WATER QUALITY BRANCH
WATER MANAGEMENT DIVISION
MINISTRY OF ENVIRONMENT, LANDS AND PARKS

Water Quality Assessment and Objectives for San Jose River Basin Williams Lake Area

OVERVIEW

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GLOSSARY

Ambient	Refers to background environmental conditions outside the zone in which water quality may be influenced by a given discharges or a sources of contamination.
Anthropogenic	Man-made or man-modified.
Attainment	To gain, accomplish or achieve something, as whether or not ambient water quality attains recommended objectives.
Concentration	Mass of a substance per unit volume of water or per unit mass of sediment.
Designated water use	A water use that is to be protected at a specific location. Designated water uses include: drinking water, aquatic life and wildlife; agriculture (irrigation, livestock watering); recreation and aesthetics; and industrial water supply (including food processing industries).
Dissolved metals/substances	Refers to metals/substances in solution, or to the fraction which passes through a filter of a specified pore size (usually 0.45µm).
Freshet	Time period when water flow in a river or a stream is suddenly increased due to spring snowmelt or heavy rainfall.
Fully recorded	Refers to a situation in a waterbody where all of the available water is allocated or authorized through licenses.
Habitat	A geographical place within an ecosystem where an organism, population or community resides, feeds, reproduces or rears.
Hydrology	Science dealing with the properties, distribution, and circulation of water in the land-soil-atmosphere environment.
Loading	The amount of a substance added to a waterbody from its surroundings.

Mainstem	The main course of a stream or a river.
Monitoring	To check, measure, or examine changes in water quality over a period of time.
Riparian	Refers to land bordering a waterbody.
Site-specific	Limited to a site in question.
Stream improvement	One or more works in or about a stream; e.g., works related to diverting, storing, measuring, conserving, conveying, retarding, confining, or using water.
Survey	A study of generalized nature.
Suspended solids	Particles of solid matter in water which do not pass through filter of a specified pore size (usually 0.45 μm). Also called non-filterable residue, suspended matter, or suspended sediment.
Suspended metals/substances	Metals/substances attached to suspended solids.
Total metals/substances	Sum of dissolved and suspended metals/substances.
Water quality objectives	Safe concentrations of substances or conditions which will protect the most sensitive water uses of a waterbody.
Water Use	Human or natural use of water. Also, see definition of 'Designated water use'.
Watershed	Either the total area drained by a river and its tributaries (the drainage basin), or the total area of land contributing runoff above a given point on a stream.

SUMMARY

THIS DOCUMENT is one in a series that presents ambient water quality objectives for British Columbia. It has two parts: an overview- which is also available as a separate document- and the report. The overview provides general information about water quality in the San Jose River basin, and a water quality objectives and monitoring table for those readers requiring data. It is intended for both technical readers and for readers who may not be familiar with the process of setting water quality objectives. The report presents the details of the water quality assessment in the San Jose River basin, and forms the basis of the recommendations and objectives presented in the overview.

In 1987, the Ministry of Environment, Lands and Parks assessed water quality and set water quality objectives in Williams Lake. The report suggested that the San Jose River basin was the major source of phosphorus loading to Williams Lake. As a result, the Northern Sub-Regional Office requested that the Water Quality Branch in Victoria carry out a detailed water quality assessment in the basin to set water quality objectives in the San Jose River and its tributaries.

This report summarizes the results of the water quality assessment of the San Jose River and its tributaries. Objectives for phosphorus in the San Jose River basin are proposed to protect water quality in Williams Lake from land use activities in basin. All available data and current water quality criteria were used to derive water quality objectives.

PREFACE

Purpose of Water Quality Objectives

WATER QUALITY OBJECTIVES are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment, Lands and Parks' mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

How Objectives Are Determined

WATER QUALITY OBJECTIVES are based on scientific guidelines called water quality criteria*. Water quality criteria relate the physical, chemical or biological characteristics of water, biota (plant and animal life) or sediment to their effects on water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the criteria by considering local water quality, water uses, water movement, waste discharges and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific site or location. A designated water use is one that is protected in a given location and is one of the following:

- raw drinking water, public water supply and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies

* The process for establishing water quality objectives is outlined more fully in *Principles for Preparing Water Quality Objectives in British Columbia*. Copies of this document are available from the Water Quality Branch, Water Management Division.

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

How Objectives Are Used

WATER QUALITY OBJECTIVES have no legal standing at this time and are not directly enforced. However, they do provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licenses and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated. Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses.

Objectives and Monitoring

WATER QUALITY OBJECTIVES are established to protect all uses that may take place in a given waterbody. Monitoring, which is sometimes called sampling, is undertaken to determine if the designated water uses are being protected. Monitoring usually takes place at a critical time, as determined by a water quality specialist, when water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat to water quality is less. Monitoring usually takes place during a five-week period, which allows specialists to measure the worst, as well as the average, condition of the water. For some waterbodies, the monitoring period and frequency of sampling may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed; for example, objectives may be expressed as a 30-day average values, maximum values or annual phosphorus loading as in this document.

INTRODUCTION

THIS REPORT, UNDERTAKEN at the request of the Northern Sub-Regional office, assesses water quality in the San Jose River basin. Water quality objectives for phosphorus in the San Jose River and its tributaries are set to protect water quality in Williams Lake. Water quality objectives to protect designated water uses in the river and the tributaries were not considered in this document. An analysis of the available data did not suggest a need for this action.

The San Jose River originates at the outlet of Lac La Hache and flows northward about 52 km before entering Williams Lake. Borland Creek, Jones Creek, Knife Creek, and Five Mile and Valley creeks —which are tributaries of Borland Creek—are the major tributaries of the river.

The river and its tributaries are licensed for domestic water supply, stream improvement, water storage and irrigation water supply. The dammed reservoirs on the San Jose River, Borland Creek, Jones Creek and Knife Creek offer opportunities for storing and controlling water flow.

Rainbow trout—the main sport species resident in Williams Lake—spawns in the San Jose River basin. Commercial species include coho and pink salmon in the Lower Williams Lake River. Knife Creek supports a small winter and summer fishery. The fisheries resource is believed to have declined in the basin because of low summer and winter flows, riparian habitat loss, urbanization, beaver dam obstructions, and reduced water quality in the lake. Nevertheless, the San Jose River and its tributaries have the potential to support a good rainbow trout fishery, aided by an enhancement program.

Agriculture is the principal activity in the San Jose River basin. Traditional ranching practices involve forage production and watering and feeding cattle adjacent to the streams, particularly in winter. As yet, no appropriate survey or study has been conducted to link agriculture with fish habitat loss in the San Jose River basin.

Commercial logging activities in the San Jose River basin are concentrated at the middle to upper elevations. A study commissioned by the Ministry of Forests, Williams Lake, concluded that the effects of forestry on water quality (e.g., phosphorus loading) in the basin are minor, if any.

San Jose River Basin Profile

Hydrology

The San Jose River is approximately 52 km long from its origin at the outlet of Lac La Hache to the point where it enters Williams Lake (Figure 1). In terms of drainage area, the three most significant tributaries to the San Jose River are Borland Creek (228 km^2), Knife Creek (234 km^2), and Jones Creek (82.6 km^2); together, they comprise about 51% of the total drainage area of the San Jose River basin. Five Mile Creek (52.1 km^2) and Valley Creek (65 km^2) are major tributaries of Borland Creek.

Streamflow records in the San Jose River basin are sparse. They span forty years, but very few of the fifteen Water Survey of Canada stations have data that are complete and comparable. The San Jose River and most of its tributaries have storage areas, small lakes, and swampy areas within the basin that affect their flow.

Streamflow in the San Jose River basin is highly variable depending on the amount and timing of snowfall and rainfall, and on the melt pattern of the snow. Tributaries such as Borland Creek show two peaks: one in March and April caused by snowmelt, and a smaller peak in the fall. Rainfall in June or July can sometimes cause later or secondary flow peaks. The tributaries are typically dry during the summer and winter months.

Knife Creek is different from the other tributaries. It maintains a small flow throughout the year because of a spring-fed creek, which is a tributary to Knife Creek located upstream from Coldspring Creek.

Streamflow in the mainstem San Jose River is moderated by Lac la Hache. In high runoff years, the lake stabilizes the river's flow by providing storage capacity for the excess runoff. However, in dry years the lake has minimal outflow, causing the river to have very low flows.

Water Uses

Licences

The San Jose River and its tributaries are licensed for domestic water supply but primarily used for livestock watering, stream improvement, water storage and irrigation water supply. There are 15 domestic water licenses in the basin, but the majority of water licenses are for irrigation and water storage. The watershed of Borland Creek and Valley Creek are fully recorded.

Recreation

Water-based recreation in the San Jose Basin has not been developed. Much of the land along the stream banks is private, and access to the streams is restricted. Also, the narrowness and shallowness of the streams discourage recreational activities. On the mainstem of San Jose River, some canoeing, bird watching, hunting or walking may take place.

Fisheries

The San Jose River and its tributaries provide a habitat for rainbow trout, which is the main sport species in the basin. However, the rearing and spawning locations for the fish are not well known, but juveniles may be reared in Borland and Jones creeks. Other fish species in the basin include largescale suckers, peamouth chub, northern squawfish, redside shiners, burbot, and lake white fish. Knife Creek supports a small winter and summer sport fishery.

In general, the fisheries resource is believed to have declined in the basin because of low summer and winter flows, riparian habitat loss, urbanization, beaver dam obstructions and reduced water quality. Destruction of fish habitat by agricultural activities, and low stream flows caused by irrigation withdrawals and drought conditions during the 1980s, are thought to be the principal causes of the decline. However, no appropriate survey or study has been conducted in the basin to link agriculture with the loss of fish habitat.

The Regional Fisheries Branch in Williams Lake has determined that the San Jose River and its tributaries have the potential to support a good rainbow trout fishery, aided by enhancement programs. Rainbow trout eggs were released into Borland, Jones and Knife creeks in June and

July, 1990, to improve fish stock in Williams Lake by 1992. Kokanee were also stocked in the San Jose River several years ago for the same reason The results are as yet unknown. Rehabilitation projects may include fencing and revegetating areas along the San Jose River to prevent cattle access, reduce summer stream temperatures, enhance fish habitat, stabilize stream-bank erosion, and water augmentation.

Waste Discharges

Several human activities influence water quality in the San Jose River basin to varying degrees. They include residential development in and around Williams Lake, logging in the headwaters of the tributaries, road development and agriculture. However, a primary concern is the impact of traditional agricultural activities on ambient water quality in the San Jose River and its tributaries.

Agriculture

Ranching is the primary agricultural activity in the San Jose River basin. It includes the ranging of cattle on upland pastures during the summer, the irrigation of lowland fields for the production of hay and the over-wintering of cattle on lowland fields.

Traditional ranching practices involve watering and feeding cattle next to the streams, primarily in winter. These activities also take place in summer to some degree, especially at higher elevations. The unrestricted access of cattle to a stream or a river channel can affect ambient water quality in several ways:

- *Overgrazing and the removal of riparian vegetation.* Vegetation along the banks prevents elevated summer water temperatures by shading the stream. It also improves a fish habitat, stabilizes the stream banks against excessive erosion and make the stream less vulnerable to erosion and siltation.

- *Trampling of the stream or river banks by cattle.* The impact is the further destablization of the stream banks causing erosion and siltation.

- *Accumulation of manure on frozen ground during the winter.* The manure will be carried with surface runoff directly into nearby streams during freshet when the ground is still frozen and soil infiltration is minimal. The results are high concentrations of bacteria and nutrients in the stream.

In earlier assessments by the Ministry of Environment, Lands and Parks, San Jose River had been identified as the principal source of nutrients such as phosphorus to Williams Lake. Excessive amounts of phosphorus going into Williams Lake from agricultural activities[1] in the San Jose River basin has resulted in unacceptable water quality for domestic water uses, primary-contact recreation, and freshwater fisheries of the lake. To reduce phosphorus loading and to improve water quality in Williams Lake, two recommendations were made. First, the agricultural practices causing the effect, including the location and extent of over-wintering areas for cattle, should be identified. Second, water quality objectives should be set to protect water uses in the San Jose River basin and Williams Lake.

Recently, the Ministry of Environment, Lands and Parks, in co-operation with the Cariboo Cattlemen's Association and the Agricultural Environmental Protection Council (B.C. Federation of Agriculture), has initiated an active program of inspecting and enforcing the Agricultural Waste Control Regulations in the San Jose River basin. In late 1992, all ranches with high impact sites have put in place Best Waste Management Plans developed with the help of the Ministry of Agriculture, Fisheries and Food. As a result, all sites that have had high and moderate impact have been upgraded to low or low-to-moderate class.

Sewage Disposal

The effects of the residential septic systems along the shore of Williams Lake are the subject of a separate report.

Forestry

Most commercial logging in the San Jose River was conducted in the 1970s and 1980s. Douglas fir, which occupies the mid-elevations of the basin, is currently harvested by faller selection. Lodgepole pine, the other main species of timber occupying upper elevations, is harvested by clearcutting.

[1]The effects of the residential septic systems along the shore of Williams Lake are the subject of a separate report.

A study commissioned by the Ministry of Forest, Williams Lake, concluded that the effects of timber harvesting and related activities on water quality in the San Jose River basin is minor, if any.

WATER QUALITY ASSESSMENT AND OBJECTIVES

Water Quality Assessment

During the assessment of the data, several observations were made regarding water quality in the San Jose River basin.

- Agricultural activity was a major reason for high phosphorus concentrations in the San Jose River. Much of the phosphorus going into the streams from agricultural areas in the basin occurred during snowmelt.

- Among the tributaries, Borland Creek was the major source of phosphorus loading in the San Jose River. In 1991, Borland Creek contributed over 30% to the dissolved phosphorus going into the San Jose River at Williams Lake. Between April 12 and December 31, 1991, the dissolved and total phosphorus loading in Borland Creek at its mouth was estimated to be 920 kg and 2000 kg, respectively.

- Within the Borland Creek watershed, Five Mile Creek was the major source of phosphorus loading. It was estimated that Five Mile Creek contributed 745 kg of dissolved phosphorus to Borland Creek between January 24 and December 19, 1991. The total dissolved phosphorus going into Borland Creek downstream from Five Mile Creek was 920 kg between April 12 and December 31, 1991. Valley Creek, the other source of phosphorus entering Borland Creek, also contributed significantly, but to a lesser degree than Five Mile Creek.

- Knife Creek and Jones Creek also contributed significantly to phosphorus loading in the San Jose River. Knife Creek contributed 623 kg of dissolved phosphorus between April 9, 1991 and March 28, 1992. Jones Creek contributed 160 kg of dissolved phosphorus between April 9, 1991 and March 28, 1992.

- The 1990-91 average phosphorus concentrations in the San Jose River downstream from Borland Creek were 0.054 mg/L dissolved phosphorus and 0.041 mg/L suspended phosphorus. These data suggested that dissolved phosphorus contributed about 57% of the total phosphorus going into the San Jose River. Upstream from Borland Creek, however, the amount of dissolved phosphorus in the San Jose River was 43% of the total phosphorus.

Water Quality Objectives

Water quality objectives have been set for the dissolved phosphorus in the San Jose River basin to protect water quality in Williams Lake (Table 1). Table 1 also shows mean annual concentrations for the average flow year. These mean annual concentrations may be used to check the attainment of the objectives in the absence of or delay in the availability of flow measurements. It was assumed that the dissolved fraction was the most important component of the phosphorus loading to Williams Lake. The proposed water quality objectives were exceeded in the San Jose River downstream from Borland Creek.

Monitoring Recommendations

In general, water quality monitoring in the San Jose River basin has been inadequate. Given that water flow and phosphorus concentrations in the San Jose River and its tributaries are highly variable, and water quality objectives in the basin are based on allowable annual phosphorus loading to protect water uses in Williams Lake, it is recommended that both phosphorus concentrations and water flow must be measured simultaneously to check water quality objectives. As well, water quality objectives should be checked based on samples collected during the entire year. In the late spring, summer and early fall, biweekly samples may be acceptable. The frequency of sampling[2] may be increased to a daily or a weekly interval during snowmelt or a storm event, depending on changes in water flow patterns.

[2]Monthly samples from June to January, 3 samples in 2 trips/week in February, 5 samples in 3 trips/week in March, and weekly samples (subject to snow melt) in April and May (This constitutes 48 to 50 samples annually). This sampling schedule is based on the report: 'Design of a Water Quality Program for the San Jose River' by S. Hart (1991).

