	7.1	654	7.8
C3	0.0	9.5	643	8.8
	1.0	8.0	649	8.9
	2.0	7.2	649	8.9
	3.0	7.2	649	8.6
	4.0	7.2	651	8.6
	5.0	7.2	651	8.5
	6.0	7.2	653	8.3

Table C1. Continued.

Site	Depth (m)	T (C)	EC, μmhos/cm at 25^{o}C	D.O. (mg/L)	Site	Depth (m)	T (C)	EC, μmhos/cm at 25^{o}C	D.O. (mg/L)
B4	0.0	7.2	614	9.4	D1	0.0	7.5	669	9.2
	1.0	7.1	619	9.4		1.0	7.0	684	9.2
	2.0	7.0	620	9.2		2.0	7.0	685	9.0
	3.0	6.8	627	9.2		3.0	7.0	687	8.8
	4.0	6.8	632	9.1		4.0	6.8	692	8.8
	5.0	6.8	632	9.0		4.5	6.9	691	7.6
	5.4	6.8	632	8.6					
					D2	0.0	8.5	675	9.6
						1.0	8.2	688	9.6
C4	0.0	9.3	663	8.8		2.0	7.0	677	9.6
	1.0	8.8	662	9.0		3.0	6.9	687	9.4
	2.0	7.5	649	8.8		4.0	6.8	689	9.2
	3.0	7.2	658	8.7		5.0	6.8	689	9.2
	4.0	7.2	666	8.6		6.0	6.8	689	9.2
	5.0	7.2	667	8.6		6.5	6.8	689	
	6.0	7.2	669	8.6					
	6.5	7.2	671	8.6	D3	0.0	8.0	644	9.4
						1.0	8.0	654	9.6
C5	0.0	8.5	675	9.0		2.0	7.8	659	9.6
	1.0	7.8	688	9.2		3.0	7.0	669	9.6
	2.0	7.2	685	9.4		4.0	7.0	671	9.4
	3.0	7.2	685	9.2		5.0	7.0	672	9.4
	4.0	7.0	690	9.2		6.0	7.0	677	9.4
	5.0	7.0	689	9.0					
	6.0	7.0	690	8.8	D4	0.0	7.8	600	9.8
	6.5	7.0	690	8.8		1.0	7.5	604	9.8
						2.0	7.2	609	9.8
						3.0	6.8	620	9.6
						4.0	6.8	623	9.4
						5.0	6.8	625	9.2

Table C2. Willard Reservoir field data, 7 April, 1986.

Sample Site	Depth (m)	T (C)	EC, µmhos/cm at 25° C	D.O. (mg/L)
A1	0.0	12.0	488	9.4
	1.0	12.0	517	9.2
	2.0	12.0	517	9.2
	3.0	12.0	524	9.2
	4.0	12.0	532	9.2
	5.0	12.0	560	9.2
	5.5	11.5	567	8.8
A2	0.0	12.0	604	9.5
	1.0	12.0	604	9.4
	2.0	12.0	604	9.4
	3.0	12.0	604	9.4
	4.0	12.0	604	9.4
	5.0	11.5	611	9.4
	6.0	10.5	627	8.8
A3	0.0	11.0	560	9.9
	1.0	11.0		

Table C3. Willard Reservoir field data, 1 May, 1986.

Site	Depth (m)	T (C)	EC, μmhos/ cm at 25°C	D.O. (mg/L)
Inlet	0.0	11.0	339	9.6
	1.0	10.5	343	9.6
	2.0	10.5	351	9.8
	2.5	10.5	351	9.8
A1	0.0	13.0	554	8.8
	1.0	12.0	535	8.8
	2.0	11.0	530	9.0
	3.0	11.5	527	9.0
	4.0	11.0	553	9.0
	5.0	10.5	537	9.0
	5.5	10.5	530	8.0
A2	0.0	13.0	603	8.8
	1.0	12.0	604	9.0
	2.0	11.5	597	9.0
	3.0	11.5	597	8.8
	4.0	11.0	604	8.8
	5.0	10.5	615	8.6
	5.5	10.5	615	8.2
A3	0.0	13.0	605	8.8
	1.0	12.5	603	9.0
	2.0	11.5	611	8.8
	3.0	11.0	616	8.8
	4.0	11.0	612	8.8
	5.0	10.5	615	8.6
	5.5	10.5	613	8.2
A4	0.0	13.0	591	9.0
	1.0	11.5	597	9.0
	2.0	11.5	594	9.0
	3.0	11.0	603	9.0
	4.0	11.0	597	8.8
	5.0	11.0	604	8.6
B1	0.0	12.0	592	9.0
	1.0	11.5	600	9.0
	2.0	11.0	604	9.0
	3.0	11.0	604	8.8
	4.0	11.0	604	8.8
	5.0	11.0	604	8.8
	6.0	11.0	604	8.8
	7.0	10.5	604	8.0
B2	0.0	13.5	584	9.0
	1.0	12.0	606	9.2
	2.0	11.5	600	9.2
	3.0	11.0	604	9.0
	4.0	11.0	597	9.0
	5.0	10.5	604	8.8
	6.0	10.5	604	8.6

Table C3. Continued.

Site	Depth (m)	T (C)	EC, μ mhos/ cm at 25° C	D.O. (mg/L)
B3	0.0	13.5	592	9.2
	1.0	13.0	591	9.4
	2.0	12.0	589	9.4
	3.0	11.5	597	9.2
	4.0	11.0	604	9.2
	5.0	10.5	601	9.2
	5.5	10.5	600	8.4
B4	0.0	13.5	581	9.4
	1.0	13.0	575	9.4
	2.0	12.0	532	9.4
	3.0	11.5	487	9.6
	4.0	11.0	435	9.6
	5.0	11.0	471	9.6
	5.5	10.5	537	8.8
C1	0.0	15.0	540	9.4
	1.0	14.0	547	9.4
	2.0	13.0	533	9.4
	3.0	12.0	546	9.4
	3.5	12.0	532	9.0
C2	0.0	14.5	594	9.2
	1.0	14.0	608	9.4
	2.0	12.5	596	9.4
	3.0	12.0	596	9.2
	4.0	11.0	553	9.0
C3	0.0	14.5	540	9.2
	1.0	13.0	547	9.2
	2.0	12.0	546	9.2
	3.0	12.0	546	9.2
	4.0	11.5	538	9.0
	5.0	10.5	525	8.8
C4	0.0	14.0	547	9.0
	1.0	13.0	554	9.2
	2.0	13.0	549	9.2
	3.0	12.0	560	9.0
	4.0	12.0	553	9.0
	5.0	11.5	560	9.0
	6.0	11.0	545	8.8
D1	0.0	14.0	560	8.8
	1.0	11.0	567	9.2
	2.0	11.0	567	9.2
	3.0	10.5	575	9.2
	4.0	10.5	575	9.2
	5.0	10.5	582	9.2
	6.0	10.5	582	9.2
D2	0.0	15.5	567	9.4
	1.0	13.5	574	9.4
	2.0	12.0	575	9.6
	3.0	11.5	575	9.6
	4.0	11.0	575	9.4
	5.0	10.5	567	9.2
	6.0	10.5	567	9.2

Table C3. Continued.

Site	Depth (m)	T (C)	EC, μmhos/ cm at 25 C	D.O. (mg/L)	Site	Depth (m)	T (C)	EC, μmhos/ cm at 25 C	D.O. (mg/L)
D3	0.0	16.0	599	9.2					
	1.0	13.0	582	9.6					
	2.0	12.0	568	9.6					
	3.0	11.5	560	9.6					
	4.0	11.0	567	9.4					
	5.0	10.5	567	9.2					
	5.5	10.5	567	8.8					
D4	0.0	16.5	592	9.6					
	1.0	13.5	581	9.6					
	2.0	12.0	546	9.6					
	3.0	12.0	553	9.6					
	4.0	11.0	575	9.4					
	5.0	10.5	582	9.4					

Table C4. Willard Reservoir field data, 28 May, 1986.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
Inlet	10:53A	0.0	13.2	379	8.1	9.1	181
		1.0	13.0	382	8.7	9.0	185
		2.0	12.9	383	8.8	8.8	188
		3.0	12.9	385	9.2	8.7	189
A1	11:13A	0.0	18.7	582	8.6	8.4	178
		1.0	18.7	585	8.4	8.4	175
		2.0	18.6	586	8.4	8.4	177
		3.0	18.6	586	8.4	8.4	179
		4.0	18.4	589	8.2	8.2	181
		5.0	14.5	567	6.4	8.2	188
A2	11:33A	0.0	19.6	570	8.4	8.4	181
		1.0	19.4	574	7.8	8.4	184
		2.0	17.8	599	7.4	8.3	188
		3.0	17.1	609	7.3	8.3	190
		4.0	13.8	650	5.9	8.2	198
		5.0	13.3	651	6.1	8.2	201
		6.0	13.3	652	6.3	8.1	203
A3		0.0	20.2	560	9.0	8.4	183
		1.0	20.0	562	8.6	8.5	186
		2.0	19.0	581	8.3	8.4	192
		3.0	14.8	645	7.6	8.3	199
		4.0	13.9	644	8.0	8.2	202
		5.0	13.2	651	8.1	8.1	205
		6.0	12.9	659	8.0	8.1	207
A4		0.0	20.4	552	10.0	8.5	185
		1.0	20.4	552	9.3	8.5	187
		2.0	19.8	562	9.1	8.5	188
		3.0	15.5	618	7.8	8.3	199
		4.0	14.5	621	7.3	8.2	204
		5.0	13.9	626	7.2	8.1	207
		6.0	13.7	631	7.7	8.1	209
A5	12:20P	0.0	20.1	554	9.5	8.5	188
		1.0	20.0	555	9.1	8.4	189
		2.0	18.5	570	8.3	8.4	192
		3.0	16.4	597	7.1	8.3	198
		4.0	15.2	615	6.4	8.2	202
		5.0	14.3	632	5.9	8.1	205
		5.5	14.2	630	6.4	8.1	207