Water quality objectives for the allowable maximum phosphorus loading are proposed for several sites in the San Jose River basin (Table 1). It is recommended, however, that only site 0600316 in the San Jose River downstream from Borland Creek be monitored for attainment of the objectives[3]. The reasons for this are:

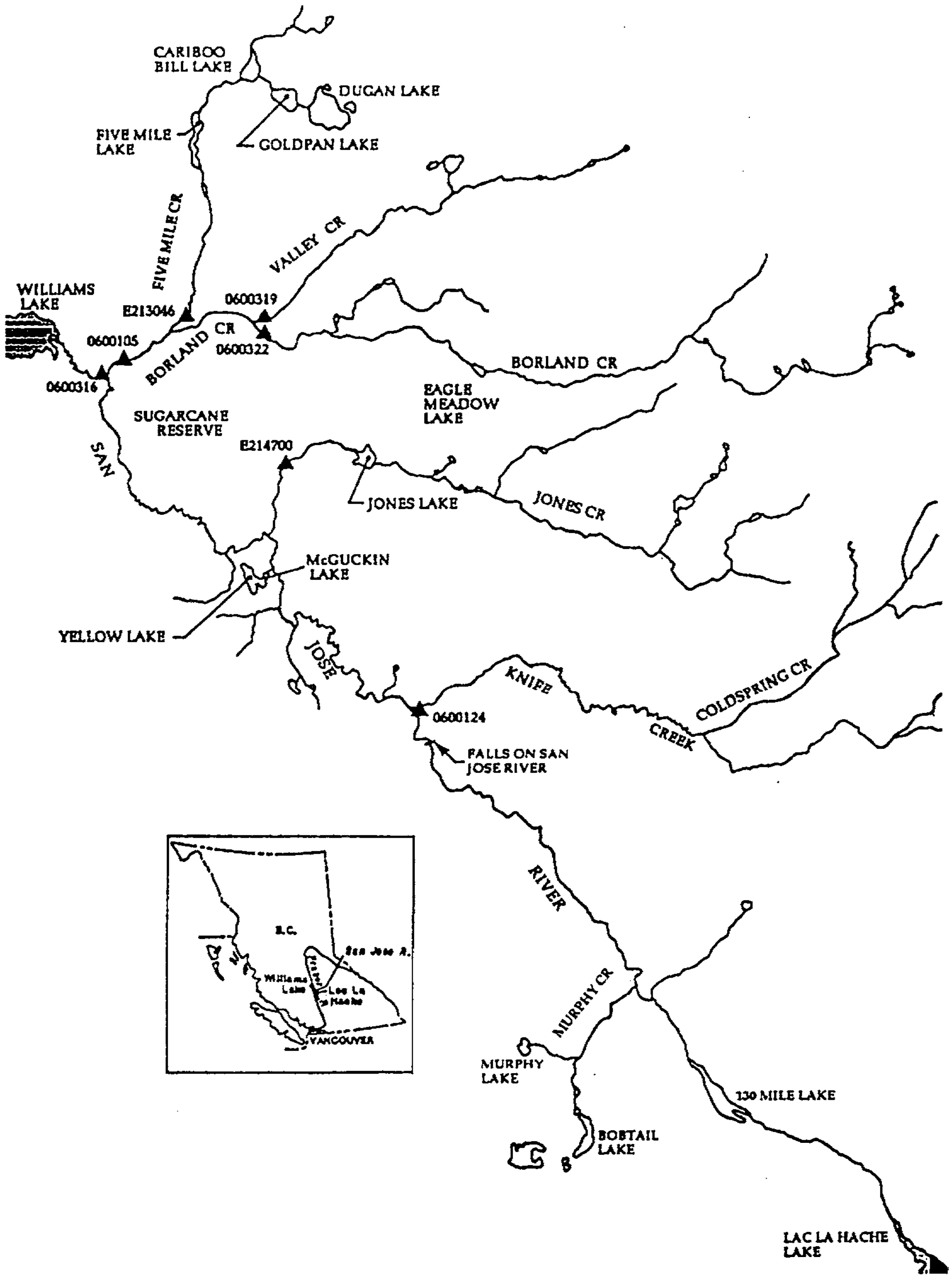
- The recommended objectives are based on protecting water quality in Williams Lake.
- Water quality in the San Jose River and its tributaries is not a major concern for aquatic life, livestock and/or irrigation water uses.
- The recommended phosphorus loading for the San Jose River and its tributaries was apportioned arbitrarily based on the size of the drainage area and not on any other watershed characteristics such as soil type, stream sensitivity to phosphorus, instream water uses, background P concentrations and/or loading, etc.. Nevertheless, the tributary-wide objectives are useful in delineating problem areas where future action may be warranted.
- Extensive monitoring will yield a better estimate of phosphorus loading to Williams Lake.

N.K. Nagpal, Ph.D.
Water Quality Branch
Water Management Division
Ministry of Environment, Lands and Parks

[3]Staff gauge and the calibration curve developed for site 0600105 should be used for flow measurements.

FIGURE 1

SAN JOSE RIVER AND SELECTED WATER QUALITY MONITORING SITES



WATER QUALITY OBJECTIVES AND MONITORING TABLE

THE FOLLOWING TABLE provides a summary of the objectives data and monitoring recommendations. For the purpose of measuring the attainment of the recommended objectives, water quality monitoring is proposed for a single site (0600316) on the mainstem of the San Jose River below Borland Creek. The corresponding water flow measurement should be obtained from the Water Survey of Canada station (08MC040) located on the San Jose River upstream from Borland Creek in conjunction with water flow measurements to be carried out at the mouth of Borland Creek.

TABLE 1

DISSOLVED PHOSPHORUS LOADING AND MEAN ANNUAL CONCENTRATIONS FOR VARIOUS WATER BASINS IN THE SAN JOSE RIVER WATERSHED

Water Basin	Site	Mean Annual Discharge* (m^3/s)	Allowable Maximum Dissolved P Loading (kg/annum)	Mean Annual Concentration+ (mg/L)	Monitoring schedule
Five Mile Creek at the mouth	E213046	0.043	120	0.090	None proposed
Valley Creek at the mouth	0600319	0.054	150	0.090	None proposed
Borland Creek above Valley Creek	0600322	0.075			None proposed
Borland Creek at the mouth	0600105	0.166	540	0.100	None proposed
Jones Creek at the mouth	E214700	0.068	200	0.090	None proposed
Knife Creek at the mouth	0600124	0.148	550	0.120	None proposed
San Jose River at Lac La Hache		0.810	300		None proposed
San Jose River below Borland Creek++	0600316	1.583	2500	0.050	Monthly samples from June to January + 3 samples in 2 trips/wk in February + 5 samples in 3 trips/wk in March + weekly samples in April and May (This constitutes 48-50 samples annually)

* From Chapman of the Hydrology Branch

+ Mean annual concentration (= column 3 ÷ {column 2 x 31536}) is for the average flow year

++ See subsection on Monitoring Recommendations for flow measurements.

MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROVINCE OF BRITISH COLUMBIA

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N.K. Nagpal, Ph.D.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

PAGE

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

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1. INTRODUCTION

The Ministry of Environment, Lands and Parks (MELP) has undertaken the task of assessing and preparing water quality objectives for various basins and sub-basins within the province, selected on a priority basis. Recently, water quality in Williams Lake was assessed by the Ministry (McKean *et al.*, 1987). The report concluded that:

(a) high phosphorus (P) concentration in the water column has resulted in the eutrophication of Williams Lake, and

(b) the agricultural activities such as hay production, pasture, and cattle overwintering in the San Jose River basin were the major source of phosphorus loading to the lake.

Therefore, it was recommended that water quality in the San Jose River basin be assessed and water quality objectives for phosphorus be set in the basin.

This report assesses water quality in the San Jose River watershed, in keeping with the recommendations in the Williams Lake Objectives' report. All up-to-date information available from the British Columbia Ministry of Environment, Lands and Parks data sources (i.e., SEAM and EQUIS data bases) was examined to set water quality objectives in the San Jose River and its tributaries for phosphorus. San Jose River and its tributaries are used for many purposes (see Section 3); however, the focus of this assessment was on phosphorus loading to Williams Lake which is the major concern in the basin. A water quality monitoring program has been recommended to appraise annual phosphorus loading from the basin to Williams Lake.

2. HYDROLOGY

The San Jose River flows from Lac La Hache in the southeast to Williams Lake in the northwest (Figure 1). There are a total of 15 Water Survey of Canada stream flow gauges in the San Jose River basin, of which 13 are seasonal due to the ephemeral nature of the tributaries. Ten stations have been discontinued (Table 1, Figure 2).

The mainstem San Jose River had two stream flow gauges (Figure 2). The seasonal station near the outlet of Lac la Hache (08MC006) has only 7 years of complete record between 1928 and 1975. The second station is an annual gauge located above Borland Creek (08MC040). It is one of the five active stations in the San Jose River watershed.

The tributaries of the San Jose River have 13 Water Survey of Canada stream flow gauges (Figure 2, Table 1). Four are located on each of Borland and Knife Creeks, two on Valley Creek, and one on each of Five Mile, Jones and Coldspring Creeks; all are seasonal gauges except for the one on Borland Creek below Valley Creek (08MC039), which is annual. The active stations on the tributaries of the San Jose River include: Borland Creek below Valley Creek (08MC039), Knife Creek at 141 Mile House (08MC014), Knife Creek above diversions (08MC047), and Coldspring Creek (08MC044).

The stream flow records for the 13 seasonal stations are scant because portions of the freshet period were not recorded. Consequently, the annual runoff could not be determined accurately. Although stream flow records span forty years, very few of the 15 stations have data that are complete and comparable. The drainage area and the estimated annual discharges for the San Jose River and its tributaries at the mouths are summarized in Table 2 and Figure 3.

The stream flow in the San Jose River watershed is highly variable depending on the amount and timing of snowfall/rainfall, and the melt pattern of the snowfall. The tributaries such as Borland Creek show two peaks: one in March-April caused by the snowmelt, and a smaller peak in the fall caused by storm events (Figure 4). Storm events in June or July can sometimes cause later or secondary flow peaks. The tributaries are typically dry during the summer and winter months.

Knife Creek is different from the other tributaries. It maintains a small flow throughout the year as a result of springfed creek, a tributary to Knife Creek located upstream from Coldspring Creek (below powerline) (Figure 5).

The stream flow in the mainstem of the San Jose River is moderated by Lac la Hache. In high runoff years (e.g., 1985 and 1986), the lake stabilizes the river flow by providing storage capacity for the excess runoff; however, in dry years (e.g., 1988) the lake has minimal outflow causing very low river flows (Figure 6).

The Williams Lake area has a semi-arid continental climate. The average annual precipitation for the area (taken at the Williams Lake airport to the north of the San Jose watershed) is 412.8 mm/yr; about one-third of the precipitation falls as snow during the winter.

The precipitation data from the Williams Lake airport were compiled to develop relationships between precipitation and runoff. No clear relationships could be determined for various reasons: (i) the San Jose River and most of its tributaries have storage areas, small lakes, and swampy areas, within the watershed; these areas require recharging after periods of low precipitation; (ii) the snow melt is the principal cause of runoff during freshet; and (iii) many of the tributaries are heavily licenced for irrigation, and they can have several diversion channels (e.g., Knife Creek). Stream flow gauges below these diversions (e.g., 08MC014) indicate severe reductions in flow.

TABLE 1

WATER SURVEY OF CANADA STREAM FLOW GAUGES IN THE SAN JOSE RIVER BASIN

Station	*Latitude/ Longitude*	*Type*	*Altitude (metres)*	*Area km2*	*Period of record*	*Status*
Borland Creek						
•150 Mile House (08MC001)	52 06 30 121 55 05	seasonal	755	?	1927-30	discontinued
•above Eagle Meadow (08MC028)	52 05 30 121 48 20	seasonal	960	79	1966-70	discontinued
•below Wise Creek (08MC037)	52 06 44 121 54 17	seasonal	785	88	1949-80	discontinued
•below Valley Creek (08MC039)	52 06 53 121 56 13	continuous	739	168	1984-	active
Coldspring Creek						
•at 950m contour (08MC044)	52 01 35 121 41 10	continuous	952	29	1987-	active
Five Mile Creek						
•below C. B. Lake (08MC027)	52 10 29 121 57 16	seasonal	938	35	1965-75	discontinued
Jones Creek						
•near 150 Mile House (08MC019)	52 04 40 121 55 05	seasonal	686	80	1949-50	discontinued
Knife Creek						
•141 Mile House (08MC014)	52 00 43 121 51 55	seasonal	695	244	1986-	active
•below Squawk Lake (08MC038)	52 00 12 121 39 20	seasonal	985	122	1987	discontinued
•above diversions (08MC047)	52 00 00 121 39 47	continuous seasonal	957	126	1988-	active
•u/s Coldspring Creek (08MC048)	52 00 23 121 40 56		922	132	1979-80	discontinued
San Jose River						
•near Lac La Hache (08MC006)	51 52 30 121 40 08	seasonal	808	1130	1928-75	discontinued
•above Borland Creek (08MC040)	52 04 30 121 59 37	continuous	595	2107	1984-	active
Valley Creek						
•near 150 Mile House (08MC002)	52 07 10 121 54 45	seasonal	785	73	1927-31	discontinued
•at mouth (08MC042)	52 06 53 121 56 13	ceasonal	755	76	1986-88	discontinued

TABLE 2

MEAN ANNUAL WATER DISCHARGES FOR SAN JOSE RIVER AND ITS TRIBUTARIES

Water basin	*Drainage area@*	*Mean annual discharge@*	
	(km²)	*m³/s*	*dam³/km²*
Five Mile Creek at the mouth	52.1	0.043	26.0
Valley Creek at the mouth	65.0	0.054	26.2
Borland Creek at the mouth	228	0.166	22.9
Jones Creek at the mouth	82.6	0.068	26.0
Knife Creek at the mouth	234	0.148	19.9
San Jose River at Lac La Hache	1 110	0.810	23.0
San Jose R. below Borland Creek	2 170	1.583	23.0

@ Chapman (1992)

FIGURE 1

SAN JOSE RIVER AND WATER QUALITY SITES

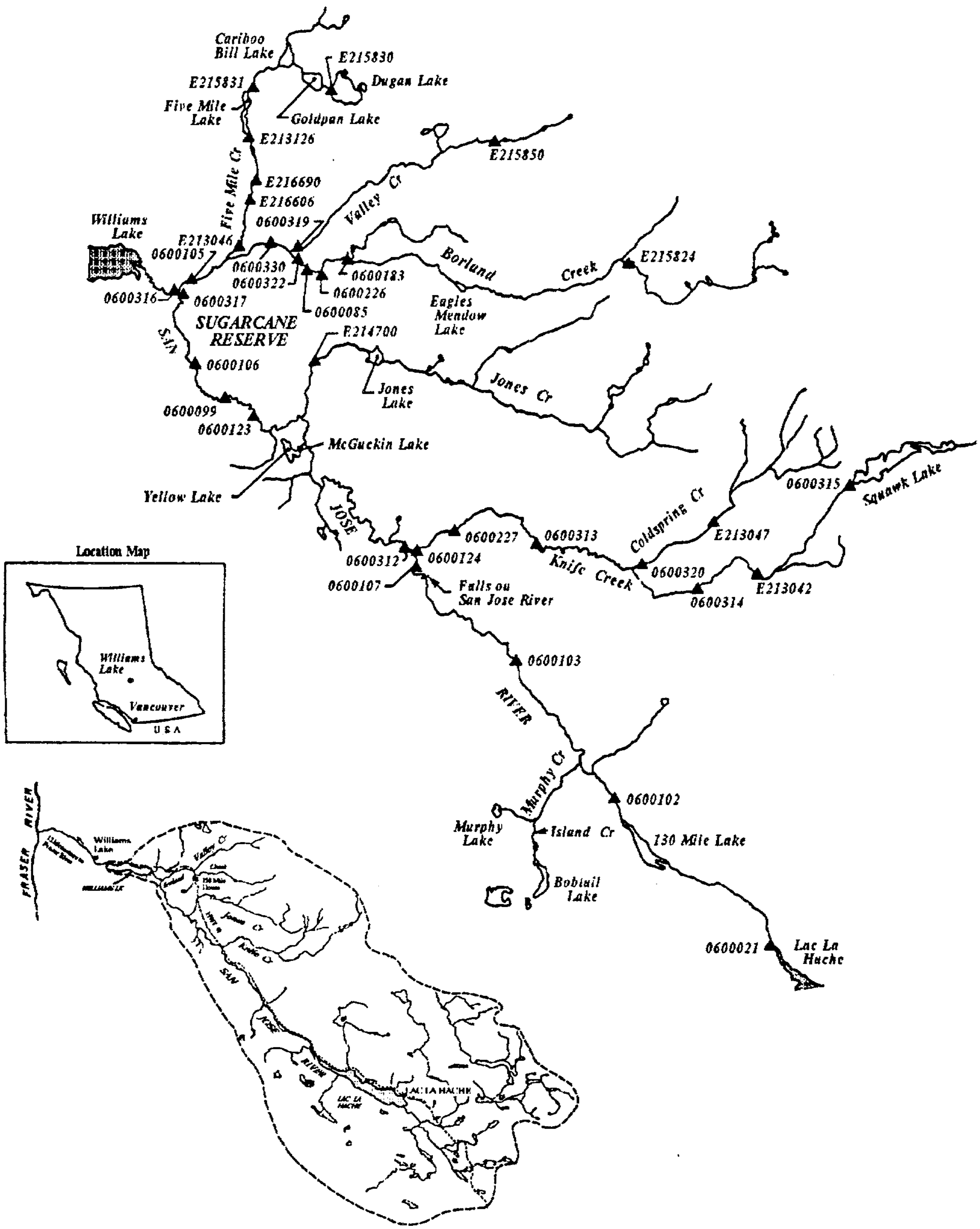


FIGURE 2

WATER SURVEY OF CANADA STREAM FLOW GAUGING STATIONS

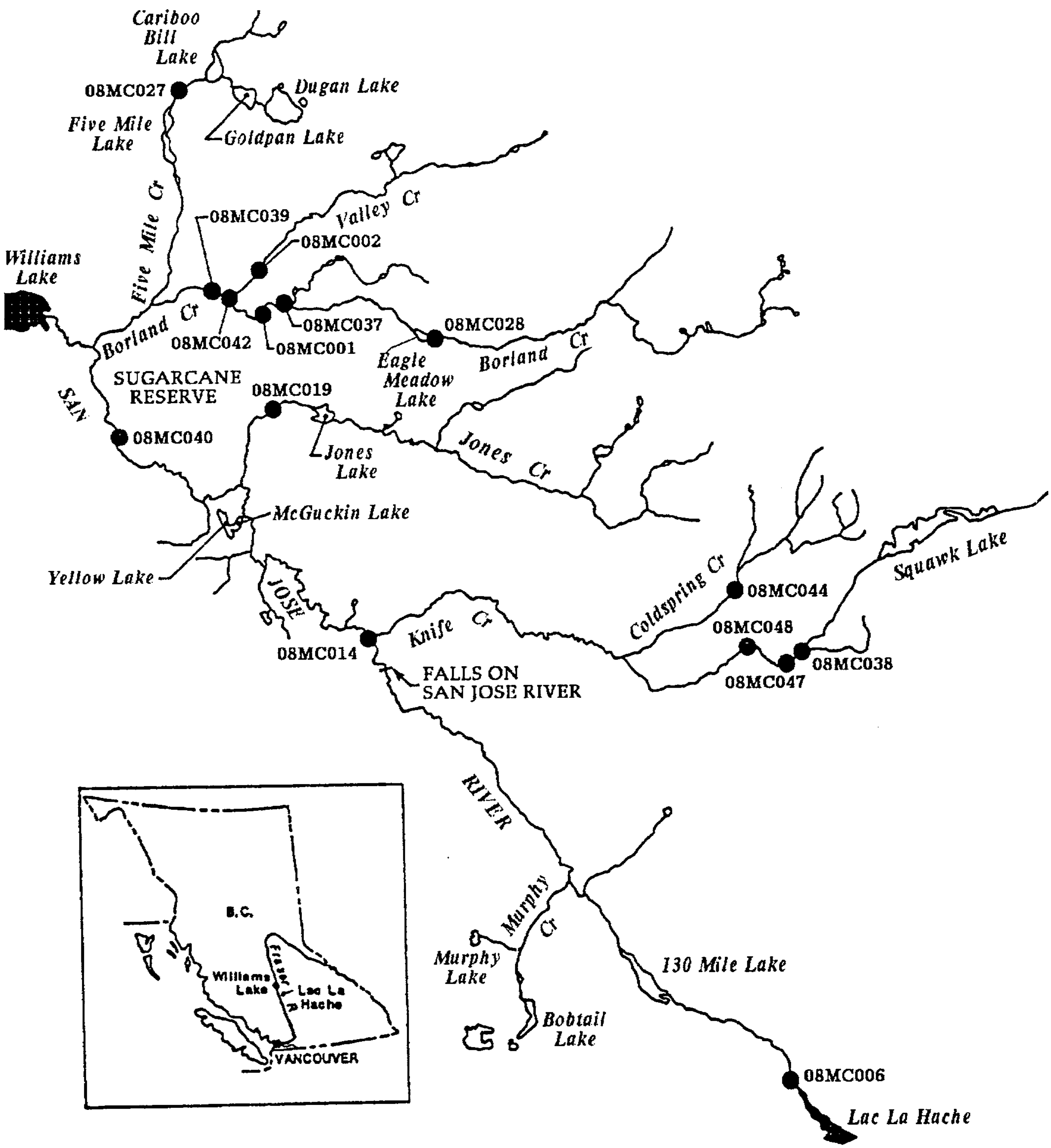


FIGURE 3

MEAN ANNUAL WATER FLOW AT VARIOUS LOCATIONS IN THE SAN JOSE RIVER BASIN

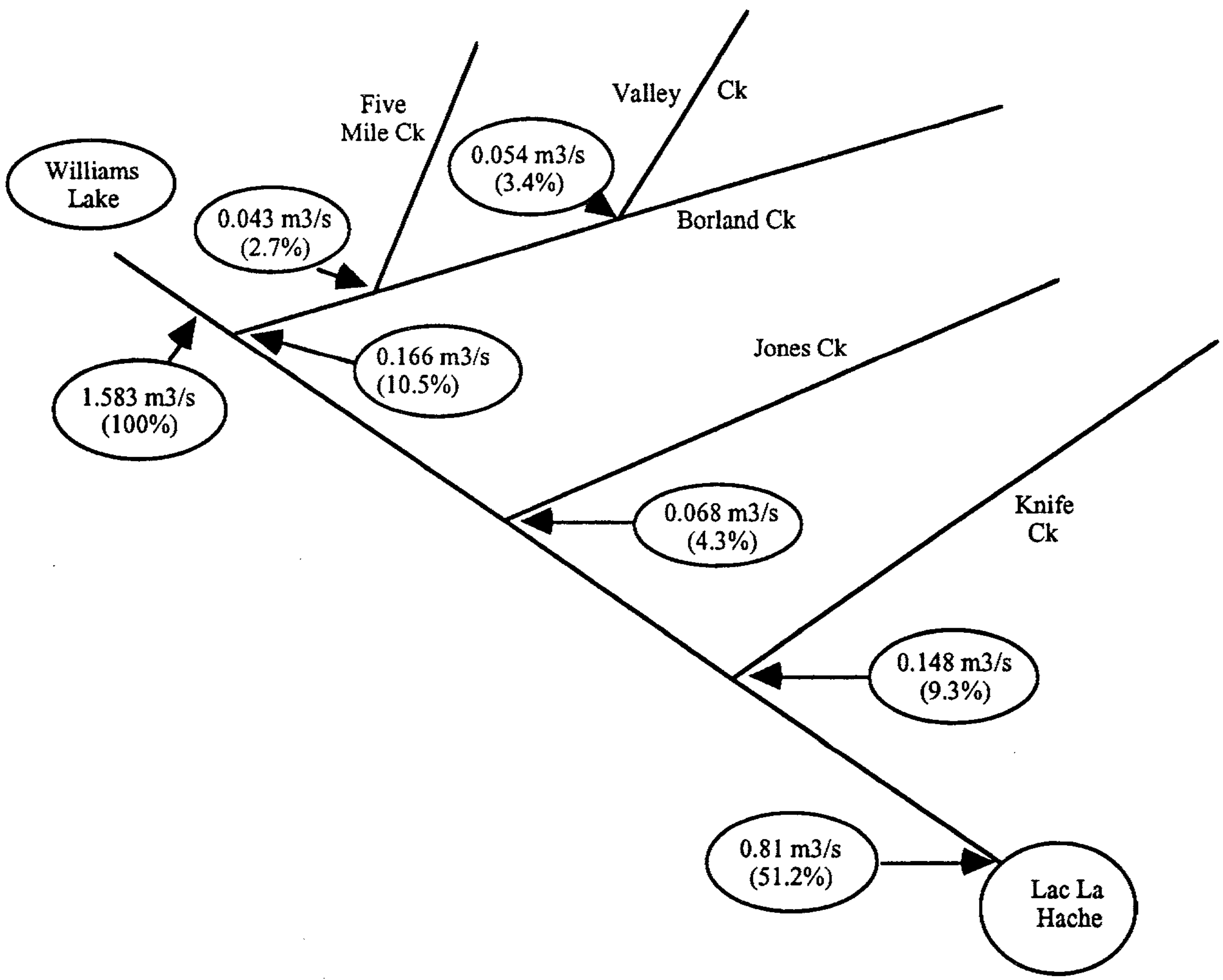


FIGURE 4

1984-89 MEAN MONTHLY FLOW IN BORLAND CREEK BELOW THE CONFLUENCE WITH VALLEY CREEK (08MC039)

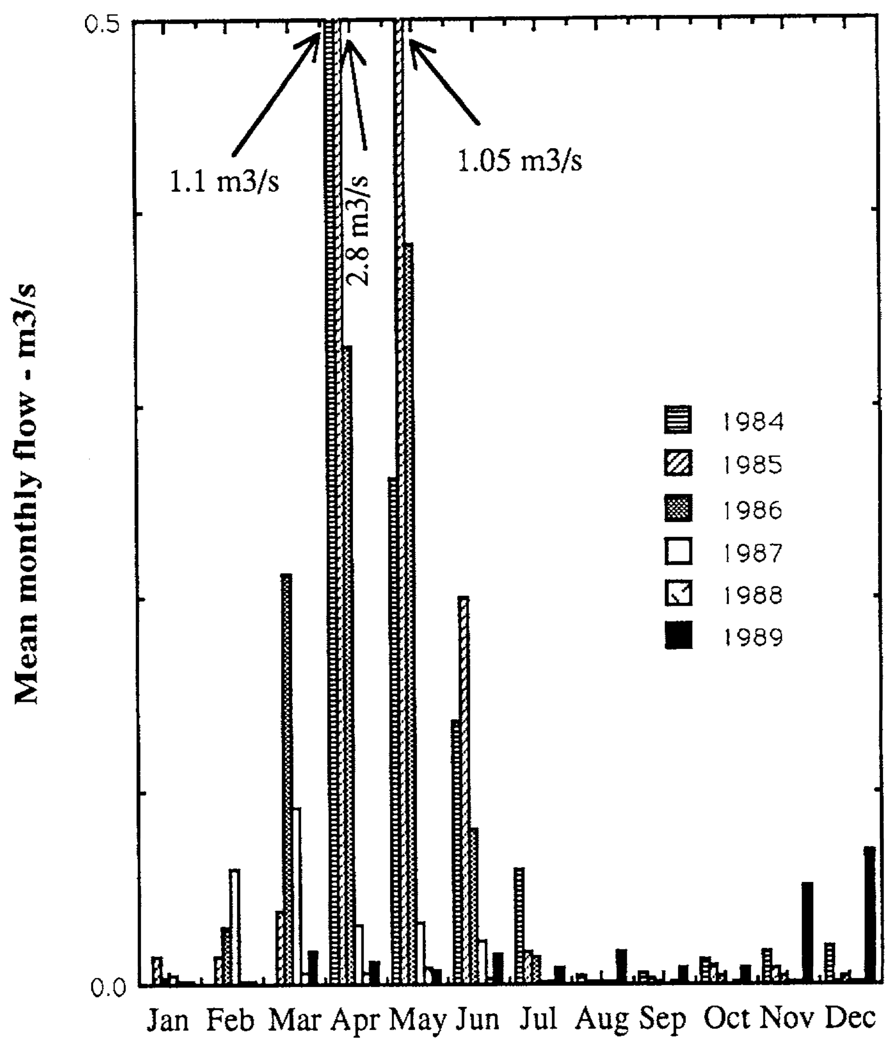


FIGURE 5

1988-89 MEAN MONTHLY FLOW IN KNIFE CREEK ABOVE THE DIVERSIONS (08MC047)

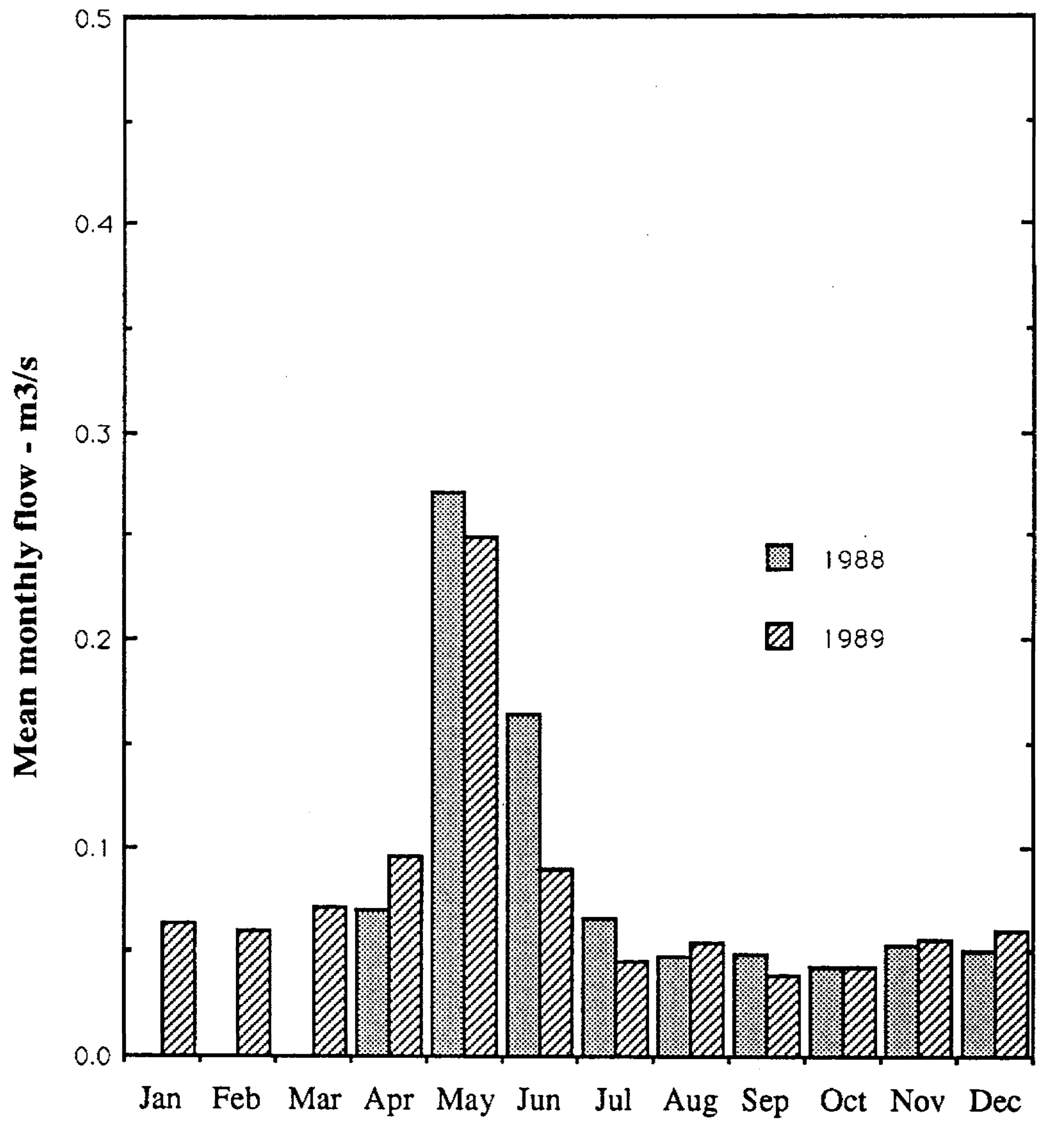
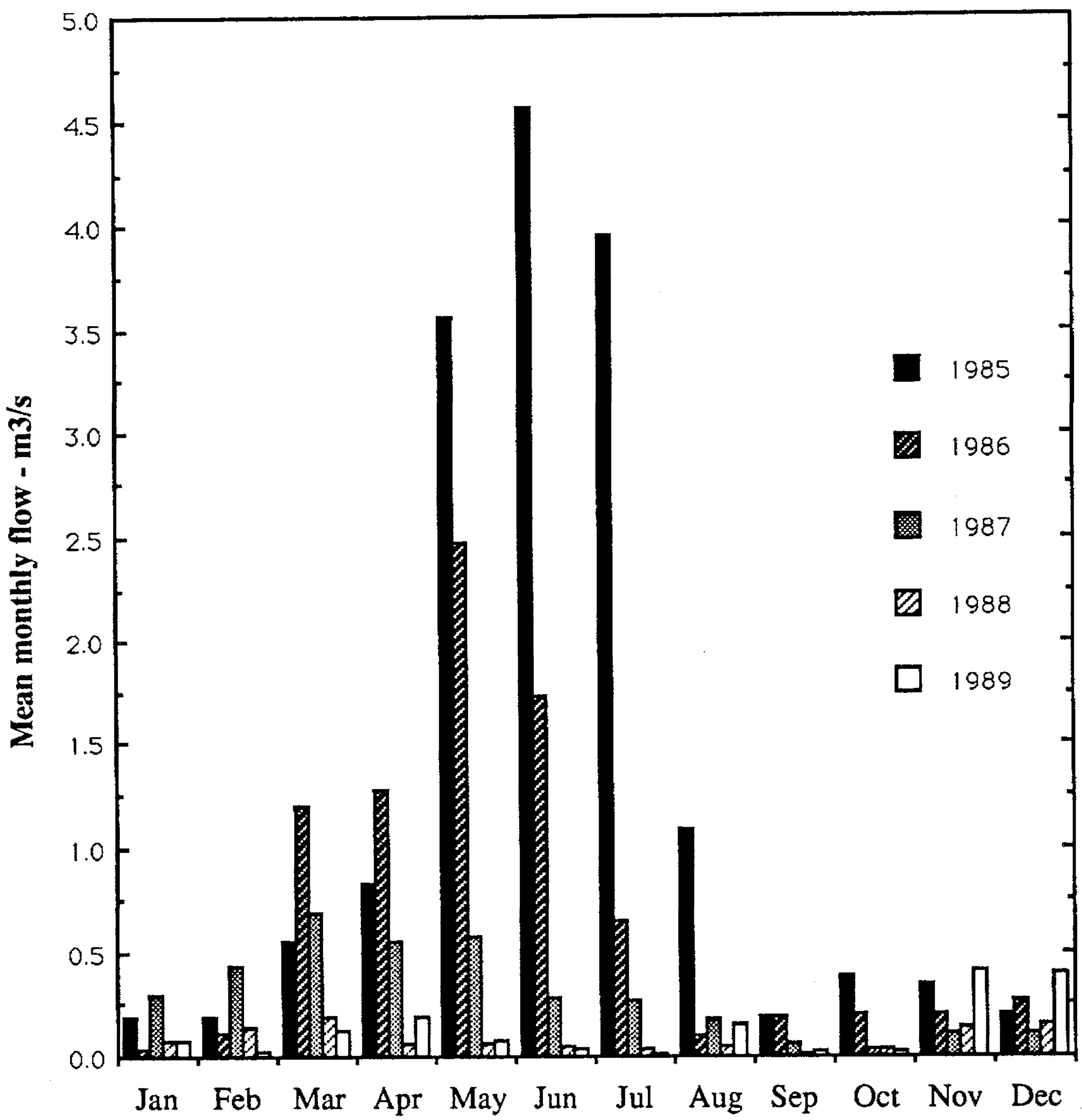