Table C4. Continued.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
B1	12:58P	0.0	18.6	568	8.6	8.6	183
		1.0	18.6	568	8.3	8.6	185
		2.0	16.6	592	7.3	8.5	190
		3.0	15.0	619	6.7	8.5	194
		4.0	14.2	631	6.7	8.5	197
		5.0	13.7	609	6.9	8.4	198
		6.0	13.3	625	6.5	8.3	201
		7.0	13.2	640	6.2	8.3	203
		7.2					
B2	1:12P	0.0	19.5	560	9.1	8.4	189
		1.0	19.4	562	8.6	8.4	188
		2.0	18.8	569	8.4	8.4	190
		3.0	15.1	629	6.7	8.3	198
		4.0	13.0	652	6.3	7.9	204
		5.0	12.8	649	6.4	7.9	207
		6.0	12.6	664	6.3	7.8	209
		6.6	12.6	667	6.8	7.7	210
B3	1:25P	0.0	19.6	561	8.8	8.4	188
		1.0	19.5	565	8.7	8.4	191
		2.0	18.8	582	8.4	8.2	194
		3.0	16.2	622	7.5	8.0	201
		4.0	15.3	636	7.0	8.0	204
		5.0	13.6	670	6.0	7.8	208
		6.0	13.3	675	6.5	7.6	210
B4	1:38P	0.0	19.1	578	8.5	8.3	193
		1.0	19.0	582	8.5	8.3	195
		2.0	18.7	586	9.0	8.0	197
		3.0	18.5	589	9.4	7.7	199
		4.0	17.5	605	9.3	7.6	202
		5.0	13.8	654	7.9	7.5	210
		6.0	13.5	653	6.6	7.4	213
C1	2:18P	0.0	20.5	559	7.9	8.4	183
		1.0	20.2	560	7.9	8.8	185
		2.0	19.1	521	7.6	8.8	187
		3.0	14.9		7.2	8.8	191
		3.4					
C2	2:30P	0.0	20.4	561	8.7	8.6	186
		1.0	20.4	561	8.5	8.6	188
		2.0	19.5	574	8.4	8.6	191
		3.0	18.8	579	7.7	8.5	194
		4.0	15.5	505	7.0	8.4	198
		5.0	14.8	552	7.0	8.4	203

Table C4. Continued.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
C3	2:40P	0.0	20.7	555	8.9	8.5	188
		1.0	20.6	558	8.7	8.3	191
		2.0	19.7	568	8.4	8.2	194
		3.0	19.2	568	8.0	8.1	196
		4.0	16.4	575	6.8	7.8	201
		5.0	15.0	615	6.2	7.8	206
		5.8	14.5	631	6.9	7.7	209
C4	2:50P	0.0	20.4	558	8.5	8.4	192
		1.0	20.3	559	8.4	8.2	195
		2.0	19.7	563	8.4	8.0	197
		3.0	18.9	572	7.7	7.9	200
		4.0	16.1	618	6.1	7.8	206
		5.0	15.5	631	6.4	7.8	209
		6.0	14.5	652	6.2	7.7	212
		7.0	14.4	653	6.6	7.6	214
D1	3:10P	0.0	18.2	584	8.3	8.4	197
		1.0	17.3	599	7.5	8.0	200
		2.0	15.9	621	7.1	8.0	204
		3.0	15.4	622	7.1	7.9	206
		4.0	14.7	629	7.0	7.7	209
		5.0	14.1	645	6.5	7.7	212
		6.0	13.9	648	6.5	7.5	213
		7.0	13.7	654	6.3	7.5	215
D2	3:21P	0.0	20.0	553	8.7	8.4	197
		1.0	18.7	571	7.7	8.0	200
		2.0	17.2	596	7.3	7.9	205
		3.0	17.0	601	7.7	7.9	207
		4.0	15.4	634	6.8	7.8	211
		5.0	14.0	663	5.9	7.6	215
		6.0	13.3	677	6.5	7.6	218
D3	3:32P	0.0	20.2	544	8.8	8.4	200
		1.0	19.7	550	8.5	8.0	202
		2.0	17.8	586	7.6	7.9	207
		3.0	17.4	599	7.7	7.9	210
		4.0	17.0	606	7.7	7.8	211
		5.0	14.5	650	6.2	7.6	217
		5.8	13.8	668	6.4	7.5	220

Table C5. Willard Reservoir field data, 30 June, 1986.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
Inlet	9:16A	0.0	23.4	512	7.2	8.7	254
		1.0	22.9	493	7.4	7.7	254
		2.0	19.7	409	7.0	8.7	249
		2.4	19.0	410	7.6	8.7	251
A1	9:45A	0.0	23.3	515	7.7	8.6	254
		1.0	23.1	518	7.4	8.6	256
		2.0	22.9	519	7.4	8.6	258
		3.0	22.8	520	7.4	8.6	259
		4.0	22.6	523	7.3	8.6	250
		5.0	22.5	523	7.2	8.6	261
		6.0	22.4	524	7.2	8.6	262
A2	10:06A	0.0	23.8	510	7.7	8.7	254
		1.0	23.6	513	7.4	8.7	256
		2.0	23.4	515	7.3	8.7	257
		3.0	23.3	516	6.9	8.6	259
		4.0	22.3	524	6.6	8.6	261
		5.0	22.3	523	6.7	8.6	262
		6.0	22.2	525	6.7	8.6	263
A3	10:18A	0.0	23.6	512	7.8	8.7	252
		1.0	23.4	514	8.0	8.7	254
		2.0	23.1	517	8.1	8.7	256
		3.0	22.9	519	8.4	8.7	258
		4.0	22.5	518	8.1	8.6	259
		5.0	22.2	513	7.5	8.5	261
		6.0	22.1	513	8.3	8.5	262
A4	10:31A	0.0	23.5	508	7.6	8.6	249
		1.0	23.2	513	7.3	8.6	252
		2.0	23.2	513	7.3	8.6	254
		3.0	23.1	514	7.4	8.7	255
		4.0	23.0	513	7.4	8.7	256
		5.0	22.7	516	6.9	8.6	257
		6.0	22.5	517	7.1	8.5	260
B1	11:10A	0.0	23.8	508	7.4	8.9	249
		1.0	23.4	509	7.4	8.9	251
		2.0	23.2	512	7.2	8.9	252
		3.0	23.1	515	7.9	8.8	254
		4.0	23.1	517	7.7	8.8	255
		5.0	22.5	510	6.2	8.7	258
		6.0	22.0	524	4.4	8.5	262
		7.0	21.8	525	4.6	8.4	263

Table C5. Continued.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
B2	11:29A	0.0	24.7	501	7.7	8.8	248
		1.0	23.8	511	7.4	8.8	251
		2.0	23.4	515	7.4	8.8	252
		3.0	23.4	514	7.5	8.8	253
		4.0	22.5	527	6.5	8.6	256
		5.0	22.1	524	6.0	8.6	258
		6.0	21.6	518	5.8	8.6	259
B3	11:47A	0.0	24.8	502	7.6	8.7	246
		1.0	23.7	514	7.1	8.7	250
		2.0	23.4	518	7.2	8.7	253
		3.0	23.4	518	7.2	8.7	253
		4.0	23.1	520	7.2	8.7	255
		5.0	22.8	524	6.9	8.6	257
		5.5	22.7	525	6.9	8.6	258
B4	12:05P	0.0	24.5	504	7.7	8.6	248
		1.0	23.4	515	7.2	8.6	253
		2.0	22.8	521	7.4	8.6	254
		3.0	22.6	524	7.7	8.6	256
		4.0	22.4	524	7.7	8.6	246
		5.0	22.1	506	8.1	8.6	256
C1	12:38P	0.0	25.2	497	7.5	8.7	243
		1.0	24.2	509	6.9	8.8	246
		2.0	23.0	519	7.0	8.8	250
		3.0	22.6	524	7.0	8.7	251
		4.0	22.6	524	7.1	8.7	252
C2	12:52P	0.0	25.2	499	7.6	8.7	245
		1.0	23.9	511	7.3	8.7	247
		2.0	23.5	516	7.3	8.7	249
		3.0	23.2	517	7.3	8.7	249
		4.0	23.2	518	7.4	8.7	251
		5.0	22.9	523	7.3	8.7	252
C3	1:04P	0.0	25.4	497	7:5	8.7	245
		1.0	25.2	497	7.6	8.7	247
		2.0	24.6	503	7.6	8.7	247
		3.0	24.0	511	7.3	8.7	249
		4.0	23.5	514	7.0	8.7	250
		5.0	23.5	515	7.5	8.7	252

Table C5. Continued.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
D1	1:24P	0.0	25.2	496	7.6	8.7	244
		1.0	24.6	503	7.5	8.7	246
		2.0	23.9	508	7.6	8.7	248
		3.0	23.7	511	7.4	8.7	248
		4.0	23.6	513	7.5	8.7	249
		5.0	23.5	514	7.5	8.7	250
		6.0	23.4	515	7.6	8.7	251
		7.0	23.2	517	8.0	8.7	252
D2	1:38P	0.0	25.5	491	7.4	8.7	244
		1.0	23.7	513	6.8	8.7	248
		2.0	23.4	516	6.9	8.7	249
		3.0	23.2	518	6.7	8.7	250
		4.0	23.0	521	6.8	8.7	251
		5.0	22.9	524	6.5	8.7	253
		6.0	22.7	526	6.5	8.6	253
D3	1:50P	0.0	25.6	496	7.3	8.7	244
		1.0	23.3	518	6.8	8.7	248
		2.0	23.3	518	7.0	8.7	251
		3.0	23.2	518	7.1	8.7	251
		4.0	23.1	519	7.1	8.7	252
		5.0	22.7	525	6.6	8.6	254
D4	2:06P	0.0	26.5	486	7.6	8.7	244
		1.0	24.2	509	6.9	8.7	248
		2.0	23.2	519	6.7	8.7	251
		3.0	22.8	524	6.8	8.6	252
		4.0	22.7	525	6.8	8.6	254
		5.0	22.5	525	6.8	8.6	255

Table C6. Willard Reservoir field data, 1 August, 1986.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
Inlet	2:27P	0.0	25.7	561	7.0	8.8	217
		1.0	25.1	553	7.0	8.8	221
		2.0	24.9	546	7.0	8.7	224
		2.4	24.3	554	6.8	8.5	229
A2	2:43P	0.0	25.2	577	7.8	8.7	201
		1.0	24.6	583	8.0	8.7	205
		2.0	23.6	596	7.8	8.6	209
		3.0	22.9	605	7.6	8.5	213
		4.0	22.6	610	7.4	8.4	216
		5.0	22.3	616	7.1	8.4	218
		5.5	22.0	624	6.7	8.3	220
A4	3:01P	0.0	25.4	575	8.1	8.6	182
		1.0	24.8	583	8.3	8.6	189
		2.0	23.3	599	7.9	8.6	193
		3.0	22.2	615	7.5	8.4	198
		4.0	22.0	618	7.5	8.3	202
		5.0	21.8	622	7.3	8.3	205
		5.5	21.6	630	6.8	8.2	207
B3	3:35P	0.0	25.7	569	8.6	8.7	170
		1.0	23.8	593	8.5	8.7	177
		2.0	22.6	611	7.7	8.5	182
		3.0	21.8	632	6.8	8.2	188
		4.0	21.4	644	6.1	8.2	190
		5.0	21.2	659	5.3	8.0	193
		5.5	21.1	671	4.4	7.9	195
B4	3:55P	0.0	25.5	569	8.2	8.6	160
		1.0	23.7	590	7.9	8.6	174
		2.0	22.9	606	8.3	8.5	178
		3.0	22.4	616	8.3	8.4	182
		4.0	21.7	637	7.7	8.2	187
		5.0	21.5	646	7.6	8.0	190
C3	4:22P	0.0	26.2	567	8.5	8.6	166
		1.0	24.0	592	8.2	8.7	173
		2.0	23.1	602	8.2	8.6	176
		3.0	21.8	625	7.7	8.4	182
		4.0	21.7	628	7.8	8.3	185
		5.0	21.6	629	7.7	8.3	188

Table C7. Willard Reservoir field data, 20 August, 1986.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
Inlet	10:48A	0.0	26.0	637	6.7	8.5	141
		1.0	25.7	636	6.5	8.5	144
		2.0	25.2	637	5.9	8.2	149
A1	12:49P	0.0	25.7	642	6.3	8.6	152
		1.0	25.5	644	6.4	8.6	154
		2.0	25.1	650	6.4	8.5	157
		3.0	25.0	652	6.4	8.5	159
		4.0	24.7	660	6.0	8.3	162
		5.0	23.8	690	4.3	7.9	169
A2	1:02P	0.0	25.6	645	6.0	8.5	165
		1.0	25.3	648	6.2	8.5	167
		2.0	25.0	652	6.3	8.4	168
		3.0	24.6	657	6.3	8.4	170
		4.0	24.5	659	6.4	8.1	172
		5.0	24.4	662	6.2	8.1	174
A3	1:19P	0.0	25.4	651	5.5	8.4	175
		1.0	25.0	655	5.6	8.4	177
		2.0	24.7	658	5.7	8.3	178
		3.0	24.3	664	5.7	8.3	179
		4.0	24.2	666	5.8	8.3	180
		5.0	24.2	668	5.8	8.1	183
B1	1:39P	0.0	25.5	653	5.1	8.3	182
		1.0	25.4	654	5.1	8.3	183
		2.0	24.7	663	5.1	8.3	185
		3.0	24.5	667	5.1	8.3	186
		4.0	24.4	668	5.1	8.2	187
		5.0	24.3	670	5.3	7.8	188
		5.5	23.6	696	3.7	7.8	191
B2	1:53P	0.0	25.9	642	5.7	8.5	183
		1.0	25.6	648	5.5	8.4	185
		2.0	24.8	658	5.6	8.4	187
		3.0	24.7	659	5.7	8.4	188
		4.0	24.6	661	5.7	8.4	189
		4.5	24.6	664	5.6	8.3	190

Table C7. Continued.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
B3	2:09P	0.0	26.0	638	5.9	8.5	187
		1.0	25.9	639	6.1	8.5	188
		2.0	25.4	646	6.4	8.2	189
		3.0	25.0	652	6.3	8.2	191
		4.0	24.7	662	5.4	8.1	196
		4.5	23.5	693	3.6	7.6	203
C1	2:21P	0.0	26.2	637	5.9	8.5	188
		1.0	26.0	639	6.2	8.5	190
		2.0	25.4	647	6.3	8.5	192
		3.0	25.2	649	6.7	8.2	194

Table C8. Willard Reservoir field data, 23 October, 1986.

Sample Site	Time	Depth (m)	T (C)	EC, mhos/ cm at 25°C	D.O (mg/l)	pH	ORP (mv)
B3	10:02A	0.0	11.7	937	7.3	8.3	199
		1.0	11.7	939	7.4	8.3	200
		2.0	11.7	937	7.5	8.3	200
		3.0	11.7	937	7.7	8.4	201
		4.0	11.7	939	7.9	8.4	202
		5.0	11.6	941	7.9	8.3	203

APPENDIX D

WILLARD RESERVOIR SALINITY MODEL RESULTS

NOTE ALL FLOWS AND VOLUMES IN THOUSAND AC-FT

DATE	BEG VOL AC-FT	WILL. CAN. INFLOW AC-FT	WILL. CAN. CON MG/L	WILL. CAN. LOAD TON/MONTH	WILL. CREEK INFLOW AC-FT	WILL CREK CON MG/L	WILL CREK LOAD TONS/MONTH	PREC AC-FT	EVAP AC-FT	NET INFLOW AC-FT	TOTAL LOAD TONS/MONTH	WILL. VOL AC-FT	WILL. RES CON MG/L	PUMPED RELEASE AC-FT	OTHER RELEASE AC-FT	TOTAL OLTFLOW AC-FT	END OF MONTH VOL AC-FT	END OF MONT CONC MG/L
1973																	165.1	562
1974 Oct	165.1	1.4	191	363.664	0.3	210	85.68	0.7	2.3	0.1	449.344	165.2	583.69		4.6	4.6	160.6	583.7
	160.6	0	225	0	0.1	200	27.2	0.8		0.9	27.2	161.5	601.05		1.2	1.2	160.3	601.0
	160.3	0	250	0	0.1	190	25.84	0.9		1	25.84	161.3	617.95		3.1	3.1	158.2	618.0
	158.2	0	270	0	0.1	165	22.44	1.4		1.5	22.44	159.7	632.97		0.2	0.2	159.5	633.0
	159.5	0.2	273	74.256	0.1	150	20.4	0.7		1	94.656	160.5	650.08		2.3	2.3	158.2	650.1
	158.2	3.6	235	1150.56	0.2	140	38.08	0.4		4.2	1188.64	162.4	659.02		4.2	4.2	158.2	659.0
	158.2	13.8	178	3340.704	0.4	135	73.44	1.2		15.4	3414.144	173.6	634.08		10.5	10.5	163.1	634.1
	163.1	48.8	147	9756.096	2.2	145	433.84	0.2	5.3	45.9	10189.936	209	546.51		26.9	26.9	182.1	546.5
	182.1	9.7	206	2717.552	2.7	175	642.6	0.2	6.8	5.8	3360.152	187.9	560.40		8.5	8.5	179.4	560.4
	179.4	5.1	240	1664.64	2.8	215	818.72	0	8	-0.1	2483.36	179.3	589.35		6.9	6.9	172.4	589.3
	172.4	4.3	235	1374.28	1.9	230	594.32	0	6.2	-4.441E-16	1968.6	172.4	616.94		7.2	7.2	165.2	616.9
	165.2	2.6	262	926.432	1.9	220	568.48	0	4.4	0.1	1494.912	165.3	643.23		5.4	5.4	159.9	643.2
1975	159.9	3.4	266	1229.984	0	210	0	2.1	2.5	3	1229.984	162.9	657.25		6.7	6.7	156.2	657.2
	156.2	0	270	0	0.1	200	27.2	0.7	0	0.8	27.2	157	675.10		2.8	2.8	154.2	675.1
	154.2	0	275	0	0.1	190	25.84	0.9	0	1	25.84	155.2	692.19		1.5	1.5	153.7	692.2
	153.7	0.8	248	269.824	0.1	165	22.44	0.8	0	1.7	292.264	155.4	707.30		0.3	0.3	155.1	707.3
	155.1	0	264	0	0.1	150	20.4	0.6	0	0.7	20.4	155.8	725.45		0.6	0.6	155.2	725.5
	155.2	3.5	275	1309	0.2	140	38.08	2.5	0	6.2	1347.08	161.4	724.22		4.4	4.4	157	724.2
	157	14.1	273	5235.048	1.8	135	330.48	1	0	16.9	5565.528	173.9	696.40		9	9	164.9	696.4
	164.9	55.2	180	13512.96	2.9	145	571.88	1.3	4.1	55.3	14084.84	220.2	583.57		37.6	37.6	182.6	583.6
	182.6	47	192	12272.64	0	175	0	1.4	5	43.4	12272.64	226	526.07		48	48	178	526.1
	178	12.1	228	3751.968	0.6	215	175.44	0.4	6.1	7	3927.408	185	539.66		18	18	167	539.7
	167	4.2	96	548.352	1.1	230	344.08	0	5.4	-0.1	892.432	166.9	563.74		6.2	6.2	160.7	563.7
	160.7	2.4	236	770.304	1.3	220	388.96	0.1	3.7	0.1	1159.264	160.8	589.27		4.3	4.3	156.5	589.3
1976	156.5	0	289	0	0	210	0	1.9	0	1.9	0	158.4	603.09		5.1	5.1	153.3	603.1
	153.3	2	220	598.4	0.1	200	27.2	0.8	0	2.9	625.6	156.2	616.02		4.9	4.9	151.3	616.[illegible]
	151.3	5.1	242	1678.512	0.1	190	25.84	0.5	0	5.7	1704.352	157	622.71		2.7	2.7	154.3	622.7
	154.3	16.8	228	5209.344	0.1	165	22.44	0.3	0	17.2	5231.784	171.5	601.99		12.3	12.3	159.2	602.0
	159.2	5.7	257	1992.264	0.1	150	20.4	2	0	7.8	2012.664	167	602.54		4	4	163	602.5
	163	4.2	284	1622.208	0.2	140	38.08	0.8	0	5.2	1660.288	168.2	610.85		2.8	2.8	165.4	610.8
	165.4	13	184	3253.12	0.5	135	91.8	1.8	2.8	12.5	3344.92	177.9	600.35		5.9	5.9	172	600.4
	172	10.6	200	2883.2	1.6	145	315.52	0.8	5.4	7.6	3198.72	179.6	606.46		2.4	2.4	177.2	606.5
	177.2	4	206	1120.64	0.4	175	95.2	1	5.3	0.1	1215.84	177.3	629.83		5	5	172.3	629.8
	172.3	4.8	223	1455.744	0.7	215	204.68	0.5	6.4	-0.4	1660.424	171.9	657.64		9.6	9.6	162.3	657.6
	162.3	4.3	250	1462	0.2	230	62.56	0.9	5.4	-4.996E-16	1524.56	162.3	684.94		10.7	10.7	151.6	684.9
	151.6	2.4	258	842.112	0.4	220	119.68	0.8	3.5	0.1	961.792	151.7	710.96		4.4	4.4	147.3	711.0
1977	147.3	0.5	284	193.12	0.9	210	257.04	0.7	1.9	0.2	450.16	147.5	734.67		5.8	5.8	141.7	734.7
	141.7	0	264	0	0.1	200	27.2	0	0	0.1	27.2	141.8	757.63		3	3	138.8	757.6
	138.8	2.4	300	979.2	0.1	190	25.84	0.1	0	2.6	1005.04	141.4	772.33		2.6	2.6	138.8	772.3
	138.8	3.2	318	1383.936	0.1	165	22.44	0.7	0	4	1406.376	142.8	781.10		1.9	1.9	140.9	781.1
	140.9	9.7	378	4966.576	0.1	150	20.4	0.1	0	9.9	5006.976	150.8	776.18		4.6	4.6	146.2	776.2
	146.2	9.3	303	3832.344	0.2	140	38.08	0.5	0	10	3870.424	156.2	765.89		3.3	3.3	152.9	765.9
	152.9	0	360	0	0.3	135	55.08	0.6	0	0.9	55.08	153.8	783.19		4.7	4.7	149.1	783.2
	149.1	10	262	3563.2	0.6	145	118.32	3.1	3.9	9.8	3681.52	158.9	772.74		6.7	6.7	152.2	772.7
	152.2	2.8	400	1523.2	2.5	175	595	0	6.3	-1	2118.2	151.2	810.04		12.9	12.9	138.3	810.0
	138.3	5	280	1904	0.8	215	233.92	0.7	6.5	0	2137.92	138.3	845.33		18.4	18.4	119.9	845.3
	119.9	3.2	293	1275.136	0	230	0	1.9	5.1	4.441E-16	1275.136	119.9	860.75		16.7	16.7	103.2	860.7
	103.2	1.9	250	646	0.5	220	149.6	1	3.5	-0.1	795.6	103.1	919.37		4.6	4.6	98.5	919.4
1978	98.5	1.4	248	472.192	0.2	210	57.12	0.3	1.7	0.2	529.312	98.7	954.97		0.8	0.8	97.9	955.0
	97.9	0.5	313	212.84	0.1	200	27.2	0.4	0	1	240.04	98.9	980.56		0.8	0.8	98.1	980.6