FIGURE 6

1985-89 MEAN MONTHLY FLOWS IN THE SAN JOSE RIVER ABOVE THE CONFLUENCE WITH BORLAND CREEK (08MC040)



3. WATER USES

3.1 Water Licences

The San Jose River and tributaries are licenced for domestic water supply, stream improvement, water storage, and irrigation water supply (Table 3). The dammed resevoirs on the San Jose River, Borland Creek, Jones Creek, and Knife Creek offer opportunites for storing and controlling water flow. All domestic water licences in the San Jose River basin are for non-consumptive (by humans) use for livestock except one (C50945 on Valley Creek) whose status in unclear (Kvist, 1992).

3.1.1 Borland Creek

Currently, Borland Creek has 19 water licences, and one water licence application. Two of the licences are for domestic water supply (31 m^3/d), 8 are for irrigation (2118 dam^3/y), 7 are for storage (728 dam^3/y), one licence for stream improvement (81 dam^3/y: Ducks Unlimited), and one licence for the rediversion of Valley Creek (volume associated with the licence is not specified) (Table 3). The application for an irrigation water licence (246 dam^3/y) had not been approved at the time of writing this report. All water licences are located in the middle and lower portions of Borland Creek (Figure 7).

There are no water licences above Eagle Meadow Lake; however, Eagle Meadow Lake and a nearby pond serve as the storage sites for irrigation licences located on the middle section of Borland Creek. Water from lower Borland Creek is diverted to storage ponds adjacent to the creek during freshet. One domestic licence is located above Valley Creek, while the other is located at the Sugar Cane Indian Reserve at the mouth of Borland Creek.

3.1.2 Valley and Five Mile Creeks

Valley and Five Mile Creeks are tributaries to Borland Creek. Valley Creek is nearly fully allocated with 10 water licences in total. Of the 10 licences, 2 are domestic (14 m^3/d), 4 are irrigation (850 dam^3/y), 3 are storage (120 dam^3/y), and one is for the rediversion of

Hawks Creek[1]. The majority of the irrigation and domestic licences are in the lower reach of Valley Creek, but some are located in the middle reach (Figure 7). Storage licences are located on the Boot/Doctors Lakes system.

There are 9 water licences on Five Mile Creek, and 3 licences on North Five Mile Creek (Table 3). Of the 12 licences, one is for domestic water supply (9 m^3/d), 5 are for water storage (870 dam^3/y), and the remaining 6 licences are for irrigation (1089 dam^3/y). The water licences are evenly spaced along Five Mile Creek (Figure 7). Two storage and two irrigation licences are located above the outlet of the reservoirs (i.e., Boot and Doctors Lakes - not shown in Figure 7), while the remaining licences of these categories are located between the reservoirs and the confluence of Borland Creek. The domestic water intake is located in the lower portion of the creek.

3.1.3 Jones Creek

There are three domestic water licences (29 m^3/d), 5 irrigation licences (1460 dam^3/y), and 4 storage licences (1233 dam^3/y) on Jones Creek. Most of the licences are issued on the lower section of the creek below Jones Lake, including a domestic licence near the mouth (Figure 7).

3.1.4 Knife Creek

The Knife Creek watershed (which includes Knife Creek, Coldspring Creek, and Squawk Lake) supports a total of 30 water licences, of which 2 are domestic (18 m^3/d), 16 are irrigation (4961 dam^3/y), 11 are storage (3933 dam^3/y), and one is industrial (no volume available) (Table 3). The mainstem Knife Creek supports 15 of the 30 approved licences, and there are 10 water licence applications. The licences are spread out through the watershed from the outlet of Squawk Lake to the confluence of the San Jose River (Figure 7).

Coldspring Creek, a tributary of Knife Creek, has one domestic, one storage, and 2 irrigation licences. Squawk Lake on the mainstem of Knife Creek is used for storage.

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[1]Hawks Ck. is located outside the San Jose River watershed.

3.1.5 San Jose River

On the mainstem San Jose River, there are a total of 18 licences. Five of the licences are for domestic water supply (148 m^3/d), 10 are for irrigation (2968 dam^3/y), 2 are for storage (216 m^3/y), and one is for conservation (219 dam^3/y: Ducks Unlimited) (Table 3). All licences are located between Lac la Hache and Jones Creek; there are no water withdrawals from the river below Jones Creek (Figure 7).

There are a number of storage licences (not shown in Table 4) at and upstream from Lac la Hache. A wier at the outlet of the lake regulates the minimum flows in the San Jose River during the summer irrigation months.

3.1.6 Summary of Water Licences

San Jose River and its tributaries have at least one domestic water licence; all domestic licences, except for one the status of which is unknown, are for non-consumptive (by humans) use for livestock. The majority of water licences in the San Jose River basin are for irrigation and water storage (Table 3). Because of low stream flows in summer, the majority of the irrigation licences require a storage licence. Storage licences are located on natural lakes and ponds (e.g, Squawk Lake) or instream reservoirs (e.g., Boot/Doctors lakes system) that have been regulated to release water directly into the stream or river. Other storage reservoirs (e.g., on Borland Creek) are dugouts located adjacent to the stream which are filled during freshet to provide irrigation water during the summer months. No attempt was made to catalogue the location and size of all storage reservoirs in the basin.

3.2 Water-based Recreation

Water-based recreation in the San Jose Basin is underdeveloped and essentially non-existent. Much of the land along the stream banks is private, and access to the streams is restricted. Also, the narrowness and shallowness of the streams deter recreational activities. On the mainstem San Jose River there may be minimal canoeing, birdwatching, hunting or walking (Zirnhelt, 1991).

3.3 Fisheries

Rainbow trout is the main sport species in the San Jose River basin. Other fish species include largescale suckers, peamouth chub, northern squawfish, redside shiners, burbot, and lake whitefish. Commercial species include coho and pink salmon in the lower Williams Lake River (outside the San Jose River basin d/s from Williams Lake). Knife Creek supports a small winter and summer sport fishery (Lirette, 1992).

Rainbow trout spend their first year in the streams and then migrate to the lakes. Migration to Williams Lake is limited by falls in the San Jose River at 141 Mile House (Figure 1). Rearing and spawning locations are not well known, but the juvenile may rear in Borland and Jones Creeks (Lirette, 1992).

In general, the fisheries resource has declined in the basin due to a combination of low summer and winter flows, riparian habitat loss, urbanization, and reduced water quality. Destruction of fish habitat by agricultural activities and low stream flows caused by the irrigation withdrawals and drought conditions during the 1980s are thought to be the principal causes of the decline in the fishery. However, no appropriate survey or study has been conducted in the basin to link agriculture with the fish habitat loss.

The Regional Fisheries Branch in Williams Lake has determined that the San Jose River and its tributaries have the potential to support a good rainbow trout fishery, aided by enhancement programs. Rainbow trout eggs were released into Borland, Jones and Knife creeks in June and July, 1990 to improve fish stock in Williams Lake by 1992. Kokanee were also stocked in the San Jose River several years ago for the same reason; the results are as yet unknown. Rehabilitation projects may include water storage and relese to augment low flows, fencing, and revegetating the watercourse in the San Jose River to limit cattle access to the streams, reduce summer stream temperatures, enhance fish habitat, and stabilize stream bank erosion (Lirette, 1992).

TABLE 3

SUMMARY OF WATER LICENCES IN THE SAN JOSE RIVER WATERSHED

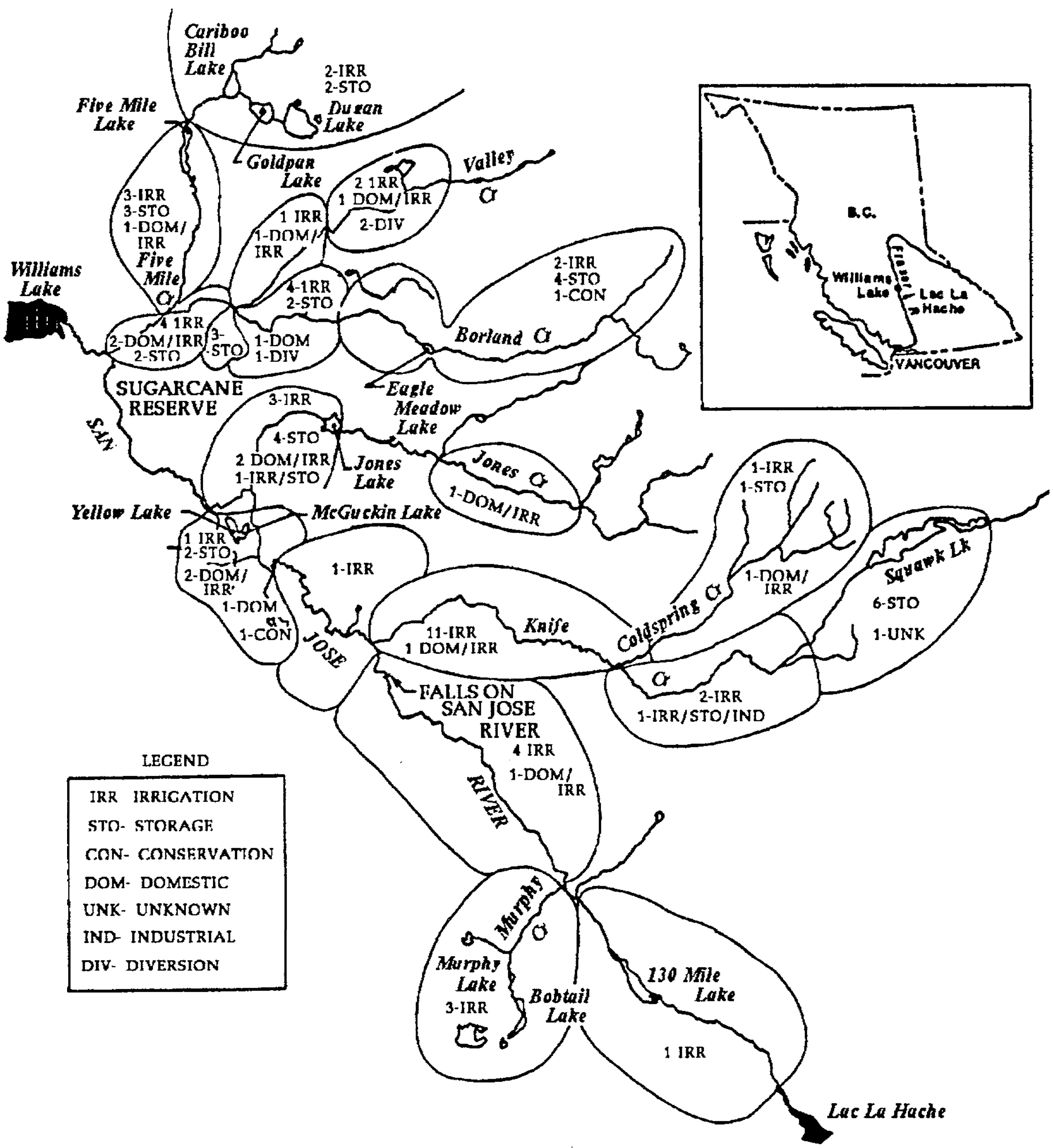
LicencesÆ Water BasinØ	***Domestic (# : m^3/d)***	***Irrigation (# : dam^3/y)***	***Storage (# : dam^3/y)***	***Others+ (# : dam^3/y)***
Borland Creek	2 : 31	8 : 2118	7 : 728	1: 81
Five Mile Creek*	1 : 9	6 : 1089	5 : 870	0
Jones Creek	3 : 29	5 : 1460	4 : 1233	0
Knife Creek**	2 : 18	16 : 4961	11 : 3933	1: no record
San Jose River	5 : 148	10 : 2968	2 : 216	1: 219
Valley Creek	2 : 14	4 : 850	3 : 120	1: volume?

* Includes North Five Mile Creek; ** Includes Coldspring Creek and Squawk Lake

\+ See text

FIGURE 7

DISTRIBUTION OF WATER LICNECES IN THE SAN JOSE RIVER WATERSHED



4. Waste Discharges

4.1 Background

Several anthropogenic activities have been identified which influence water quality in the San Jose River basin to a varying degree. They are: residential development in and around the basin including Lac La Hache and Williams Lake, logging in the headwaters of tributaries, road development, and agriculture. However, the impact of the traditional agricultural activities on ambient water quality in the San Jose River and its tributaries is of primary concern.

Ranching is the primary agricultural activity in the San Jose River basin. It includes the ranging of cattle on upland pastures during the summer, the irrigation of lowland fields for the production of hay, and the over-wintering of cattle on the lowland fields. The traditional ranching practices involve watering and feeding of cattle adjacent to the streams primarily in winter, but also in summer to some degree especially at higher elevations. The unrestricted access of cattle to a stream or a river channel can impact the ambient water quality in several ways:

(a) *Overgrazing and the removal of riparian vegetation.* Riparian vegetation prevents elevated summer water temperatures by shading streams. It also offers a better fish habitat, stabilizes the stream banks against excessive erosion, and make streams less vulnerable to erosion and siltation.

(b) *Trampling of stream or river banks by cattle.* The impact is the further destabilization of stream banks causing erosion and siltation.

(c) *Accumulation of manure on frozen ground during the winter.* The manure will be carried with surface runoff directly into the nearby stream during freshet when the ground is still frozen and soil infiltration is minimal. The result is high concentrations of bacteria and nutrients in the stream.

Stitt *et al.* (1979) and McKean *et al.* (1987) identified the San Jose River as the principal source of nutrients (e.g., phosphorus) to Williams Lake. The excessive phosphorus

(P) loading from agricultural activities in the San Jose River watershed has resulted in unacceptable water quality for domestic water uses, primary contact recreation, and freshwater fisheries in the lake. To reduce phosphorus loading and, to improve water quality in Williams Lake at the same time, McKean *et al.* (1987) recommended that:

(a) the traditional agricultural practices causing enrichment of the nutrient, including the location and extent of over-wintering areas, be identified, and

(b) water quality objectives be set to protect the water users in the San Jose River basin and Williams Lake.

Hart and Mayall (1990) addressed the effects of winter livestock management practices on water quality of the San Jose River and its tributaries in a report. Their results are summarized in the following section.

4.2 Livestock Management Practices

Table 4 illustrates the system used by Hart and Mayall (1990) for evaluating the impact of livestock overwintering areas on water quality.

The impact of an overwintering area on stream water quality is dependent on: (a) the total livestock density it supports, and (b) its potential to generate surface runoff. Hart and Mayall (1990) determined the surface runoff potential for an agricultural area from its soil (e.g., texture, drainage conditions, infiltration , etc.), vegetation (e.g., cover), and landscape characteristics (e.g., slope, and flood hazard). A map of the overwintering areas in the San Jose River watershed (also identified as agricultural sites in the text to follow) is shown in Figure 8.

The 1989/90 survey of the San Jose River watershed by Hart and Mayall (1990) identified 62 cattle overwintering sites (Figure 8). Of the 62 sites, 12 were identified as having a high or moderate-to-high potential to transport phosphorus to the adjacent watercourses; 22 sites had moderate or low-to-moderate potential; and 28 sites were assigned a low potential or were considered to have no impact on the stream water quality. Hart and Mayall (1990) emphasized that the rating for the potential impact was based on the conditions encountered during the study period. The rating of the agricultural sites and their impact on water quality of the adjacent streams are discussed in Section 5.