	98.1	10.1	244	3351.584	0.1	190	25.84	0.8	0	11	3377.424	109.1	934.78		4.1	4.1	105	934.8
	105	17.7	254	6114.288	0.1	165	22.44	1.1	0	18.9	6136.728	123.9	855.31		9.2	9.2	114.7	855.3
	114.7	11.1	300	4528.8	0.1	150	20.4	1.9	0	13.1	4549.2	127.8	819.71		0	0	127.8	819.7
	127.8	33.9	265	12217.56	0.2	140	38.08	1.3	0	35.4	12255.64	163.2	717.39		11.9	11.9	151.3	717.4
	151.3	42.3	168	9664.704	0.4	135	73.44	1.9	0	44.6	9738.144	195.9	607.51		11.9	11.9	184	607.5
	184	29	139	5482.16	1.8	145	354.96	0.9	4	27.7	5837.12	211.7	563.92		26.5	26.5	185.2	563.9
	185.2	29.2	219	8696.928	2	175	476	0.2	5	26.4	9172.928	211.6	541.08		26.6	26.6	185	541.1
	185	5.1	245	1699.32	0.2	215	58.48	0.2	5.6	-0.1	1757.8	184.9	566.26		6.7	6.7	178.2	566.3
	178.2	4.3	213	1245.624	0.2	230	62.56	0.6	5.1	1.665E-16	1308.184	178.2	590.22		10	10	168.2	590.2
	168.2	1.3	287	507.416	0	220	0	1.5	2.8	2.220E-16	507.416	168.2	612.11		2.9	2.9	165.3	612.1
1979	165.3	1.2	302	492.864	0.7	210	199.92	0	2	-0.1	692.784	165.2	635.60		4	4	161.2	635.6
	161.2	0	310	0	0.1	200	27.2	0.9	0	1	27.2	162.2	652.20		2.4	2.4	159.8	652.2
	159.8	6.8	200	1849.6	0.1	190	25.84	0.8	0	7.7	1875.44	167.5	650.21		7.7	7.7	159.8	650.2
	159.8	12.9	261	4578.984	0.1	165	22.44	1.5	0	14.5	4601.424	174.3	634.51		12.4	12.4	161.9	634.5
	161.9	26.4	256	9191.424	0.1	150	20.4	1.6	0	28.1	9211.824	190	593.73		26.5	26.5	163.5	593.7
	163.5	26.6	246	8899.296	0.2	140	38.08	0.5	0	27.3	8937.376	190.8	560.57		31	31	159.8	560.6
	159.8	50.2	186	12698.592	2	135	367.2	0.4	2.9	49.7	13065.792	209.5	489.23		45.4	45.4	164.1	489.2
	164.1	29.8	116	4701.248	1.1	145	216.92	1	4	27.9	4918.168	192	454.21		5.8	5.8	186.2	454.2
	186.2	0.6	188	153.408	0.6	175	142.8	0.3	5.4	-3.9	296.208	182.3	483.27		0	0	192.3	483.3
	182.3	0.7	164	156.128	0	215	0	1.4	6.2	-4.1	156.128	178.2	513.60		0	0	178.2	513.6
	178.2	0	200	0	0	230	0	1.1	4.9	-3.8	0	174.4	543.77		3.7	3.7	170.7	543.8
	170.7	0	250	0	0	220	0	0	3.3	-3.3	0	167.4	574.25		2.3	2.3	165.1	574.3
1980	165.1	0	283	0	0	210	0	1.5	0	1.5	0	166.6	588.94		3.6	3.6	163	588.9
	163	0.5	297	201.96	0.1	200	27.2	0.5	0	1.1	229.16	164.1	606.19		1.1	1.1	163	606.2
	163	3.6	330	1615.68	0.1	190	25.84	0.1	0	3.8	1641.52	166.8	619.45		0.3	0.3	166.5	619.4
	166.5	14.5	342	6744.24	0.1	165	22.44	2.7	0	17.3	6766.68	183.8	606.22		0.2	0.2	183.6	606.2
	183.6	9.8	283	3771.824	0.1	150	20.4	1.1	0	11	3792.224	194.6	603.28		10.4	10.4	184.2	603.3
	184.2	23.7	281	9057.192	0.2	140	38.08	1.2	0	25.1	9095.272	209.3	578.70		25.9	25.9	183.4	578.7
	183.4	33.5	256	11663.36	0.2	135	36.72	1.5	0	35.2	11700.08	218.6	540.00		41.2	41.2	177.4	540.0
	177.4	38.2	139	7221.328	1.4	145	276.08	3.1	3.5	39.2	7497.408	216.6	483.00		32.6	32.6	184	483.0
	184	16.1	170	3722.32	1.5	175	357	1.5	5.4	13.7	4079.32	197.7	481.44		15.8	15.8	181.9	481.4
	181.9	0.8	252	274.176	0	215	0	0.6	5.8	-4.4	274.176	177.5	513.15		0	0	177.5	513.2
	177.5	0	200	0	0.4	230	125.12	0.5	5.2	-4.3	125.12	173.2	545.53		1.7	1.7	171.5	545.5
	171.5	0	256	0	0	220	0	0.5	3.2	-2.7	0	168.8	573.85		0.4	0.4	168.4	573.9
1981	168.4	0	258	0	0	210	0	1.1	1.8	-0.7	0	167.7	595.98	0	2.8	2.8	164.9	596.0
	164.9	0	484	0	0.1	200	27.2	0.7	0	0.8	27.2	165.7	613.19	0	2	2	163.7	613.2
	163.7	0	280	0	0.1	190	25.84	0.4	0	0.5	25.84	164.2	631.59	0	1.5	1.5	162.7	631.6
	162.7	5.3	339	2443.512	0.1	165	22.44	1.2	0	6.6	2465.952	169.3	637.22	0	0.4	0.4	168.9	637.2
	168.9	6.2	375	3162	0.1	150	20.4	0.1	0	6.4	3182.4	175.3	646.18	0	0.3	0.3	175	646.2
	175	9.1	270	3341.52	0.2	140	38.08	1.8	0	11.1	3379.6	186.1	638.77	0	0.3	0.3	185.8	638.8
	185.8	9.2	183	2289.696	2	135	367.2	0.6	3.2	8.6	2656.896	194.4	637.59	0	10	10	184.4	637.6
	184.4	0	160	0	1.4	145	276.08	2.6	3.6	0.4	276.08	184.8	655.21	0	0.3	0.3	184.5	655.2
	184.5	2	293	796.96	1.5	175	357	0.4	5.1	-1.2	1153.96	183.3	682.18	3.7	1.3	5	178.3	682.2
	178.3	0	486	0	1.5	215	438.6	0	6.7	-5.2	438.6	173.1	723.65	12.8	3.6	16.4	156.7	723.6
	156.7	0	534	0	1.3	230	406.64	0.2	5.8	-4.3	406.64	152.4	767.74	12.1	3.3	15.4	137	767.7
	137	0	334	0	1.3	220	388.96	0.1	3.7	-2.3	388.96	134.7	807.54	5.4	3.4	8.8	125.9	807.5
1982	125.9	0	292	0	0	210	0	3.9	0	3.9	0	129.8	808.77	0	1.4	1.4	128.4	808.8
	128.4	0	298	0	0.1	200	27.2	0.5	0	0.6	27.2	129	830.81	0	2.9	2.9	126.1	830.8
	126.1	5.2	297	2100.384	0.1	190	25.84	1.1	0	6.4	2126.224	132.5	827.45	0	0.3	0.3	132.2	827.5
	132.2	11.5	281	4394.84	0.1	165	22.44	0.6	0	12.2	4417.28	144.4	802.95	0	0.2	0.2	144.2	802.9
	144.2	6	206	1680.96	0.1	150	20.4	0.6	0	6.7	1701.36	150.9	797.52	0	9.7	9.7	141.2	797.5
	141.2	27.4	257	9576.848	0.2	140	38.08	2.6	0	30.2	9614.928	171.4	717.55	0	13	13	158.4	717.5
	158.4	45.5	245	15160.6	0.2	135	36.72	1	2.9	43.8	15197.32	202.2	633.74	0	43.2	43.2	159	633.7
	159	43.9	147	8776.488	1.4	145	276.08	0.9	4.1	42.1	9052.568	201.1	550.62	0	26.2	26.2	174.9	550.6
	174.9	1.7	200	462.4	1.5	175	357	0.2	5.2	-1.8	819.4	173.1	578.94	0	0.3	0.3	172.8	578.9
	172.8	1.6	190	413.44	0	215	0	2.5	6.3	-2.2	413.44	170.6	607.59	0.7	0.2	0.9	169.7	607.6

	169.7	0	205	0	0.4	230	125.12	0.4	5.1	-4.3	125.12	165.4	643.95	0	2.1	2.1	163.3	643.9
	163.3	0	245	0	0	220	0	6.1	3	3.1	0	166.4	651.83	0	4.4	4.4	162	651.8
1983	162	18.5	291	7321.56	0	210	0	1.8	0	20.3	7321.56	182.3	626.93		40	40	142.3	626.9
	142.3	0.9	200	244.8	0.1	200	27.2	1.5	0	2.5	272	144.8	640.34		32.2	32.2	112.6	640.3
	112.6	0	240	0	0.1	190	25.84	2.3	0	2.4	25.84	115	655.91		2.4	2.4	112.6	655.9
	112.6	17.1	235	5465.16	0.1	165	22.44	0.7	0	17.9	5487.6	130.5	622.22		2	2	128.5	622.2
	128.5	27.2	240	8878.08	0.1	150	20.4	1.1	0	28.4	8898.48	156.9	572.38		1.4	1.4	155.5	572.4
	155.5	34.3	231	10775.688	0.2	140	38.08	2.3	0	36.8	10813.768	192.3	521.40		25.3	25.3	167	521.4
	167	48	202	13186.56	0.4	135	73.44	2.2	0	50.6	13260	217.6	460.17		55.8	55.8	161.8	460.2
	161.8	58.4	174	13819.776	2.1	145	414.12	1.8	3.6	58.7	14233.896	220.5	400.14		51.3	51.3	169.2	400.1
	169.2	48	158	10314.24	2.9	175	690.2	0.6	4.8	46.7	11004.44	215.9	366.39		47	47	168.9	366.4
	168.9	0	183	0	0	215	0	1	5.4	-4.4	0	164.5	396.30		3.6	3.6	160.9	396.3
	160.9	0	235	0	0	230	0	3.4	5.2	-1.8	0	159.1	421.59		1.6	1.6	157.5	421.6
	157.5	0	245	0	0	220	0	2.3	3.4	-1.1	0	156.4	445.71		3.9	3.9	152.5	445.7

DATE	BEG VOL AC-FT	WILL. CAN. INFLOW AC-FT	WILL. CAN. CON MG/L	WILL. CAN. LOAD TON/MONTH	WILL. CREEK INFLOW AC-FT	WILL CREK CON MG/L	WILL CREK LOAD TONS/MONTH	PREC AC-FT	EVAP AC-FT	NET INFLOW AC-FT	TOTAL LOAD TON/MONTH	WILL VOL AC-FT	WILL RES CON MG/L	PUMPED RELEASE AC-FT	OTHER RELEASE AC-FT	TOTAL OUTFLOW AC-FT	END OF MONTH VOL AC-FT	END OF MONTH CONC MG/L
NOTE ALL FLOWS AND VOLUMES IN THOUSAND AC-FT																		
1973																	165.1	562
1974 Oct	165.1	1.4	191	363.664	0.3	210	85.68	0.7	2.3	0.1	449.344	165.2	563.66		4.6	4.6	160.6	563.7
	160.6	0	225	0	0.1	200	27.2	0.8		0.9	27.2	161.5	560.64		1.2	1.2	160.3	560.6
	160.3	0	250	0	0.1	190	25.84	0.9		1	25.84	161.3	557.28		3.1	3.1	158.2	557.3
	158.2	0	270	0	0.1	165	22.44	1.4		1.5	22.44	159.7	552.15		0.2	0.2	159.5	552.2
	159.5	0.2	273	74.256	0.1	150	20.4	0.7		1	94.656	160.5	549.15		2.3	2.3	158.2	549.1
	158.2	3.6	235	1150.56	0.2	140	38.08	0.4		4.2	1188.64	162.4	540.33		4.2	4.2	158.2	540.3
	158.2	13.8	178	3340.704	0.4	135	73.44	1.2		15.4	3414.144	173.6	506.86		10.5	10.5	163.1	506.9
	163.1	48.8	147	9756.096	2.2	145	433.84	0.2	5.3	45.9	10189.936	209	431.39		26.9	26.9	182.1	431.4
	182.1	9.7	206	2717.552	2.7	175	642.6	0.2	6.8	5.8	3360.152	187.9	431.22		8.5	8.5	179.4	431.2
	179.4	5.1	240	1664.64	2.8	215	818.72	0	8	-0.1	2483.36	179.3	441.65		6.9	6.9	172.4	441.6
	172.4	4.3	235	1374.28	1.9	230	594.32	0	6.2	-4.441E-16	1968.6	172.4	450.04		7.2	7.2	165.2	450.0
	165.2	2.6	262	926.432	1.9	220	568.48	0	4.4	0.1	1494.912	165.3	456.42		5.4	5.4	159.9	456.4
1975	159.9	3.4	266	1229.984	0	210	0	2.1	2.5	3	1229.984	162.9	453.57		6.7	6.7	156.2	453.6
	156.2	0	270	0	0.1	200	27.2	0.7	0	0.8	27.2	157	451.38		2.8	2.8	154.2	451.4
	154.2	0	275	0	0.1	190	25.84	0.9	0	1	25.84	155.2	448.60		1.5	1.5	153.7	448.6
	153.7	0.8	248	269.824	0.1	165	22.44	0.8	0	1.7	292.264	155.4	445.07		0.3	0.3	155.1	445.1
	155.1	0	264	0	0.1	150	20.4	0.6	0	0.7	20.4	155.8	443.17		0.6	0.6	155.2	443.2
	155.2	3.5	275	1309	0.2	140	38.08	2.5	0	6.2	1347.08	161.4	432.28		4.4	4.4	157	432.3
	157	14.1	273	5235.048	1.8	135	330.48	1	0	16.9	5565.528	173.9	413.81		9	9	164.9	413.8
	164.9	55.2	180	13512.96	2.9	145	571.88	1.3	4.1	55.3	14084.84	220.2	356.92		37.6	37.6	182.6	356.9
	182.6	47	192	12272.64	0	175	0	1.4	5	43.4	12272.64	226	328.31		48	48	178	328.3
	178	12.1	228	3751.968	0.6	215	175.44	0.4	6.1	7	3927.408	185	331.49		18	18	167	331.5
	167	4.2	96	548.352	1.1	230	344.08	0	5.4	-0.1	892.432	166.9	335.62		6.2	6.2	160.7	335.6
	160.7	2.4	236	770.304	1.3	220	388.96	0.1	3.7	0.1	1159.264	160.8	340.72		4.3	4.3	156.5	340.7
1976	156.5	0	289	0	0	210	0	1.9	0	1.9	0	158.4	336.63		5.1	5.1	153.3	336.6
	153.3	2	220	598.4	0.1	200	27.2	0.8	0	2.9	625.6	156.2	333.32		4.9	4.9	151.3	333.3
	151.3	5.1	242	1678.512	0.1	190	25.84	0.5	0	5.7	1704.352	157	329.20		2.7	2.7	154.3	329.2
	154.3	16.8	228	5209.344	0.1	165	22.44	0.3	0	17.2	5231.784	171.5	318.62		12.3	12.3	159.2	318.6
	159.2	5.7	257	1992.264	0.1	150	20.4	2	0	7.8	2012.664	167	312.60		4	4	163	312.6
	163	4.2	284	1622.208	0.2	140	38.08	0.8	0	5.2	1660.288	168.2	310.19		2.8	2.8	165.4	310.2
	165.4	13	184	3253.12	0.5	135	91.8	1.8	2.6	12.5	3344.92	177.9	302.22		5.9	5.9	172	302.2
	172	10.6	200	2883.2	1.6	145	315.52	0.8	5.4	7.6	3198.72	179.6	302.53		2.4	2.4	177.2	302.5
	177.2	4	206	1120.64	0.4	175	95.2	1	5.3	0.1	1215.84	177.3	307.40		5	5	172.3	307.4
	172.3	4.8	223	1455.744	0.7	215	204.68	0.5	6.4	-0.4	1660.424	171.9	315.22		9.6	9.6	162.3	315.2
	162.3	4.3	250	1462	0.2	230	62.56	0.9	5.4	-4.996E-16	1524.56	162.3	322.13		10.7	10.7	151.6	322.1
	151.6	2.4	258	842.112	0.4	220	119.68	0.8	3.5	0.1	961.792	151.7	326.58		4.4	4.4	147.3	326.6
1977	147.3	0.5	284	193.12	0.9	210	257.04	0.7	1.9	0.2	450.16	147.5	328.38		5.8	5.8	141.7	328.4
	141.7	0	264	0	0.1	200	27.2	0	0	0.1	27.2	141.8	328.29		3	3	138.8	328.3
	138.8	2.4	300	979.2	0.1	190	25.84	0.1	0	2.6	1005.04	141.4	327.48		2.6	2.6	138.8	327.5
	138.8	3.2	318	1383.936	0.1	165	22.44	0.7	0	4	1406.376	142.8	325.54		1.9	1.9	140.9	325.5
	140.9	9.7	378	4986.576	0.1	150	20.4	0.1	0	9.9	5006.976	150.8	328.59		4.6	4.6	146.2	328.6
	146.2	9.3	303	3832.344	0.2	140	38.08	0.5	0	10	3870.424	156.2	325.77		3.3	3.3	152.9	325.8
	152.9	0	360	0	0.3	135	55.08	0.6	0	0.9	55.08	153.8	324.13		4.7	4.7	149.1	324.1
	149.1	10	262	3563.2	0.6	145	118.32	3.1	3.9	9.8	3681.52	158.9	321.17		6.7	6.7	152.2	321.2
	152.2	2.8	400	1523.2	2.5	175	595	0	6.3	-1	2118.2	151.2	333.60		12.9	12.9	138.3	333.6
	138.3	5	280	1904	0.8	215	233.92	0.7	6.5	0	2137.92	138.3	344.96		18.4	18.4	119.9	345.0
	119.9	3.2	293	1275.136	0	230	0	1.9	5.1	4.441E-16	1275.136	119.9	352.78		16.7	16.7	103.2	352.8
	103.2	1.9	250	646	0.5	220	149.6	1	3.5	-0.1	795.6	103.1	358.80		4.6	4.6	98.5	358.8
1978	98.5	1.4	248	472.192	0.2	210	57.12	0.3	1.7	0.2	529.312	98.7	362.02		0.8	0.8	97.9	362.0
	97.9	0.5	313	212.84	0.1	200	27.2	0.4	0	1	240.04	98.9	360.14		0.8	0.8	98.1	360.1