Recently, B.C. Ministry of Environment, Lands and Parks, in cooperation with the Cariboo Cattlemen's Association and the Agricultural Environmental Protection Council (B.C. Federation of Agriculture), has initiated an active program of inspecting and enforcing the Agricultural Waste Control Regulations in the San Jose River basin. In late 1992, all ranches with high impact[2] sites have in place Best Waste Management Plans developed with the help of the Ministry of Agriculture, Fisheries, and Food. As a result, all high and moderate impact sites have been upgraded to low or low-to-moderate class.

4.3 Logging Practices

Most commercial logging in the San Jose River basin has been conducted in the 1970s and 1980s. Douglas fir, which occupies the mid elevations of the basin, is currently harvested by faller selection. Lodgepole pine, the other main species of timber occupying the upper elevations, is harvested by clearcutting. Details of forestry activities can be found elsewhere (Hart, 1990).

A study commisioned by the Ministry of Forest, Williams Lake concluded that the effect of forestry (i.e., timber harvesting, random site disturbance within cutblock, and active forest roads on uplands and those follow and cross streams) on water quality (e.g., phosphorus) in the San Jose River basin is minor, if any (Hart, 1990).

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[2]In 1991, Hart and Mayall revised their technique for rating potential impact of agricultural sites in consideration of additional soil and landscape characteristics (e.g., slope, setback distance from stream, extent of site, etc.- see Table 4). The revised scheme was used to delineate high, medium, and low impact sites in this case.

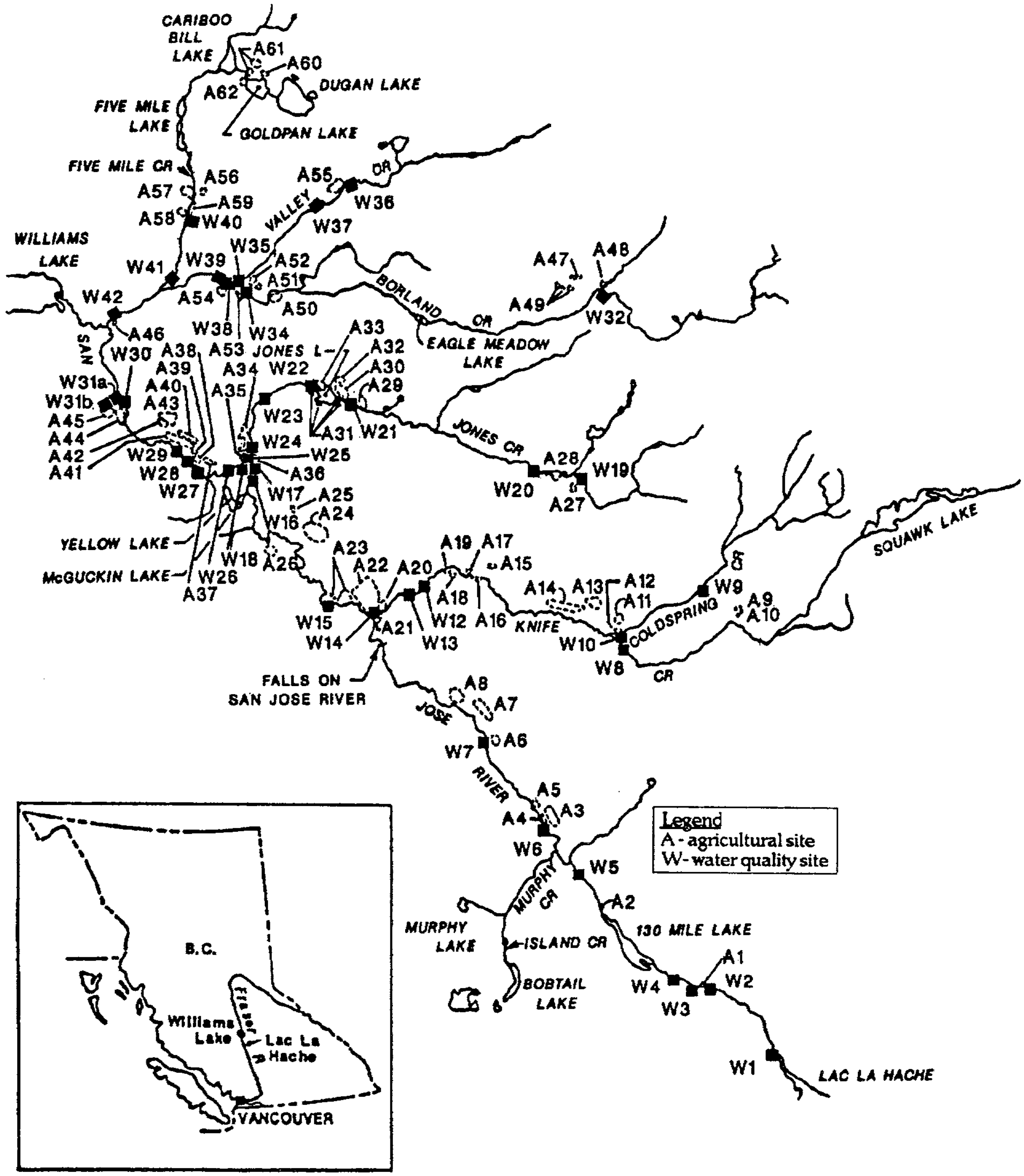
TABLE 4

POTENTIAL IMPACT OF OVERWINTER AREAS ON WATER QUALITY AS A FUNCTION OF SURFACE RUNOFF POTENTIAL AND TOTAL LIVESTOCK DENSITY (FROM HART AND MAYALL, 1990)

Total Livestock Density ⇒ ***Surface Runoff Potential ⇓***	***LOW***	***MODERATE***	***HIGH***
	-Potential Impact Rating-		
LOW	low	low	low
MODERATE	low-moderate	moderate	moderate-high
HIGH	moderate	moderate-high	high

FIGURE 8

CATTLE OVERWINTERING AREAS IN THE SAN JOSE RIVER WATERSHED (HART AND MAYALL, 1990)



5. WATER QUALITY ASSESSMENT

This section focuses on phosphorus loading from the San Jose River and its tributaries to Williams Lake. The non-point P loading was identified to be the major concern in the basin (McKean *et al.*, 1987). Other parameters such as nitrogen (NH3-N, NO2-N, and NO3-N), suspended solids, and coliform, which are are commonly associated with agriculture (the major activity in the San Jose River basin), were not considered in this assessment. The analyses of 1977 and 1978 data[3] by Stitt *et al* (1979) suggested that the nitrogen and suspended solids concentrations did not exceed the Provincial criteria for aquatic life, domestic water supply, and irrigation (Nordin and Pommen, 1986; Singleton, 1985). During the spring runoff, high fecal coliform concentration was occasionally recorded in Borland Creek (3033 MPN/100 mL[4], March 1978- site 0600085 at Hwy 97), Knife Creek (1600 MPN/100 mL, February 1978- site 0600124 at 141 Mile House), and the mainstem San Jose River (350 MPN/100 mL, February, 1978- site 061006 at Onward). As indicated in Section 3, all domestic water licences are for non-consumptive use by humans. Furthermore, the Provincial fecal coliform criteria do not apply to aquatic life (except shellfish harvesting) and water used by free-ranging livestock in the basin; the summer fecal coliform concentrations are less than the Provincial criterion for general irrigation water use (1 000 MPN/100 mL) (Warrington, 1988).

5.1 Borland CreekWater Quality Surveys

Borland Creek is one of the major tributaries of the San Jose River. It drains an area of 230 km^2 and contributes an average of about 10.5% to the total water flow in the San Jose River at Williams Lake.

Figure 9 shows the stream profile (distance *versus* elevation) for Borland Creek. Included in the figure are approximate locations at which the two major tributaries (e.g., Valley and Five Mile Creeks) enter Borland Creek; the Ministry of Enviroment, Lands and Parks (MELP) ambient water quality sites, as shown in Figure 1, are also shown.

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[3]No other data were available for these parameters.
[4]This exceptionally high fecal coliform concentration was measured below a feedlot which is no longer.

Water quality in Borland Creek has been examined occasionally:

(a) In 1978, Stitt *et al.*, (1979) examined phosphorus concentrations at 5 sites along the creek (Table 5);

(b) The same five sites were sampled again in 1985 for dissolved phosphorus (DP) and suspended phosphorus (SP) concentrations (Table 6);

(c) In 1990, Hart and Mayall (1990) studied the impact of agricultural practices (i.e., cattle overwintering sites) on stream water quality in the San Jose River watershed, including Borland Creek (Tables 7 and 8);

(d) and finally in 1990/91, MELP reinitiated water quality monitoring in Borland Creek at several established sites; an additional site (E215824), located upstream from all the agricultural sites in the watershed, was also included in the monitoring program.

5.1.1 Borland Creek above Hoff's Ranch (Site E215824)

In 1991, the Ministry of Environment, Lands and Parks established site E215824 to determine background water quality conditions in Borland Creek; site E215824 is located above all the agricultural sites in the watershed.

The results show that the dissolved P concentrations in Borland Creek varied narrowly between 0.01 mg DP/L and 0.04 mg DP/L; the average concentration was 0.022 ± 0.007 mg DP/L (Site E215824 - Figure 10). The suspended P concentration varied relatively widely, but the average concentration (0.021 ±0.026 mg SP/L) was similar to the dissolved P concentration.

During their study, Hart and Mayall (1990) collected one water sample (on March 27, 1990) from site W32 on Borland Creek. (Figure 8) located above all the agricultural sites (Table 8). The dissolved (0.040 mg DP/L) and suspended (0.036 mg SP/L) P concentrations measured by Hart and Mayall were within the range observed for the background site E215842 in 1991/92 (Figure 10).

5.1.2 Borland Creek above 150 Mile House- Pidgeon Road Bridge (Site 0600183)

Water quality site 0600183 is located approximately 15 km downstream from three agricultural sites A47, A48, and A49 (Hart and Mayall, 1990). The potential impact of the agricultural sites on surface water quality was determined to be low-to-moderate for sites A47 and A48, and low for site A49 (Table 7).

1978 DATA

In 1978, the average freshet and non-freshet dissolved P concentrations for site 0600183 ranged narrowly between 0.051 and 0.053 mg/L. During the same period, the average suspended P concentrations for the site were much lower and varied between 0.003 mg/L (non-freshet) and 0.01 mg/L (freshet) (Table 5).

1985 DATA

Table 6 and Figure 11 summarize the 1985 water quality data for Borland Creek at site 0600183. A comparison of the data suggests that the average dissolved P concentration for the site in 1985 (0.047±0.016 mg DP/L, Table 6) was similar to 1978 (0.051-0.053 mg DP/L, Table 5). However, this trend was not upheld by the average suspended P concentration, which was much higher in 1985 (0.027±0.076 mg SP/L, Table 6) than in 1978 (0.003-0.01 mg SP/L, Table 5).

The concentration-time plot (Figure 11) suggests that the dissolved P concentration (a) remained relatively constant between 0.050 and 0.060 mg DP/L during the winter months, but (b) declined to between 0.020-0.040 mg DP/L from dilution during periods of high stream flow. During the monitoring period, however, the suspended P concentration fluctuated widely more or less in phase with the stream flow (Figure 11). For instance, the suspended P concentration during the low flow periods in winter ranged between 0.001 and 0.005 mg SP/L. It increased dramatically during the freshet, peaking at 0.290 mg SP/L at the maximum stream flow. Past the hydrograph peak, the suspended P concentration declined to a level below 0.010 mg SP/L during minimum flows.

That the suspended P concentration increased while the dissolved P concentration decreased during the peak flow conditions (Figure 11), suggests that the suspended fraction contributed significantly to the P load in Borland Creek at the Pidgeon Road bridge (Site 0600183) during peak flows. More data are required to determine the source(s) of the suspended fraction; i.e., agricultural runoff versus stream bank erosion.

1991 DATA

In 1991, MELP collected only one water sample (April 17/1991) at site 0600183. The dissolved and suspended P concentrations for the day were 0.039 mg DP/L and 0.251 mg SP/L, respectively. Because of the lack of data, no attempt was made to compare the 1991 results with those of other years.

5.1.3 Borland Creek at Hwy 97 (Site 0600085)

Water quality site 0600085 on Borland Creek is about 2.4 km downstream from site 0600183 (Figure 1). In this stretch of the stream, two overwintering sites (A50 and A51) were found which supported low livestock density on soils with low to moderate potential for surface runoff (Table 7). Both A50 and A51 were rated low for potential impact on the surface water quality. Stitt *et al.*, (1979) noted that the area in the vicinity of site 0600085 on Borland was used as a winter feedlot; however, the feedlot operation was discontinued in the early 1980s (Zirnhelt, 1991).

1978 DATA

In 1978, the phosphorus concentrations in this reach of Borland Creek (site 0600085) were elevated significantly (Table 5). For instance, the dissolved P concentration during the freshet increased from an average of 0.053 mg DP/L at an upstream site (0600183) to 0.265 mg DP/L at the site in question. During the same period, the average suspended P concentrations for the two sites were 0.010 mg SP/L (site 0600183) and 0.076 mg SP/L (site 0600085). Runoff from the feedlot (now closed) was considered to be the principal cause for the elevated P concentrations at site 0600085 (Stitt *et al.*, 1979).

1985 DATA

The 1985 phosphorus concentrations for site 0600085 are shown in Table 6 and Figure 12. While the average dissolved P concentration for site 0600085 (0.046±0.027 mg DP/L) was similar to upstream site 0600183 (0.047±0.016 mg DP/L), the average suspended P concentration was substantially greater for site 0600085 (0.050±0.096 mg SP/L) than the upstream site (0.027±0.076 mg SP/L) (Table 6). Stream bank erosion, in part, may have been responsible for this additional suspended P loading in the stream. The absence of an apparent increase in the dissolved P concentration in this reach compared to upstream (site 0600183) suggests that the erosion may not be associated with agricultural activities.

A comparison of the data suggests that the 1985 phosphorus concentrations for site

0600085 were much lower than those observed in 1978 during the freshet (Tables 5 and 6). Closure of the feedlot was the most likely reason for the observed improvement in water quality in 1985.

1991 DATA

In 1991, MELP collected only one water sample on April 17/1991 at site 0600085 (Figure 12). The low dissolved P concentration (0.040 mg DP/L) and the relatively high suspended P concentration (0.410 mg SP/L) for the day were similar to the concentrations observed during the same time period in another year (e.g., 1985 - Figure 12). Note that high flows prevailed in the creek during the month of April (Figures 11) and, as a result, the stream bank erosion has been implicated as the cause for the high suspended P concentrations in the creek relative to the dissolved phosphorus.

5.1.4 Borland Creek above Valley Creek (Site 0600322)

Water quality site 0600322 is located just above the confluence of Valley Creek about 0.3 km downstream from site 0600085 and 2.8 km downstream from site 0600183 (Figures 1 and 9). This reach of Borland Creek has two agricultural sites nearby (sites A52 and A53: Table 7), which were rated low-to-moderate (A53) and moderate (A52) for potential impact on the stream water quality (Hart and Mayall, 1990). In 1990, both agricultural sites supported moderate livestock density while providing livestock access to the creek.

1985 DATA

The 1985 data for site 0600322 are summarized in Table 6 and Figure 13. Similarity between the average dissolved (0.044 and 0.046 mg DP/L, respectively) and suspended (0.052 and 0.050 mg SP/L, respectively) P concentrations for sites 0600322 and 0600085 (Table 6) indicates that the impact of the agricultural activities at the time of sampling was small, if any. Nevertheless, Figure 13 provides some evidence that both agriculture and stream bank erosion have impacted, to some degree, the stream water quality at the site during a part of the year. For instance, the relatively higher dissolved and suspended P concentrations during March and April, 1985 may, in part, be attributed to agricultural runoff from snowmelt. On the other hand, the relatively high increase in the suspended P concentration, while the dissolved fraction continued to decrease between April 11 and April 17, was most likely the result of erosion within the stream.

1990 DATA

In the 1990 study, Hart and Mayatt (1990) found that the dissolved and suspended P concentrations for site W35 (which was located in the proximity of water quality site 0600322) downstream from agricultural sites A51 and A52, were higher than those for the upstream site W34 (located in the proximity of water quality site 0600085) (Tables 7 and 8).

5.1.5: Borland Creek below Valley Creek (Site 0600330)

Water quality site 0600330 on Borland Creek is located only a few hundred metres downstream from the site 0600322, but it includes the flow from Valley Creek. (Section 5.2). In 1990, the southern stream bank of this reach of Borland Creek had one agricultural site (A53). It had livestock access to the creek and was rated low-to-moderate for potential impact on surface water quality (Table 7).

1978 DATA

In 1978, the average dissolved and suspended P concentrations in Borland Creek at site 0600330 were higher relative to upstream site 0600322 during the non-freshet (Table 5). This increase in the P concentration (especially for the dissolved fraction) was, in part, attributed to higher phosphorus concentration in Valley Creek (relative to site 0600322) during the non-freshet period (0.106 mg DP/L; Valley Creek has several agricultural sites in its watershed - Section 5.2).

Valley Creek appeared to exert a moderating influence on P concentration in Borland Creek during the freshet. Both the dissolved and suspended P concentrations decreased in this reach of Borland Creek (Site 0600330) during the freshet period, relative to the upstream site (Table 5). The average dissolved and suspended P concentrations in Valley Creek during the freshet (0.098 mg DP/L and 0.016 mg SP/L, respectively, for site 0600319: Section 5.2) were lower than those in Borland Creek above Valley Creek (0.225 mg DP/L and 0.049 mg SP/L, respectively, for site 0600322 - Table 5).

1985 DATA

The 1985 phosphorus concentrations in Borland Creek at site 0600330 are shown in Table 6 and Figure 14. The results indicate that the average dissolved P concentration for the site was higher than at all upstream stations (Table 6). Note, however, that one sample at the peak flow (April 17, 1985) was missing, and that the dissolved P concentration in the stream is lower at the peak flow. Comparison of the mean suspended phosphorus concentrations to other upstream sites was not possible because of the lack of data (Table 6).

The results in Figure 14 show that both the dissolved and suspended P concentrations increased or decreased simultaneously during the snowmelt (March to early April in 1985). This trend is similar to that observed for upstream site 0600322 and is typical of the impact on surface water quality due to surface runoff from cattle overwintering areas.

1991 DATA

Water quality site 0600330 was also monitored in 1991. Although both the dissolved and suspended P concentrations were lower (relative to the 1985 concentrations) at the site during the snowmelt period, the general trends were similar for both sampling periods (Figure 14).

5.1.6 Borland Creek at Sugar Cane Reserve (Site 0600105)

Water quality site 0600105 is approximately 0.5 km upstream from the confluence with the San Jose River, and about 3.5 km downstream from site 0600330. This reach (between sites 0600330 and 0600105) is relatively steeper (Figure 9), does not have any agricultural or overwintering site, and receives the discharge from Five Mile Creek. Note that the Five Mile Creek. watershed is one of the major contributors to the San Jose River phosphorus loading (Section 5.3).

1978 DATA

In 1978, the average dissolved P concentration at this site (0.237 mg DP/L) during the freshet increased by a factor of two relative to the nearest upstream site 0600330 (Table 5). However, during the same time, the suspended P concentrations remained unchanged between the two stations (0.037 - 0.039 mg SP/L). The large increase in dissolved P concentration during the freshet was attributed to the agricultural activities within the Five Mile Creek watershed (see Section 5.3).

1985 DATA

The 1985 phosphorus data for this reach of Borland Creek (Site 0600105) are shown in Table 6 and Figure 15. The average dissolved and suspended P concentrations for the site during the 1985 study period were 0.139±0.102 mg DP/L and 0.035±0.053 mg SP/L, respectively (Table 6). The dissolved P concentration for the site showed approximately a three-fold increase over the concentration at the farthest upstream site 0600183 and a two-fold increase over the nearest upstream site 0600330, located below Valley Creek.

The results in Figure 15 show that the dissolved P concentration at site 0600105 attained the maximum level (0.400 mg DP/L) well before the stream flow peaked. This trend typifies input of the nutrient from surface runoff originating from nearby agricultural areas (e.g., in the Five Mile Creek watershed). On the other hand, the suspended phosphorus concentrations, which may be influenced by agricultural activities as well as stream bank erosion, fluctuated more or less in unison with the flow.

1990/92 DATA

Figure 16 summarizes the more recent water quality data for site 0600105 on Borland Creek. It also includes the 1985 data. Several observations were made from the data:

a) Dissolved phosphorus constituted the major proportion of the total phosphorus for the most part (during snowmelt and when stream flow was less than the peak);
b) At and near the hydrograph peaks, the suspended P concentration in the creek increased (while the dissolved P concentration decreased) as a result of the stream bank erosion;
c) A sudden increase in the dissolved P concentration during early snowmelt periods typifies the contribution from agricultural runoff. Observations made during the January - February/1992 period (also February-early April/1985) are in accordance with these trends;
d) At peak flows and during the receding limb of the hydrograph (e.g., May 1985 and May-Dec. 1991), the dissolved P concentration in the creek decreased when stream flows were high and it increased as the flow decreased; and
e) The dissolved P concentrations in the creek between January and May were lower in 1992 (0.086±0.054 mg/L) than in 1985 (0.139±0.102 mg/L). Note that the flow regime for the two periods is different; hence the results. The average dissolved P concentration at the site in 1991 was 0.105±0.046 mg DP/L.

The surface runoff and stream bank erosion periods have been identified in Figure 15.

5.1.7 Borland Creek Phosphorus Loading

1985 DATA

The 1985 dissolved and suspended P loadings for the 5 water quality stations on Borland Creek were estimated using water chemistry data and the flow records from the Water Survey of Canada station on Borland Creek below Valley Creek (08MC039). Since the first three water quality stations (Sites 0600183, 0600085, and 0600322) are above the flow gauge, and do not include the flow from Valley Creek, they were rated at 90% of the stream flow at the gauge. Site 0600330 was rated at 100% of the flow at the gauge because it is located near the stream flow gauge downstream from Valley Creek, while site 0600105, which includes the flow from Five Mile Creek, was rated at 110% of the flow at the gauge.

Using these flow assumptions, the dissolved and suspended P loadings were calculated at various sites during the five month study period in 1985. The results are summarized in Table 9.

The dissolved and suspended P loadings in Borland Creek at site 0600183 between January - May, 1985 were approximately 400 and 1200 kg (Table 9). The higher suspended P loading for the site was caused by stream bank erosion during periods of high stream flow. Whether water quality site 0600183 represented the background phosphorus load for Borland Creek could not be determined, as the degree to which the three agricultural sites (e.g., sites 47, 48, and 49 - Tablel 7 - located upstream) influenced the stream water quality could not be ascertained due to the lack of flow data upstream from site 0600183.

Downstream from water quality site 0600183, Borland Creek flowed past three additional agricultural sites, but the dissolved P loading did not increase at sites 0600085 and 0600322. Through the same stretch (i.e., from site 0600183 to 0600322), however, the suspended P loading increased from 1190 kg to 1880 kg in the creek. This increase in the suspended P loading, in the absence of a similar increase in the dissolved P loading, was attributed to stream bank erosion and not agricultural runoff (Similar conclusions were drawn from changes in the phosphorus concentrations - Section 5.1.4). It is, however, unclear from the data whether the erosion was caused by watershed activities or natural processes.

The 250 kg increase in the dissolved P loading at site 0600330 reflected the influence of Valley Creek on Borland Creek water quality. Because of the lack of stream flow data, the contribution of Valley Creek to dissolved P loading in Borland Creek, based on concentration data from Valley Creek, could not be confirmed.

The estimated loading of 920 kg dissolved P for site 0600105, represented an increase of 520 kg over site 0600322, located upstream from Valley Creek. Both Valley and Five Mile creeks contributed to this increase in the dissolved P loading in Borland Creek at site 0600105. In contrast, the suspended P load decreased by 680 kg between the two sites (i.e., 0600322 and 0600105). It is unclear if the decrease was the result of sedimentation, or an error caused by infrequent sampling.

Several additional observations were made during the phosphorus loading calculations (Table 9):

a) No net increase in the suspended P loading was observed over the length of Borland Creek (from water quality site 0600183 to site 0600105); and
b) The phosphorus entering San Jose River from Borland Creek was approximately 60% suspended and 40% dissolved P.

1991 DATA

In 1991, the dissolved and suspended P loadings in Borland Creek were estimated for site 0600105 for which both flow and concentration data were available (Table 9). The following conclusions were drawn:

a) The 1991 P entering San Jose River from Borland Creek, is about 54% suspended and 46% dissolved P (the 1985 partitioning was 60% suspended and 40% dissolved P);
b) Most of the 1991 P loadings to the San Jose River from Borland Creek occurred during April and May. The dissolved and suspended P loadings between April 12 and May 31, 1991 were 67% and 94% (not shown in Table 9), respectively, of the total dissolved and the total suspended P loadings (from April 12 to December 31, 1991) in Table 9; and
c) Between April 12 and May 31, 1991, the dissolved and the suspended P loadings in Borland Creek near the mouth (Site 0600105) were estimated at about 619 kg and 1016 kg, respectively. During the same period in 1985 (April 11 - May 28, 1985), the phosphorus loadings in the creek were slightly higher: 887 kg for the dissolved fraction and 1193 kg for the suspended fraction. Note that peak flow in 1985 was also slightly higher than in 1991 (Figure 16).

5.2 Valley Creek Water Quality Surveys

Valley Creek, which meets Borland Creek in the vicinity of 150 Mile House, is moderately steep for two thirds of its length upstream from the mouth. The creek flows through a much steeper slope for the rest of the way before it flattens out at the headwaters (Figure 17). It has several small ponds/lakes within its watershed (presumably used for water storage), and only two areas of potential agricultural impact.

The total drainage area for Valley Creek was estimated at 65 km^2. In terms of flow, Valley Creek contributes about 32% to the total flow in Borland Creek at the mouth.

Two agricultural sites were identified in the Valley Creek watershed. Overwintering site A55 is located about halfway up from the mouth of Valley Creek, and was rated high for potential impact on water quality (Hart and Mayall, 1990). The other agricultural site (A52) is located near the confluence with Borland Creek, and was alloted a moderate potential impact rating with livestock access to Valley Creek.

Valley Creek had one MELP water quality monitoring station (Site 0600319) located near the confluence with Borland Creek. (Figure 1). This site has been sampled extensively in 1978 and 1985. Sampling by Hart and Mayall in 1990 was, however, limited to one sample above and one sample below agricultural site A55. In May, 1991, the regional office of the Ministry of Environment, Lands and Parks in Williams Lake established another site (E215850) on Valley Creek near the headwaters to monitor background concentrations.

5.2.1 Valley Creek above Turcott's (Site E215850)

Site E215850 was established in 1991 by the MELP to assess background water quality conditions in Valley Creek. It was located above all agricultural sites identified by Hart and Mayall (1990).

Figure 18 shows that the phosphorus concentrations at site E215850 fluctuated during the year. The maximum concentrations recorded in 1991 were 0.075 mg DP/L for the dissolved fraction (July 18, 1991) and 0.024 mg SP/L for the suspended fraction (September 18, 1991). The average P concentrations (0.035 mg/L dissolved P and 0.012 mg/L suspended

P) for the 1991 monitoring period were two to three times lower than the 1985 or 1991 concentration in Valley Creek at the confluence with Borland Creek (Site 0600319); the 1992 averages are even lower (Table 10). These results demonstrate the influence of agricultural activities on water quality in Valley Creek.

5.2.2 Valley Creek at the confluence with Borland Creek (Site 0600319)

1978 DATA

In 1978, the average P concentrations in Valley Creek (site 0600319-Table 10) were relatively constant during the freshet (0.106 mg DP/L and 0.012 mg SP/L) and the non-freshet (0.098 mg DP/L and 0.016 mg SP/L) periods (Stitt *et al.*, 1979).

1985 DATA

The average dissolved P concentrations in 1985 (0.096 mg DP/L) and 1978 (0.098-0.106 mg DP/L) in Valley Creek at the mouth (Site 0600319) were about the same , but the 1985 average suspended P concentration (0.028 mg SP/L) was about twice the 1978 concentration (0.012 to 0.016 mg SP/L) (Table 10). The relatively higher stream flows, in part, may have caused higher supended P load in the creek in 1985; however, 1978 stream flow data were not available to verify this conclusion.

Figure 19 shows the 1985 phosphorus concentrations as a function of time in Valley Creek for site 0600319. The dissolved P concentration at the site increased steadily through March before reaching a maximum of 0.168 mg DP/L on April 4. During the same period the suspended P concentration in the creek declined or remained fairly constant at about 0.02 mg/L. Furthermore, the peak suspended P concentration (0.178 mg SP/L on April 11, 1985) lagged behind the peak dissolved P concentration. This trend, similar to the Borland Creek (Site 0600105, Figures 15) downstream from Valley Creek, was attributed to snowmelt-generated runoff from the adjacent agricultural site (A52). The results also show that the dissolved P concentration declined to a minimum value of 0.038 mg DP/L during the freshet, but it increased again presumably as the stream flow declined. As noted above, the maximum suspended P concentration (0.178 mg SP/L) was recorded on April 11, 1985 (Figure 19). There were no stream flow data for this tributary, but the maximum concentration was presumed to coincide with maximum stream flow for the study period. The suspended P concentrations declined as stream flow declined.

1990 DATA BY HART AND MAYALL

On March 27, 1990, Hart and Mayall (1990) sampled Valley Creek at two locations. Water quality site W36, located above both agricultural sites A52 and A55 (Figure 8), was considered a background site. The other water quality site (W37) was located downstream from agricultural site A55, which was classified as a high potential impact site (Hart and Mayall, 1990). The results indicated that the dissolved and suspended P concentrations, respectively, in the creek were 0.045 mg DP/L and 0.018 mg SP/L above the agricultural site A55, and 0.322 mg DP/L and 0.044 mg SP/L below the agricultural site. There was only one set of water quality data from the two sites (i.e., W36 and W37), but the water chemistry results suppported the Hart and Mayall conclusion (based on soil characteristics and livestock density/access information) that the agricultural site A55 can have an adverse effect on surface water quality during the snowmelt.

1991/92 DATA

The more recent (1991/92) results of water quality monitoring for site 0600319 are shown in Table 10 and Figure 20 (the 1985 data are also plotted for comparison). The 1991 average P concentrations for the site were similar to those measured in March to May, 1985 (Table 10). The results in Figure 20 also show that the dissolved P concentrations from March-May/1991 were similar to or less than those measured during the same period in 1985.

In section 5.1.5, it was concluded Valley Creek increased the dissolved P concentration in Borland Creek (Site 0600330). The relatively high dissolved P concentration in Valley Creek (site 0600319 - Table 10) supports this conclusion.

5.2.3 Phosphorus Loading from Valley Creek

Phosphorus loadings in Valley Creek (Sites 0600319 and E215850) were estimated to define agricultural input in the watershed (Table 10). The 10- to 11-month period between April 1991 and March 1992, for which both the concentration and flow data were available, was chosen for the analysis.

The results show that the suspended P loading in Valley Creek at the confluence with Borland Creek nearly quadrupled (90 kg, Site 0600319) over the background (24 kg, Site E215850). Between the same two sites, the dissolved P loading increased by about 10 times to 344 kg (Site 0600319) over the background (35 kg, Site E215850) during the same period. A part of the increase in the P loading is due to flow (i.e., erosion), but, as suggested by the dissolved P analysis, most of the increase was due to agriculture. The results also show that Valley Creek (Site 0600319, Table 10) represented about 22% of the total (dissolved+ suspended) phosphorus load in Borland Creek at the mouth (Site 0600105, Table 9).

5.3 Five Mile Creek Water Quality Surveys

Five Mile Creek is the second major tributary to Borland Creek. It climbs steeply north from its confluence with Borland Creek (Figure 21) through several storage basins and 7 agricultural sites. Two of the seven agricultural sites are rated as high potential impact sites (A57 and A59), whereas the remaining 5 are low potential impact sites (A56, A58, A60, A61, and A62) (Hart and Mayall, 1990).

The total drainage area for Five Mile Creek is estimated at 52.1 km^2. In terms of flow, Five Mile Creek contributes about 26% to the total flow in Borland Creek at the mouth.

1990 DATA BY HART AND MAYALL

On March 18, 1990, Hart and Mayall (1990) sampled Five Mile Creek at two locations (W40 and W41, Figure 8). Site W40 was downstream from all the reservoirs, and all but one (A59) of the agricultural sites. The dissolved and suspended P concentrations for site W40 were 2.620 mg DP/L and 2.060 mg SP/L, respectively. The other water quality site (W41) at Highway 97 was below all agricultural sites, but dilution from stream flow resulted in dissolved and suspended P concentrations for site W41 (0.930 mg DP/L and 0.180 mg SP/L, respectively) which were lower than those observed for site W40.

1991/92 DATA

In 1991/92, Ministry of Environment, Lands and Parks sampled Five Mile Creek basin at various locations starting from the headwaters to its confluence with Borland Creek. The results of this study are summarized below.

5.3.1 Dugan Lake Outlet (Site E215830)

Water quality site E215830 at the outlet of Dugan Lake is located upstream from all agricultural sites (Figure 1). Figure 22 shows that the P concentrations at the site varied widely during the monitoring period, ranging from a minimum of 0.013 mg/L dissolved P and 0.001 mg/L suspended P to a maximum of 0.144 mg/L dissolved P and 0.041 mg/L suspended P. The maximum concentration of 0.144 mg/L for dissolved P appeared to be anomalous, since no source of phosphorus was identified in the vicinity of the site. The 1991/92 average P concentrations at the site varied from 0.022-0.026 mg DP/L (discounting the anomalous value of 0.144 mg/L) for the dissolved fraction to 0.012-0.014 mg SP/L for the suspended fraction (Table 11).