	98.1	10.1	244	3351.584	0.1	190	25.84	0.8	0	11	3377.424	109.1	346.59		4.1	4.1	105	346.6
	105	17.7	254	6114.289	0.1	165	22.44	1.1	0	18.9	6136.728	123.9	330.14		9.2	9.2	114.7	330.1
	114.7	11.1	300	4528.8	0.1	150	20.4	1.9	0	13.1	4549.2	127.8	322.47		0	0	127.8	322.5
	127.8	33.9	265	12217.56	0.2	140	38.08	1.3	0	35.4	12255.64	163.2	307.74		11.9	11.9	151.3	307.7
	151.3	42.3	168	9664.704	0.4	135	73.44	1.9	0	44.6	9738.144	195.9	274.23		11.9	11.9	184	274.2
	184	29	139	5482.16	1.8	145	354.96	0.9	4	27.7	5837.12	211.7	258.62		26.5	26.5	185.2	258.6
	185.2	29.2	219	8696.928	2	175	476	0.2	5	26.4	9172.928	211.6	258.23		26.6	26.6	185	258.2
	185	5.1	245	1699.32	0.2	215	58.48	0.2	5.6	-0.1	1757.8	184.9	265.36		6.7	6.7	178.2	265.4
	178.2	4.3	213	1245.624	0.2	230	62.56	0.6	5.1	1.665E-16	1308.184	178.2	270.76		10	10	168.2	270.8
	168.2	1.3	287	507.416	0	220	0	1.5	2.8	2.220E-16	507.416	168.2	272.98		2.9	2.9	165.3	273.0
1979	165.3	1.2	302	492.864	0.7	210	199.92	0	2	-0.1	692.784	165.2	276.23		4	4	161.2	276.2
	161.2	0	310	0	0.1	200	27.2	0.9	0	1	27.2	162.2	274.65		2.4	2.4	159.8	274.6
	159.8	6.8	200	1849.6	0.1	190	25.84	0.8	0	7.7	1875.44	167.5	270.25		7.7	7.7	159.8	270.3
	159.8	12.9	261	4578.984	0.1	165	22.44	1.5	0	14.5	4601.424	174.3	267.18		12.4	12.4	161.9	267.2
	161.9	26.4	256	9191.424	0.1	150	20.4	1.6	0	28.1	9211.824	190	263.32		26.5	26.5	163.5	263.3
	163.5	26.6	246	8899.296	0.2	140	38.08	0.5	0	27.3	8937.376	190.8	260.08		31	31	159.8	260.1
	159.8	50.2	186	12698.592	2	135	367.2	0.4	2.9	49.7	13065.792	209.5	244.24		45.4	45.4	164.1	244.2
	164.1	29.8	116	4701.248	1.1	145	216.92	1	4	27.9	4918.168	192	227.59		5.8	5.8	186.2	227.6
	186.2	0.6	188	153.408	0.6	175	142.8	0.3	5.4	-3.9	296.208	182.3	233.65		0	0	182.3	233.6
	182.3	0.7	164	156.128	0	215	0	1.4	6.2	-4.1	156.128	178.2	239.67		0	0	178.2	239.7
	178.2	0	200	0	0	230	0	1.1	4.9	-3.8	0	174.4	244.89		3.7	3.7	170.7	244.9
	170.7	0	250	0	0	220	0	0	3.3	-3.3	0	167.4	[illegible]		2.3	2.3	165.1	249.7
1980	165.1	0	283	0	0	210	0	1.5	0	1.5	0	166.6	247.47		3.6	3.6	163	247.5
	163	0.5	297	201.96	0.1	200	27.2	0.5	0	1.1	229.16	164.1	246.84		1.1	1.1	163	246.8
	163	3.6	330	1615.68	0.1	190	25.84	0.1	0	3.8	1641.52	166.8	248.45		0.3	0.3	166.5	248.5
	166.5	14.5	342	6744.24	0.1	165	22.44	2.7	0	17.3	6766.68	183.8	252.14		0.2	0.2	183.6	252.1
	183.6	9.8	283	3771.824	0.1	150	20.4	1.1	0	11	3792.224	194.6	252.21		10.4	10.4	184.2	252.2
	184.2	23.7	281	9057.192	0.2	140	38.08	1.2	0	25.1	9095.272	209.3	253.92		25.9	25.9	183.4	253.9
	183.4	33.5	256	11663.36	0.2	135	36.72	1.5	0	35.2	11700.08	218.6	252.39		41.2	41.2	177.4	252.4
	177.4	38.2	139	7221.328	1.4	145	276.08	3.1	3.5	39.2	7497.408	216.6	232.16		32.6	32.6	184	232.2
	184	16.1	170	3722.32	1.5	175	357	1.5	5.4	13.7	4079.32	197.7	231.25		15.8	15.8	181.9	231.2
	181.9	0.8	252	274.176	0	215	0	0.6	5.8	-4.4	274.176	177.5	238.11		0	0	177.5	238.1
	177.5	0	200	0	0.4	230	125.12	0.5	5.2	-4.3	125.12	173.2	244.56		1.7	1.7	171.5	244.6
	171.5	0	256	0	0	220	0	0.5	3.2	-2.7	0	168.8	248.47		0.4	0.4	168.4	248.5
1981	168.4	0	258	0	0	210	0	1.1	1.8	-0.7	0	167.7	249.51	0	2.8	2.8	164.9	249.5
	164.9	0	484	0	0.1	200	27.2	0.7	0	0.8	27.2	165.7	248.42	0	2	2	163.7	248.4
	163.7	0	280	0	0.1	190	25.84	0.4	0	0.5	25.84	164.2	247.78	0	1.5	1.5	162.7	247.8
	162.7	5.3	339	2443.512	0.1	165	22.44	1.2	0	6.6	2465.952	169.3	248.83	0	0.4	0.4	168.9	248.8
	168.9	6.2	375	3162	0.1	150	20.4	0.1	0	6.4	3182.4	175.3	253.10	0	0.3	0.3	175	253.1
	175	9.1	270	3341.52	0.2	140	38.08	1.8	0	11.1	3379.6	186.1	251.35	0	0.3	0.3	185.8	251.4
	185.8	9.2	183	2289.696	2	135	367.2	0.6	3.2	8.6	2656.896	194.4	250.28	0	10	10	184.4	250.3
	184.4	0	160	0	1.4	145	276.08	2.6	3.6	0.4	276.08	184.8	250.84	0	0.3	0.3	184.5	250.8
	184.5	2	293	796.96	1.5	175	357	0.4	5.1	-1.2	1153.96	183.3	257.11	3.7	1.3	5	178.3	257.1
	178.3	0	486	0	1.5	215	438.6	0	6.7	-5.2	438.6	173.1	266.70	12.8	3.6	16.4	156.7	266.7
	156.7	0	534	0	1.3	230	406.64	0.2	5.8	-4.3	406.64	152.4	276.18	12.1	3.3	15.4	137	276.2
	137	0	334	0	1.3	220	388.96	0.1	3.7	-2.3	388.96	134.7	283.02	5.4	3.4	8.8	125.9	283.0
1982	125.9	0	292	0	0	210	0	3.9	0	3.9	0	129.8	274.52	0	1.4	1.4	128.4	274.5
	128.4	0	298	0	0.1	200	27.2	0.5	0	0.6	27.2	129	273.40	0	2.9	2.9	126.1	273.4
	126.1	5.2	297	2100.384	0.1	190	25.84	1.1	0	6.4	2126.224	132.5	271.99	0	0.3	0.3	132.2	272.0
	132.2	11.5	281	4394.84	0.1	165	22.44	0.6	0	12.2	4417.28	144.4	271.50	0	0.2	0.2	144.2	271.5
	144.2	6	206	1680.96	0.1	150	20.4	0.6	0	6.7	1701.36	150.9	267.74	0	9.7	9.7	141.2	267.7
	141.2	27.4	257	9576.848	0.2	140	38.08	2.6	0	30.2	9614.928	171.4	261.81	0	13	13	158.4	261.8
	158.4	45.5	245	15160.6	0.2	135	36.72	1	2.9	43.8	15197.32	202.2	260.36	0	43.2	43.2	159	260.4
	159	43.9	147	8776.488	1.4	145	276.08	0.9	4.1	42.1	9052.568	201.1	238.96	0	26.2	26.2	174.9	239.0
	174.9	1.7	200	462.4	1.5	175	357	0.2	5.2	-1.8	819.4	173.1	244.92	0	0.3	0.3	172.8	244.9
	172.8	1.6	190	413.44	0	215	0	2.5	6.3	-2.2	413.44	170.6	249.86	0.7	0.2	0.5	169.7	249.9