5.3.2 Five Mile Lake Inlet (Site E215831)

Water quality site E215831 at the Five Mile Lake inlet is about 4 km downstream from site E215830 at the Dugan Lake outlet. Three agricultural sites, A60, A61, and A62, were identified in this stretch, but all of them were rated low for potential impact on the surface water quality (Hart and Mayall, 1990).

The results show that the 1991 average P concentrations at site E215831 increased from 6- (suspended P) to 8-fold (dissolved P) over the background (Site E215830) (Table 11, Figures 22 and 23). This increase in the concentration was not clear, since the 3 agricultural sites, upstream from site E215831, were located in an area of low phosphorus-transfer-susceptibility (hence were assigned low impact rating as noted above).

5.3.3 Five Mile Lake Outlet (Site E213126)

The dissolved P concentration versus time plots for site E213126 (Figure 24) showed a trend which is similar to the site E215830 at the outlet of Dugan Lake (Figure 22). That is, the dissolved P concentrations were generally (a) independent of the flow, and (b) higher during winter than other times of the year. The average P (dissolved and suspended) concentrations at site E213126 were much higher than at site E215830 (Section 5.3.2), but were similar to site E215831 at the lake inlet (Table 11). Obviously, Five Mile Lake had little influence in moderating the quality of water from the upstream site E215831.

5.3.4 Five Mile Creek above 153 Yearlings (Site E216690)

Two agricultural sites (A56 and A57) were identified in this reach of Five Mile Creek, stretching from the 5 Mile Lake outlet (Site E213126) to water quality site E216690 (both agricultural sites were in the proximity of site E216690). Site A57 was rated high for its potential impact on surface water quality, whereas a low impact rating was assigned to site A56 (Hart and Mayall, 1990).

Between January and April, 1992, 21 water quality samples were collected from site E216690. The results show that P concentrations at the site varied widely (Figure 25). The average dissolved P concentration at site E216690 (0.500±0.572 mg/L) was one of the highest in the entire San Jose River watershed including the Five Mile Creek basin (Table 11). Figure 25 also indicates that (a) the dissolved and suspended P concentrations fluctuated in unison and (b) the suspended fraction was always lower than the dissolved fraction. These trends appear to suggest that surface runoff from the land (rather than erosion within the stream environment) was the more likely cause of high phosphorus concentrations in the creek. Water flow rates were not measured at this site.

5.3.5 Five Mile Creek below 153 Mile Ranch (Site E216606)

Water quality site E216606 on Five Mile Creek is located about 0.5 kilometre downstream from site E216690 and about 3 km upstream from the confluence with Borland Creek. This stretch of the creek is relatively steeper (Figure 21) and supported two agricultural sites (A58 and A59) (Figure 8). The potential impact on the surface water quality was rated high for one of the sites (A59) and low for the other (A58) (Hart and Mayall, 1990).

The results show that site E216606 (Figure 26) behaved more or less in a manner similar to site E216690 (Figure 25). For instance, (a) both dissolved and suspended P concentrations varied widely during the monitoring period; (b) the average dissolved P concentration of 0.599 mg/L was one of the highest in the entire San Jose River watershed (Table 11).

Table 11 shows that the average suspended P concentration at site E216606 (0.143 mg/L) was higher than that at site E216690 (0.062 mg/L). Note, however, the variability in the suspended concentration was also much higher for the site. Water flow measurements at the site were not made.

5.3.6 Five Mile Creek at Hwy 97 (Site E213046)

Water quality site E213046, the last site on Five Mile Creek, is located at the confluence with Borland Creek. No agricultural sites were identified in this portion of the creek, stretching from site E216606 to site E213046.

The results show that the dissolved P concentration in the creek at site E213046 fluctuated from a minimum of about 0.1 mg DP/L to a maximum of about 0.6 mg DP/L during 1991/92 (Figure 27). The observed fluctuations in the dissolved P concentration were determined, in part, by the stream flow, but the patterns of the fluctuations differed during the year. For instance, during the snowmelt (i.e., around the first peak in the winter of 1991), the P concentration appeared to increase and decrease with the flow (this behaviour was noted at other sites in the Borland Creek watershed). However, the trend was reversed later in the year. This reversal in the trend (i.e., decrease in the dissolved P concentration during high flows and increase in the concentration during low flows) was attributed to dilution by the streamflow.

Table 11 shows that the average dissolved and suspended P concentrations in the creek at site E213046 were high, but much lower than at the two upstream sites (E216690 and E216606). Dilution by streamflow and sampling error due to lag in the movement of water front between u/s and d/s sites, were partly responsible for the reduced concentrations at the site. Settlement of suspended material also may have caused some reduction in the suspended P concentration in the creek.

5.3.7 Phosphorus Loading from Five Mile Creek

The phosphorus loadings in the Five Mile Creek basin were calculated for three water quality sites (E215830, E213126, and E213046) for which both flow and phosphorus concentrations simultaneously were available in 1991 (Table 11).

The dissolved and suspended P loadings in Five Mile Creek at the background site (E215830), from May 8-Dec.19/91, were relatively minor at 9 kg and 4 kg, respectively. During the same period, the P loading increased from 10- (suspended fraction) to over 20-fold (dissolved fraction) at site E213126 located downstream from Five Mile Lake outlet. Three agricultural sites A60, A61, and A62 (Section 5.3.3) were identified upstream from Five Mile Lake inlet, but all of them were rated low for their potential impact. The P loadings of 745 kg for the dissolved fraction and 103 kg for the suspended fraction in Five Mile Creek at the mouth (Site E213046) were over 3.5 and 2.5 times, respectively, higher than the loadings at the Five Mile Lake outlet.

The results also show that the Five Mile Creek basin is the major source of P loading to Borland Creek (Tables 9 and 11). For instance, 5 Mile Creek contributed about 42% to the total (dissolved+suspended) P loading in Borland Creek at the mouth (Site 0600105); this is about twice the P loading contributed by Valley Creek (Section 5.2.2).

5.4 Jones Creek Water Quality Surveys

Jones Creek is the third major tributary to the San Jose River. It drains an area of about 83 km^2, while contributing about 4.3% to the total flow in the San Jose River at Williams Lake. Jones Creek has a fairly constant gradient from the mouth (i.e., its point of entry to San Jose River) to its headwaters (Figure 28).

Ten cattle overwintering sites (A27-A36) were identified within the Jones Creek watershed (Hart and Mayall, 1990). Sites A27 and A28 were located at the top of the watershed; sites A29, A30, A31, A32 and A33 were clustered around Jones Lake; and sites A34, A35, and A36 were located near the confluence with the San Jose River (Figure 8).

Based on soil analyses and agricultural management practices (i.e., livestock density and their access to the creek, etc.), the potential impact on water quality from the ten agricultural sites was considered to be high for site A36, moderate to high for site A34, moderate for sites A28 and A31, low to moderate for sites A27, A29, and A35, and low for sites A30, A32, and A33. Six of the ten sites had livestock access to the creek (Table 12).

1988 DATA

The water quality data for Jones Creek are limited. During the summer of 1988, the Ministry of Environment, Lands and Parks (MELP) collected three samples from two sites near the confluence with the San Jose River. On July 20, 1988, the dissolved P concentrations in Jones Creek above (Site E207575) and below (Site E207576) agricultural site A34 were 0.213 and 1.94 mg/L, respectively.

1990 DATA BY HART AND MAYALL

Hart and Mayall (1990) sampled several locations on Jones Creek during the 1990 freshet (Figure 8). The water quality site W19 was located above the agricultural sites. On March 27, 1990, the dissolved and suspended P concentrations at site W19 were 0.042 mg DP/L and 0.022 mg SP/L, respectively. The dissolved P concentration in Jones Creek at site W19 was about twice the background average concentration (0.022 mg DP/L - E215824) in Borland Creek (Section 5.1.6). Nevertheless, the concentration of 0.042 mg DP/L was not far from the upper value of the observed range in concentration (0.012-0.032 mg DP/L-Figure 15) for site E215824.

Water quality site W20 was located a short distance downstream from water quality site W19 and agricultural sites A27 and A28 (Figure 8). A sample collected from this site (W20) on the March 27, 1990, showed a substantial increase (over site W19) in the dissolved (0.130 mg/L) and the suspended (0.051 mg/L) P concentrations.

On the same day (March 27, 1990), Hart and Mayall also sampled Jones Creek at two other locations, one upstream (W21) and the other downstream (W22) from Jones Lake (Figure 8). Both sites W21 and W22 were located ≥ 5 km downstream from W20. The results indicated that the dissolved P concentrations at the two sites were lower (i.e., 0.072 mg DP/L at W21 and 0.052 mg DP/L at W22) relative to upstream site W20 which was impacted by the agricultural activities in the area. Dilution by streamflow, and sampling error (due to lag time in the movement of water front between u/s site W20 and d/s sites W21 and W22) were partly responsible for this decrease. Suspended P concentrations at the two sites were 0.049 mg/L (W21) and 0.039 mg/L (W22), respectively.

1991/92 DATA

In 1991 MELP established another water quality site (E214700, Figure 1) on Jones Creek below Hwy 97 for trend monitoring purposes (Figure 29). Both the dissolved and the suspended P concentrations at the site varied widely during the year. However, the 1991 (0.057±0.026 mg DP/L, 0.029±0.021 mg SP/L, n=30) and the 1992 (0.050±0.019 mg DP/L, 0.021±0.016 mg SP/L, n=20) average values were similar to those of Hart and Mayall (1990) at their background site (W19) (see above). It is worth noting that (a) there were seven agricultural sites in the watershed, but all were rated low or low-to-moderate for their potential impact on surface water quality (A27 to A33 - Table 12); and (b) the nearest agricultural sites (i.e., A31 and A33) were located about 2 km upstream from site E214700.

5.4.1 Phosphorus loading from Jones Creek

Between April 9/91 and March 20/92 both flow and P concentration data were available for Jones Creek at Hwy 97 (Site E214700). The phosphorus loadings for this period were calculated to be 160 kg for the dissolved fraction and 92 kg for the suspended fraction. As compared to Borland Creek (920 kg dissolved P and 1080 kg suspended P between April 12 and December 31, 91 - Table 9), the P loadings to the San Jose River from Jones Creek were relatively much smaller (< 12% total P).

More water quality and stream flow sampling are required at several points along Jones Creek to determine the extent of the agricultural impact on the water quality of Jones Creek.

5.5 Knife Creek Water Quality Surveys

Knife Creek (234 km^2) drains an area which is equivalent to the area drained by Borland Creek (228 km^2). The mean annual flow for Knife Creek at the mouth was estimated at 0.148 m^3/s or 9% of the total discharge in the San Jose River before it enters William Lake. The creek has quite a steep gradient rising 300 m in about 20 km, although some reaches are quite gradual in slope (Figure 30). A small pond lies at the headwaters, and Squawk Lake is found about 10 km downstream. Coldspring Creek, a tributary, meets Knife Creek several kilometres below the outlet of Squawk Lake.

Fourteen agricultural sites were identified in the Knife Creek watershed (Figure 8; Table 13, Hart and Mayall, 1990). The majority of the 14 agricultural sites were located between the confluence of Coldspring Creek and the confluence with the San Jose River (Figure 8). There were no agricultural sites on Coldstream Creek or adjacent to Squawk Lake.

There are six water quality sites on Knife Creek, one on Coldspring Creek, and two on Squawk Lake (Figure 1, Table 14). Of the 9 sites, 5 were surveyed extensively in 1978. The 1978 dissolved and suspended P concentrations for the freshet and nonfreshet periods for 4 stations on Knife Creek, and one station on Coldspring Creek were summarized by Stitt *et al.*, (1979) (Table 14).

In 1990, MELP established two more water quality sites in the Knife Creek watershed: E213047 on Coldspring Creek and E213042 on Knife Creek. Water quality site E213042 was located upstream from all the agricultural sites in the watershed. As noted above, no agricultural sites were identified in the Coldspring Creek watershed. Additionally, water quality was also measured in Knife Creek at the mouth (Site 0600124). The 1990/92 water quality results for these sites are shown in Table 15.

5.5.1 Knife Creek at Squawk Lake (Site 0600315)

The 1978 background P concentrations in Knife Creek are represented by water quality site 0600315 at the outlet of Squawk Lake (Table 14). The results show that the dissolved P concentration (0.030 to 0.033 mg DP/L) was fairly constant during the freshet and non-freshet periods. The suspended P concentration increased from a low of 0.011 mg SP/L in the non-freshet, to 0.034 mg SP/L in the freshet. It is unclear from the data whether the increase in the suspended P concentration was the result of suspended sediment from stream bank erosion or organic P associated with phytoplankton in Squawk Lake.

5.5.2 Knife Creek upstream K. Smith Hobby Ranch (Site E213042)

Phosphorus concentrations in Knife Creek at site E213042 are shown in Figure 31 and Table 15. The results show that the P concentrations varied during the year. The 1991 and 1992 average dissolved (0.027-0.045 mg DP/L) and suspended (0.024-0.026 mg SP/L) P concentrations for the site were similar to the 1978 concentrations during the freshet and non-freshet periods (Table 14). No agricultural site was identified upstream from site E213042; hence it may be considered a background site.

5.5.3 Knife Creek above Coldspring Creek (Site 0600314)

In 1978, the dissolved P concentration (0.043 mg/L) in Knife Creek upstream from Coldspring Creek (Site 0600314) increased moderately over the concentration at the Squawk Lake site (Table 14). Two agricultural sites (A9 and A10) were identified by Hart and Mayall (1990) upstream from site 0600314, but both of them were rated low for their potential impact on surface water quality (Figure 8, Table 13). The available data show that the 1978 dissolved P concentrations for site 0600314 (a) fall with in the range specified by the two background sites; i.e., site 0600320 on Coldspring Creek and site 0600315 on Knife Creek at Squawk Lake; and (b) are similar to that of site E213042 (Table 15), which was established recently for the purpose of assessing background water quality in Knife Creek.

In contrast, the suspended P concentrations (0.007 and 0.010 mg SP/L during the non-freshet and freshet periods, respectively) for site 0600314 on Knife Creek were lower compared to the concentrations in the creek at the Squawk Lake outlet (site 0600315) (Table 14) or the 1990/92 average concentration (0.024 mg/L) for site E213042 (Table 15).

5.5.4 Knife Creek at First Bridge (Site 0600313)

Four agricultural sites (A11, A12, A13, and A14) were identified between water quality sites 0600313 and 0600314; however, all of them were rated to have low to moderate potential impact on surface water quality (Table 13). The 1978 dissolved P concentrations in Knife Creek at First Bridge (site 0600313; Figure 1) increased slightly over the upstream site (0600314) during the freshet (Table 14). During the same period, the increase in the suspended P concentration between the two sites was much higher (0.010 to 0.024 mg SP/L-Table 14). Much of the increase in the suspended P concentration at site 0600313 was attributed to stream bank erosion. Note that the dissolved and the suspended P concentrations for site 0600313 were within the range of the concentrations (average ± one standard deviation) at the recently established background site (Site E213042 - Table 15).

5.5.5 Knife Creek at the Dump (Site 0600227)

Five agricultural sites (A15 to A19) were identified in the stretch of Knife Creek between Site 0600313 and Site 0600227 (Table 13). The potential impact on surface water quality was rated low for one (A15) and low-to-moderate for the other four sites. One of the sites (A16) had livestock access to the creek.

Phosphorus concentrations in Knife Creek at site 0600227 were measured during the 1978 freshet only. The results show that the dissolved P concentration at site 0600227 was slightly higher than the upstream site 0600313, whereas the suspended P concentration decreased from 0.024 mg/L (Site 0600227) to 0.012 mg/L (Site 0600313) (Table 14).

5.5.6 Knife Creek at 141 Mile House (Site 0600124)

1978 DATA

The last water quality station on Knife Creek (Site 0600124) is located near the confluence with the San Jose River. During the 1978 freshet, the dissolved P concentration at the site (0.142 mg/L) increased by about 3-fold over the upstream site 0600227 (Table 14). This increase in the dissolved P concentrations was probably caused by the three agricultural sites (A20, A21, and A22: Table 13) located adjacent to Knife Creek. Note that livestock had access to the creek at two of the sites (A20 and A21).

1990 DATA BY HART AND MAYALL

The March 28, 1990 results by Hart and Mayall (1990) did not yield the same increase in the concentration as in 1978. For instance, the dissolved P concentrations in Knife Creek increased slightly from 0.035 mg/L (water quality site W11 - Knife Creek at the bridge) above the three agricultural sites to 0.049 mg/L (water quality site W14 - Knife Creek at Hwy 97) below the agricultural sites. Hart and Mayall (1990) suggested that the agricultural sites had little potential impact on the water quality of Knife Creek.