	169.7	0	205	0	0.4	230	125.12	0.4	5.1	-4.3	125.12	165.4	256.91	0	2.1	2.1	163.3	256.9
	163.3	0	245	0	0	220	0	6.1	3	3.1	0	166.4	252.13	0	4.4	4.4	162	252.1
1983	162	18.5	291	7321.56	0	210	0	1.8	0	20.3	7321.56	182.3	253.58		40	40	142.3	253.6
	142.3	0.9	200	244.8	0.1	200	27.2	1.5	0	2.5	272	144.8	250.59		32.2	32.2	112.6	250.6
	112.6	0	240	0	0.1	190	25.84	2.3	0	2.4	25.84	115	245.52		2.4	2.4	112.6	245.5
	112.6	17.1	235	5465.16	0.1	165	22.44	0.7	0	17.9	5487.6	130.5	242.76		2	2	128.5	242.8
	128.5	27.2	240	8878.08	0.1	150	20.4	1.1	0	28.4	8898.48	156.9	240.52		1.4	1.4	155.5	240.5
	155.5	34.3	231	10775.688	0.2	140	38.08	2.3	0	36.8	10813.768	192.3	235.84		25.3	25.3	167	235.8
	167	48	202	13186.56	0.4	135	73.44	2.2	0	50.6	13260	217.6	225.81		55.8	55.8	161.8	225.8
	161.8	58.4	174	13819.776	2.1	145	414.12	1.8	3.6	58.7	14233.896	220.5	213.16		51.3	51.3	169.2	213.2
	169.2	46	158	10314.24	2.9	175	690.2	0.6	4.8	46.7	11004.44	215.9	204.53		47	47	168.9	204.5
	168.9	0	183	0	0	215	0	1	5.4	-4.4	0	164.5	210.00		3.6	3.6	160.9	210.0
	160.9	0	235	0	0	230	0	3.4	5.2	-1.8	0	159.1	212.38		1.6	1.6	157.5	212.4
	157.5	0	245	0	0	220	0	2.3	3.4	-1.1	0	156.4	213.87		3.9	3.9	152.5	213.9

PREDICTED MAXIMUM 1124.60678

DATE	BEG VOL AC-FT	WILL. CAN. INFLOW AC-FT	BEAR RIVER CON MG/L	BEAR RIVER LOAD TON/MONTH	WILL. CREEK INFLOW AC-FT	WILL CREK CON MG/L	WILL CREK LOAD TONS/MONTH	PREC AC-FT	EVAP AC-FT	NET INFLOW AC-FT	TOTAL LOAD TONS/MONTH	WILLARD VOL. AC-FT	WILL RES CON MG/L	PUMPED RELEASE AC-FT	OTHER RELEASE AC-FT	TOTAL OUTFLOW AC-FT	END OF MONTH VOL AC-FT	END OF MONT CONC MG/L
NOTE ALL FLOWS AND VOLUMES IN THOUSAND AC-FT																		
1973																	165.1	562
1974 OCT	165.1	1.4	390	742.56	0.3	210	85.68	0.7	2.3	0.1	828.24	165.2	585.38		4.6	4.6	160.6	585.4
NOV	160.6	0	384	0	0.1	200	27.2	0.8		0.9	27.2	161.5	602.73		1.2	1.2	160.3	602.7
DEC	160.3	0	418	0	0.1	190	25.84	0.9		1	25.84	161.3	619.62		3.1	3.1	158.2	619.6
JAN	158.2	0	418	0	0.1	165	22.44	1.4		1.5	22.44	159.7	634.62		0.2	0.2	159.5	634.6
FEB	159.5	0.2	300	81.6	0.1	150	20.4	0.7		1	102	160.5	651.75		2.3	2.3	158.2	651.8
MAR	158.2	3.6	398	1948.608	0.2	140	38.08	0.4		4.2	1986.688	162.4	664.27		4.2	4.2	158.2	664.3
APR	158.2	13.8	408	7657.344	0.4	135	73.44	1.2		15.4	7730.784	173.6	657.14		10.5	10.5	163.1	657.1
MAY	163.1	48.8	374	24821.632	2.2	145	433.84	0.2	5.3	45.9	25255.472	209	617.51		26.9	26.9	182.1	617.5
JUN	182.1	9.7	327	4313.784	2.7	175	642.6	0.2	6.8	5.8	4956.384	187.9	635.45		8.5	8.5	179.4	635.5
JUL	179.4	5.1	396	2746.656	2.8	215	818.72	0	8	-0.1	3565.376	179.3	668.88		6.9	6.9	172.4	668.9
AUG	172.4	4.3	372	2175.456	1.9	230	594.32	0	6.2	-4.441E-16	2769.776	172.4	699.89		7.2	7.2	165.2	699.9
SEP	165.2	2.6	410	1449.76	1.9	220	568.48	0	4.4	0.1	2018.24	165.3	728.46		5.4	5.4	159.9	728.5
1975	159.9	3.4	390	1803.36	0	210	0	2.1	2.5	3	1803.36	162.9	743.49		6.7	6.7	156.2	743.5
	156.2	0	384	0	0.1	200	27.2	0.7	0	0.8	27.2	157	760.91		2.8	2.8	154.2	760.9
	154.2	0	418	0	0.1	190	25.84	0.9	0	1	25.84	155.2	777.45		1.5	1.5	153.7	777.4
	153.7	0.8	418	454.784	0.1	165	22.44	0.8	0	1.7	477.224	155.4	792.49		0.3	0.3	155.1	792.5
	155.1	0	300	0	0.1	150	20.4	0.6	0	0.7	20.4	155.8	810.27		0.6	0.6	155.2	810.3
	155.2	3.5	398	1894.48	0.2	140	38.08	2.5	0	6.2	1932.56	161.4	808.45		4.4	4.4	157	808.4
	157	14.1	408	7823.808	1.8	135	330.48	1	0	16.9	8154.288	173.9	783.39		9	9	164.9	783.4
	164.9	55.2	374	28076.928	2.9	145	571.88	1.3	4.1	55.3	28648.808	220.2	697.34		37.6	37.6	182.6	697.3
	182.6	47	327	20901.84	0	175	0	1.4	5	43.4	20901.84	226	646.07		48	48	178	646.1
	178	12.1	396	6516.576	0.6	215	175.44	0.4	6.1	7	6692.016	185	666.11		18	18	167	666.1
	167	4.2	372	2124.864	1.1	230	344.08	0	5.4	-0.1	2468.944	166.9	697.21		6.2	6.2	160.7	697.2
	160.7	2.4	410	1338.24	1.3	220	388.96	0.1	3.7	0.1	1727.2	160.8	725.25		4.3	4.3	156.5	725.3
1976	156.5	0	390	0	0	210	0	1.9	0	1.9	0	158.4	737.44		5.1	5.1	153.3	737.4
	153.3	2	384	1044.48	0.1	200	27.2	0.8	0	2.9	1071.68	156.2	749.98		4.9	4.9	151.3	750.0
	151.3	5.1	418	2899.248	0.1	190	25.84	0.5	0	5.7	2925.088	157	757.52		2.7	2.7	154.3	757.5
	154.3	16.8	418	9550.464	0.1	165	22.44	0.3	0	17.2	9572.904	171.5	741.89		12.3	12.3	159.2	741.9
	159.2	5.7	300	2325.6	0.1	150	20.4	2	0	7.8	2346	167	737.38		4	4	163	737.4
	163	4.2	398	2273.376	0.2	140	38.08	0.8	0	5.2	2311.456	168.2	744.36		2.8	2.8	165.4	744.4
	165.4	13	408	7213.44	0.5	135	91.8	1.8	2.8	12.5	7305.24	177.9	740.85		5.9	5.9	172	740.9
	172	10.6	374	5391.584	1.6	145	315.52	0.8	5.4	7.6	5707.104	179.6	751.29		2.4	2.4	177.2	751.3
	177.2	4	327	1778.88	0.4	175	95.2	1	5.3	0.1	1874.08	177.3	777.30		5	5	172.3	777.3
	172.3	4.8	396	2585.088	0.7	215	204.68	0.5	6.4	-0.4	2789.768	171.9	810.29		9.6	9.6	162.3	810.3
	162.3	4.3	372	2175.456	0.2	230	62.56	0.9	5.4	-4.996E-16	2238.016	162.3	840.82		10.7	10.7	151.6	840.8
	151.6	2.4	410	1338.24	0.4	220	119.68	0.8	3.5	0.1	1457.92	151.7	869.14		4.4	4.4	147.3	869.1
1977	147.3	0.5	390	265.2	0.9	210	257.04	0.7	1.9	0.2	522.24	147.5	893.00		5.8	5.8	141.7	893.0
	141.7	0	384	0	0.1	200	27.2	0	0	0.1	27.2	141.8	915.84		3	3	138.8	915.8
	138.8	2.4	418	1364.352	0.1	190	25.84	0.1	0	2.6	1390.192	141.4	929.63		2.6	2.6	138.8	929.6
	138.8	3.2	418	1819.136	0.1	165	22.44	0.7	0	4	1841.576	142.8	936.25		1.9	1.9	140.9	936.2
	140.9	9.7	300	3957.6	0.1	150	20.4	0.1	0	9.9	3978	150.8	916.12		4.6	4.6	146.2	916.1
	146.2	9.3	398	5033.904	0.2	140	38.08	0.5	0	10	5071.984	156.2	902.53		3.3	3.3	152.9	902.5
	152.9	0	408	0	0.3	135	55.08	0.6	0	0.9	55.08	153.8	919.03		4.7	4.7	149.1	919.0
	149.1	10	374	5086.4	0.6	145	118.32	3.1	3.9	9.8	5204.72	158.9	907.25		6.7	6.7	152.2	907.3
	152.2	2.8	327	1245.216	2.5	175	595	0	6.3	-1	1840.216	151.2	944.09		12.9	12.9	138.3	944.1
	138.3	5	396	2652.8	0.8	215	233.92	0.7	6.5	0	2926.72	138.3	983.57		18.4	18.4	119.9	983.6
	119.9	3.2	372	1618.944	0	230	0	1.9	5.1	4.441E-16	1618.944	119.9	1021.10		16.7	16.7	103.2	1021.1
	103.2	1.9	410	1059.44	0.5	220	149.6	1	3.5	-0.1	1209.04	103.1	1062.80		4.6	4.6	98.5	1062.8
1978	98.5	1.4	390	742.56	0.2	210	57.12	0.3	1.7	0.2	799.68	98.7	1100.13		0.8	0.8	97.9	1100.1

	97.9	0.5	384	261.12	0.1	200	27.2	0.4	0	1	288.32	98.9	1124.61		0.8	0.8	98.1	1124.6
	98.1	10.1	418	5741.648	0.1	190	25.84	0.8	0	11	5767.488	109.1	1080.42		4.1	4.1	105	1080.4
	105	17.7	418	10062.096	0.1	165	22.44	1.1	0	18.9	10084.536	123.9	1002.16		9.2	9.2	114.7	1002.2
	114.7	11.1	300	4528.8	0.1	150	20.4	1.9	0	13.1	4549.2	127.8	951.50		0	0	127.8	951.5
	127.8	33.9	398	18349.392	0.2	140	38.08	1.3	0	35.4	18387.472	163.2	848.23		11.9	11.9	151.3	848.2
	151.3	42.3	408	23471.424	0.4	135	73.44	1.9	0	44.6	23544.864	195.9	760.38		11.9	11.9	184	760.4
	184	29	374	14750.56	1.8	145	354.96	0.9	4	27.7	15105.52	211.7	728.98		26.5	26.5	185.2	729.0
	185.2	29.2	327	12985.824	2	175	476	0.2	5	26.4	13461.824	211.6	700.45		26.6	26.6	185	700.4
	185	5.1	396	2746.656	0.2	215	58.48	0.2	5.6	-0.1	2805.136	184.9	729.88		6.7	6.7	178.2	729.9
	178.2	4.3	372	2175.456	0.2	230	62.56	0.6	5.1	1.665E-16	2238.016	178.2	757.68		10	10	168.2	757.7
	168.2	1.3	410	724.88	0	220	0	1.5	2.8	2.220E-16	724.88	168.2	780.52		2.9	2.9	165.3	780.5
1979	165.3	1.2	390	636.48	0.7	210	199.92	0	2	-0.1	836.4	165.2	804.74		4	4	161.2	804.7
	161.2	0	384	0	0.1	200	27.2	0.9	0	1	27.2	162.2	820.31		2.4	2.4	159.8	820.3
	159.8	6.8	418	3865.664	0.1	190	25.84	0.8	0	7.7	3891.504	167.5	819.43		7.7	7.7	159.8	819.4
	159.8	12.9	418	7333.392	0.1	165	22.44	1.5	0	14.5	7355.832	174.3	801.28		12.4	12.4	161.9	801.3
	161.9	26.4	300	10771.2	0.1	150	20.4	1.6	0	28.1	10791.6	190	741.95		26.5	26.5	163.5	742.0
	163.5	26.6	398	14398.048	0.2	140	38.08	0.5	0	27.3	14436.128	190.8	708.77		31	31	159.8	708.8
	159.8	50.2	408	27854.976	2	135	367.2	0.4	2.9	49.7	28222.176	209.5	655.47		45.4	45.4	164.1	655.5
	164.1	29.8	374	15157.472	1.1	145	216.92	1	4	27.9	15374.392	192	636.34		5.8	5.8	186.2	636.3
	186.2	0.6	327	266.832	0.6	175	142.8	0.3	5.4	-3.9	409.632	182.3	669.75		0	0	182.3	669.8
	182.3	0.7	396	376.992	0	215	0	1.4	6.2	-4.1	376.992	178.2	705.29		0	0	178.2	705.3
	178.2	0	372	0	0	230	0	1.1	4.9	-3.8	0	174.4	739.63		3.7	3.7	170.7	739.6
	170.7	0	410	0	0	220	0	0	3.3	-3.3	0	167.4	773.97		2.3	2.3	165.1	774.0
1980	165.1	0	390	0	0	210	0	1.5	0	1.5	0	166.6	786.86		3.6	3.6	163	786.9
	163	0.5	384	261.12	0.1	200	27.2	0.5	0	1.1	288.32	164.1	803.04		1.1	1.1	163	803.0
	163	3.6	418	2046.528	0.1	190	25.84	0.1	0	3.8	2072.368	166.8	813.72		0.3	0.3	166.5	813.7
	166.5	14.5	418	8242.96	0.1	165	22.44	2.7	0	17.3	8265.4	183.8	788.20		0.2	0.2	183.6	788.2
	183.6	9.8	300	3998.4	0.1	150	20.4	1.1	0	11	4018.8	194.6	775.83		10.4	10.4	184.2	775.8
	184.2	23.7	398	12828.336	0.2	140	38.08	1.2	0	25.1	12866.416	209.3	743.80		25.9	25.9	183.4	743.8
	183.4	33.5	408	18588.48	0.2	135	36.72	1.5	0	35.2	18625.2	218.6	701.82		41.2	41.2	177.4	701.8
	177.4	38.2	374	19430.048	1.4	145	276.08	3.1	3.5	39.2	19706.128	216.6	656.98		32.6	32.6	184	657.0
	184	16.1	327	7159.992	1.5	175	357	1.5	5.4	13.7	7516.992	197.7	656.14		15.8	15.8	181.9	656.1
	181.9	0.8	396	430.848	0	215	0	0.6	5.8	-4.4	430.848	177.5	692.84		0	0	177.5	692.8
	177.5	0	372	0	0.4	230	125.12	0.5	5.2	-4.3	125.12	173.2	729.67		1.7	1.7	171.5	729.7
	171.5	0	410	0	0	220	0	0.5	3.2	-2.7	0	168.8	760.94		0.4	0.4	168.4	760.9
1981	168.4	0	390	0	0	210	0	1.1	1.8	-0.7	0	167.7	783.85	0	2.8	2.8	164.9	783.9
	164.9	0	384	0	0.1	200	27.2	0.7	0	0.8	27.2	165.7	800.16	0	2	2	163.7	800.2
	163.7	0	418	0	0.1	190	25.84	0.4	0	0.5	25.84	164.2	817.99	0	1.5	1.5	162.7	818.0
	162.7	5.3	418	3012.944	0.1	165	22.44	1.2	0	6.6	3035.384	169.3	818.83	0	0.4	0.4	168.9	818.8
	168.9	6.2	300	2529.6	0.1	150	20.4	0.1	0	6.4	2550	175.3	818.50	0	0.3	0.3	175	818.5
	175	9.1	398	4925.648	0.2	140	38.08	1.8	0	11.1	4963.728	186.1	807.07	0	0.3	0.3	185.8	807.1
	185.8	9.2	408	5104.896	2	135	367.2	0.6	3.2	8.6	5472.096	194.4	809.09	0	10	10	184.4	809.1
	184.4	0	374	0	1.4	145	276.08	2.6	3.6	0.4	276.08	184.8	826.34	0	0.3	0.3	184.5	826.3
	184.5	2	327	889.44	1.5	175	357	0.4	5.1	-1.2	1246.44	183.3	854.80	3.7	1.3	5	178.3	854.8
	178.3	0	396	0	1.5	215	438.6	0	6.7	-5.2	438.6	173.1	901.46	12.8	3.6	16.4	156.7	901.5
	156.7	0	372	0	1.3	230	406.64	0.2	5.8	-4.3	406.64	152.4	950.57	12.1	3.3	15.4	137	950.6
	137	0	410	0	1.3	220	388.96	0.1	3.7	-2.3	388.96	134.7	993.49	5.4	3.4	8.8	125.9	993.5
1982	125.9	0	390	0	0	210	0	3.9	0	3.9	0	129.8	989.13	0	1.4	1.4	128.4	989.1
	128.4	0	384	0	0.1	200	27.2	0.5	0	0.6	27.2	129	1010.33	0	2.9	2.9	126.1	1010.3
	126.1	5.2	418	2956.096	0.1	190	25.84	1.1	0	6.4	2981.936	132.5	1003.05	0	0.3	0.3	132.2	1003.1
	132.2	11.5	418	6537.52	0.1	165	22.44	0.6	0	12.2	6559.96	144.4	974.62	0	0.2	0.2	144.2	974.6
	144.2	6	300	2448	0.1	150	20.4	0.6	0	6.7	2468.4	150.9	965.30	0	9.7	9.7	141.2	965.3
	141.2	27.4	398	14831.072	0.2	140	38.08	2.6	0	30.2	14869.152	171.4	878.31	0	13	13	158.4	878.3
	158.4	45.5	408	25247.04	0.2	135	36.72	1	2.9	43.8	25283.76	202.2	796.36	0	43.2	43.2	159	796.4
	159	43.9	374	22329.296	1.4	145	276.08	0.9	4.1	42.1	22605.376	201.1	729.75	0	26.2	26.2	174.9	729.8
	174.9	1.7	327	756.024	1.5	175	357	0.2	5.2	-1.8	1113.024	173.1	760.17	0	0.3	0.3	172.8	760.2

	172.8	1.6	396	861.696	0	215	0	2.5	6.3	-2.2	861.696	170.6	793.09	0.7	0.2	0.9	169.7	793.1
	169.7	0	372	0	0.4	230	125.12	0.4	5.1	-4.3	125.12	165.4	834.27	0	2.1	2.1	163.3	834.3
	163.3	0	410	0	0	220	0	6.1	3	3.1	0	166.4	838.61	0	4.4	4.4	162	838.6
1983	162	18.5	390	9812.4	0	210	0	1.8	0	20.3	9812.4	182.3	802.95		40	40	142.3	803.0
	142.3	0.9	384	470.016	0.1	200	27.2	1.5	0	2.5	497.216	144.8	814.47		32.2	32.2	112.6	814.5
	112.6	0	418	0	0.1	190	25.84	2.3	0	2.4	25.84	115	826.41		2.4	2.4	112.6	826.4
	112.6	17.1	418	9721.008	0.1	165	22.44	0.7	0	17.9	9743.448	130.5	793.31		2	2	128.5	793.3
	128.5	27.2	300	11097.6	0.1	150	20.4	1.1	0	28.4	11118	156.9	722.90		1.4	1.4	155.5	722.9
	155.5	34.3	398	18565.904	0.2	140	38.08	2.3	0	36.8	18603.984	192.3	672.91		25.3	25.3	167	672.9
	167	49	408	26634.24	0.4	135	73.44	2.2	0	50.6	26707.68	217.6	621.88		55.8	55.8	161.8	621.9
	161.8	56.4	.374	29704.576	2.1	145	414.12	1.8	3.6	58.7	30118.696	220.5	571.77		51.3	51.3	169.2	571.8
	169.2	49	327	21346.56	2.9	175	690.2	0.6	4.8	46.7	22036.76	215.9	538.47		47	47	168.9	538.5
	168.9	0	396	0	0	215	0	1	5.4	-4.4	0	164.5	572.99		3.6	3.6	160.9	573.0
	160.9	0	372	0	0	230	0	3.4	5.2	-1.8	0	159.1	600.27		1.6	1.6	157.5	600.3
	157.5	0	410	0	0	220	0	2.3	3.4	-1.1	0	156.4	625.65		3.9	3.9	152.5	625.6