1990/92 DATA

The 1990/92 results for site 0600124 were similar to those of the background site E213042 in 1991 (Figure 32, Table 15). For instance, the average dissolved P concentrations of 0.047 mg/L at site 0600124 (based on 66 measurements between 1990/92) and the 1991 concentration of 0.045 mg/L at the recently established background site E213042 were similar in magnitude. Between January and May/92, however, the average dissolved P concentration in Knife Creek at the mouth (Site 0600124) was 1.7 times higher than the average concentration at the background site (E213042) (Table 15). This trend was not clearly understood from the data.

The 1990/92 suspended P concentrations for site 0600124 were similar to the upstream site E213042 (Table 15).

5.5.7 Coldspring Creek at the confluence with Knife Creek (Site 0600320)

Two water quality sites, one in 1978 (Site 0600320) and the other in 1990 (E213047), were established in this reach of Coldspring Creek. The intent for the 1990 station was to assess the background water quality in the Knife Creek watershed. The phosphorus concentrations as a function of time for site E213047 are shown in Figure 33.

1978 DATA

The 1978 results indicate that the dissolved P concentrations in Coldspring Creek (Site 0600320) during the non-freshet and the freshet periods were 1.5 to 2 times higher than the background concentrations in Knife Creek (Site 0600315) (Table 14). The trend reversed for the suspended fraction during the freshet, but the suspended P concentrations during the non-freshet period were similar in magnitude for sites 0600320 (Coldspring Creek) and 0600315 (background site on Knife Creek) (Table 14). There was no agricultural site in these stretches of Coldspring Creek and Knife Creek.

1990/92 DATA

The 1991 and 1992 average dissolved P concentrations of 0.040 and 0.028 mg/L, respectively, in Coldspring Creek (Site E213047- Table 15) were similar to the 1991 and 1992 dissolved P concentrations in Knife Creek at the background site (Site E213042) (Table 15). That the 1991/92 average suspended phosphorus concentrations (0.014-0.019 mg/L) for site E213047 were lower than those measured at site E213042 (Table 15) reflect differences in site characteristics (e.g., stream flow, gradient, etc.).

5.5.8 Phosphorus loading from Knife Creek

The phosphorus loadings in the Knife Creek basin were calculated for water quality site 0600124 at the mouth (Table 15).

The annual (between April 9/91 and March 28/92) dissolved and suspended phosphorus loadings at the site were estimated at 623 kg and 580 kg, respectively. The total (dissolved+suspended) phosphorus loading in Knife Creek (between April 12/91 and December 31/91) represented about 41% of the phosphorus loading in Borland Creek at the mouth (Site 0600105- Table 9).

5.6 San Jose River

The San Jose River is approximately 52 km long, from its origin at the outlet of Lac la Hache to the point it enters Williams Lake. There is one small lake (130 Mile Lake) on the mainstem of the river; in addition, there are several lakes (Yellow, McGuchlin, etc.) adjacent to the river. Borland Creek, Jones Creek, and Knife Creek are three major tributaries (see Sections 5.1, 5.3, and 5.4) on the northern side of the river. The river has a fairly uniform gradient (Figure 34). Twenty three agricultural sites were identified by Hart and Mayall (1990) along the river. The potential impact on water quality of the San Jose River was rated low for 10 of the 23 agricultural sites; low-to-moderate for 3 sites; moderate for 3 sites; moderate-to-high for one site; and high for six sites (Table 16).

Water quality in the San Jose River was monitored by (a) Stitt *et al.* (1979) in 1978, (b)

Hart and Mayall (1990) in 1990, and (c) the Ministry of Environment, Lands and Parks in 1991/92 (Tables 17, 18, and 19).

5.6.1 San Jose River at Lac La Hache Outlet (Site 0600021)

The phosphorus concentrations for site 0600021 at the outlet of Lac la Hache (Figure 1) are shown as a function of time in Figures 35a and 35b.

In 1978, the dissolved and suspended P concentrations, respectively, at site 0600021 averaged from 0.006 mg DP/L to 0.007 mg SP/L during the freshet and from 0.006 mg DP/L to 0.010 mg SP/L during the non-freshet period (Table 17). The 1990 (site W1-Table 18) and the early 1991 (Table 19) results were similar. The average concentrations for the dissolved (0.015 mg DP/L) and the suspended (0.012 mg SP/L) fractions at the site (0600021) were highest in 1980 (Table 19, Figures 35a and 35b).

The low (relative to the backgound in the tributaries - see sections above) P concentrations for site 0600021 were expected due to the mesotrophic[5] nature of Lac la Hache.

5.6.2 San Jose River at 133 Mile House (Site 0600102)

Water quality site 0600102 is about 8.8 km downstream from Lac la Hache (Site 0600021). Also located within this reach are 130 Mile Lake and two agricultural sites (A1 and A2). The potential impact on surface water quality was rated high for site A1 and moderate for site A2 (Table 16, Hart and Mayall, 1990).

1978 DATA

The 1978 dissolved (freshet and non-freshet) and suspended (freshet) P concentrations in the San Jose River at site 0600102 showed a small increase over site 0600021 (Table 17). The increase in the total (dissolved+suspended) P concentration was even smaller.

1990 DATA BY HART AND MAYALL

In 1990, Hart and Mayall (1990) found that the dissolved and suspended P concentrations, respectively, in the San Jose River downstream from site A1 increased from

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[5]Mesotrophic or moderately productive lakes have average epilimnetic total phosphorus concentrations ranging between 0.010-0.030 mg/L (Nordin, 1985).

0.022 mg DP/L and 0.005 mg SP/L (water quality site W2), to 0.116 mg DP/L and 0.043 mg SP/L (water quality site W4) (Table 18, Figure 8). These investigators also found that the phosphorus concentrations (0.660 mg DP/L, and 0.420 mg SP/L) in the agricultural runoff from site A1 on March 26, 1990 were much higher (site W3-Table 18); the agricultural site A1 was assigned a high potential impact rating (Table 16).

The dissolved and suspended P concentrations, respectively, in the San Jose River decreased from 0.116 and 0.043 mg/L at the upstream site (W4) to 0.039 and 0.021 mg/L below 130 Mile Lake (W5) (Table 18). These preliminary results indicate that 130 Mile Lake is a phosphorus trap, and site 0600102 is not adequate to assess the impact of agricultural site A1.

This site was not included in the 1990/92 monitoring program of the Ministry of Environment, Lands and Parks.

5.6.3 San Jose River at Enterprise Road (Site 0600103)

Water quality site 0600103 is located approximately 7.6 km downstream from site 0600102 (Figure 1a). Agricultural sites A3, A4, A5, and A6, and a small tributary (Murphy Creek) are located in this reach of the San Jose River (Figure 8). In the 1990 survey, the potential impact on surface water quality was rated high for site A4, moderate for sites A3 and A5, and low for site A6 (Table 16).

1978 DATA

The 1978 data indicated that the dissolved P concentration (0.014 mg/L) in this reach (Site 0600103) during the non-freshet was similar to upstream site 0600102 (Table 17). During the freshet, however, the dissolved P concentration (0.030 mg/L) increased over 3-fold relative to the upstream site. Whether the observed increase in the dissolved fraction was due to the agricultural activities or Murphy Creek, could not be determined from the data.

1990 DATA BY HART AND MAYALL

In 1990, water quality sampling within this reach of the San Jose River was limited to three sites; site W5 was located at the top of the reach, W6 was located below Murphy Creek, but above the 4 agricultural sites, and W7 was located at the bottom of the reach (same site as MELP site 0600103) (Figure 8, Table 18). From three samples taken between March 18 and April 5, 1990, Hart and Mayall (1990) found that both the dissolved and suspended P concentrations were elevated at site W6 relative to site W5, indicating substantial P loading from Murphy Creek (Table 18).

No clear effect of agriculture on water quality was found in this reach of the San Jose River (i.e., water quality site W7). For instance, the dissolved P concentrations for sites W7 and W6 (located upstream from the agricultural areas) were similar. The suspended P concentrations were lower for the downstream site W7 on all three occasions, but may have resulted from some settling of particulate P prior to high stream flows (Table 18).

1990/91 DATA

MELP monitored P concentrations in the San Jose River at site 0600103 between December 1990 and April 1991. The average dissolved P concentration (0.026 mg DP/L, Table 19) during the period was in the range determined by the 1978 freshet and the non-freshet concentrations (Table 17). However, the 1990/91 average suspended P concentration (0.030 mg SP/L, Table 19) for the site was 3 to 4 times larger than the 1978 concentrations measured during the freshet and the non-freshet periods (Table 17). The reason for this difference could not be ascertained due to the lack of data (e.g., flow).

Water quality site 0600103 was not included in the more recent monitoring program of the Ministry of Environment, Lands and Parks.

5.6.4 San Jose River above Knife Creek (Site 0600107)

Water quality site 0600107 on the San Jose River above Knife Creek is located approximately 6.4 km downstream from site 0600103 (Figure 1). There are two agricultural sites (A7 and A8, both rated low for potential impact) within this reach (Table 16, Figure 8). Water quality samples in this reach are limited to the 1978 data reported by Stitt *et al.*, (1979).

During the non-freshet, the dissolved and suspended P concentrations in the San Jose River (Site 0600107 above knife Creek) were similar to the upstream site 0600103 (Table 17). The dissolved P concentration, however, increased from an average of 0.030 mg/L at site 0600103, to 0.043 mg/L at site 0600107 during the freshet. The reason for this increase was not clear from the data. Note that (a) the two agricultural sites in this reach were rated low for their impact on surface water quality; and (b) a tributary such as Murphy Creek has been shown to increase P (dissolved and suspended) concentration in the San Jose River (Section 5.6.2).

The 1978 suspended P concentrations in this reach (between sites 0600103 and 0600107) did not change during the freshet and non-freshet periods (Table 17).

5.6.5 San Jose River below Knife Creek (Site 0600312)

Water quality site 0600312 on San Jose River is located within several hundred metres of site 0600107 (Figure 1). This small reach has no agricultural site, but includes the drainage from Knife Creek. Water quality analyses for this reach are limited to the 1978 data reported by Stitt *et al.*, (1979).

In 1978, the dissolved P concentrations in San Jose River downstream from Knife Creek (site 0600312) increased about 2-fold relative to upstream (site 0600107) during the non-freshet. However, the dissolved P concentrations were similar at sites 0600312 and 0600107 during the freshet (Table 17), despite significantly higher concentration (0.142 mg DP/L) in the Knife Creek discharge (site 0600124-Table 14). There were not enough relevant data (e.g., including flow) to explain these differences.

The suspended P concentrations did not exhibit a change between sites 0600107 and 0600312 during the non-freshet, but increased moderately from 0.010 mg/L (Site 0600107) to 0.016 mg/L at site 0600312 during the freshet (Table 17).

Further monitoring is required to determine the impact of Knife Creek on the San Jose River water quality.

5.6.6 San Jose River above Cariboo Students Residence (Site 0600123)

Water quality site 0600123 is located below Jones Creek about 14 km downstream from site 0600312 (Figure 1). Among 6 agricultural sites identified in this reach of the river (Table 16, Figure 8), three (A24, A25, and A26) were rated low for their potential impact on surface water quality, one (A37) had a low to moderate rating, and two sites (A23 and A36) were assigned a high impact rating.

1978 DATA

The 1978 water quality results (Stitt *et al.*, 1979) indicated that the dissolved P concentration in this reach (site 0600123) was similar to the upstream (site 0600312) during the non-freshet (Table 17). In contrast, the dissolved P concentrations doubled from 0.045 mg/L at site 0600312 to 0.090 mg/L at site 0600123 during the freshet. Between the same sites the suspended P concentration also increased by about 50% during the non-freshet and freshet periods (Table 17), suggesting that stream erosion also was an important factor in determining P loading in the river at site 0600123. Note that site 0600123 was located in the relatively steeper stretch of the river (Figure 34).

1990 DATA BY HART AND MAYALL

Hart and Mayall (1990) sampled several locations in this reach to differentiate (at least partially) the influence of Jones Creek on water quality from that of the agricultural sites on the mainstem San Jose River . Water samples were collected from above (W16), at (W17) and below (W18) agricultural site A36 (a high potential impact site located above Jones Creek) on March 17, 1990 (Table 18, Figure 8). The dissolved P concentration increased from 0.134 mg DP/L (W16) above the agricultural site to 0.292 mg DP/L (W18) below the agricultural site. Between the same two sites, the suspended P concentration also increased from 0.076 to 0.398 mg SP/L. A sample of the runoff from the site A36 had 2.6 mg/L dissolved P, and 0.030 mg/L suspended P. The lower (relative to sites W16 and W18) suspended P concentrations in the runoff (W17) suggested that stream bank erosion (probably due to trampling by livestock which had access to the creek - see above) was responsible for the higher suspended P concentration at the downstream site W18 relative to upstream (W16).

Water quality site 0600123 was not included in the recent monitoring program of the Ministry of Environment, Lands and Parks.

5.6.7 San Jose River at Onward (Site 0600106)

Water quality site 0600106 on the San Jose River at Onward is approximately 3.6 km downstream of the Cariboo Student Residence (0600123) (Figure 1). Eight agricultural sites (A38 to A45) were identified in this reach with no major tributaries (Table 16, Figure 8). The potential impact on surface water quality from agriculture was rated low for four sites (A40, A41, A42, and A43), low to moderate for one site (A44), moderate to high for one site (A45), and high for two sites (A38, and A39). None of the agricultural sites in this reach were observed to have livestock access to the river.

1978 DATA

During the 1978 freshet and non-freshet periods, the average dissolved and suspended P concentrations in the San Jose River at site 0600106 (0.043 mg DP/L and 0.099 mg SP/L- freshet; 0.011 mg DP/L and 0.031 mg DP/L- non-freshet) increased slightly over the upstream site 0600123 (0.037 mg DP/L and 0.090 mg SP/L- freshet; 0.010 mg DP/L and 0.024 mg DP/L- non-freshet) (Table 17).

1990 DATA BY HART AND MAYALL

Water quality sampling by Hart and Mayall (1990) was restricted to the agricultural sites A38 (water quality site W27), A39 (water quality sites W28 and W29), and A45 (water quality site W31) (Table 18). Surface runoff from sites A39 and A45 were sampled on March 17, 1990 and March 26, 1990, respectively.

The results show that the dissolved and suspended P concentrations in the surface runoff from the agricultural sites were high; 6.7 mg DP/L and 5.7 mg SP/L, respectively, at site A39 (Water quality site W28), and 2.56 mg DP/L and 0.54 mg SP/L, respectively, at site A45 (Water quality site W31) (Table 18).

Water quality sites W27 (upstream from A38) and W29 (downstream from A39) encompassed high potential impact sites A38 and A39. Nevertheless, the dissolved P concentrations in the San Jose River between the two sites did not change (W27=0.182 mg/L vs W29=0.183 mg/L), despite high levels of P in the surface runoff from site A39 on March 17, 1990. The suspended P concentrations between the same two locations and sampling dates decreased from 0.091 mg/L (W27) to 0.069 mg/L (W29) (Table 18).

Water quality site 0600106 was not included in the recent monitoring program of the Ministry of Environment, Lands and Parks.

5.6.8 San Jose River above Borland Creek (Site 0600317)

Water quality site 0600317 on the San Jose River above Borland Creek is located approximately 3.8 km downstream from site 0600106 (Figure 1). There are no major tributaries or agricultural sites within this reach of the river.

1978 DATA

The total (dissolved+suspended) P concentrations at this site (0600317) during the freshet and non-freshet periods in 1978 were similar to those at the upstream site (0600106) (Table 17). However, as compared to site 0600021 at the outlet of Lac La Hache (which may be considered a background site for the San Jose River mainstem), the total P concentration at site 0600317 had increased by about 3.5 times during the non-freshet to about 10 times during the freshet period (Table 17); most of this increase was due to the dissolved fraction.

1991/92 DATA

The results of a recently initiated monitoring program for site 0600317 by MELP are shown in Table 19 and Figure 36. In general, between January and April, 1991, the total P concentration in San Jose River at site 0600317 increased about 10 times over the site 0600021 at the Lac La Hache outlet. In this respect the 1991 results are similar to the 1978 results (Table 17); however, unlike 1978, most of the increase in the total P concentration in 1991 was due to the suspended fraction.

Sufficient data (e.g., flow in 1978, livestock numbers, etc.) were not available to explain the difference between the 1978 and 1991/92 results. One may speculate, however, that stream flow must have been higher in 1991/92 which resulted in higher suspended phosphorus concentrations (due to erosion) and lower dissolved P concentrations (due to dilution) for site 0600317.

5.6.9 San Jose River below Borland Creek (Site 0600316)

Water quality site 0600316 is the last site on the San Jose River before it enters Williams Lake. It is located several kilometres above Williams Lake, but is only a few hundred metres below site 0600317 (Figure 1). Site 0600316 was established to determine the impact of Borland Creek on the San Jose River water quality.

In 1978, both the dissolved (0.052 mg DP/L to 0.106 mg DP/L) and suspended (0.012 mg SP/L to 0.030 mg SP/L) P concentrations in the San Jose River downstream from Borland Creek (Site 0600316) showed a slight increase (relative to site 0600317 upstream from Borland Creek) during the freshet and non-freshet (Table 17). During 1990/91, however, the dissolved P concentration in the San Jose River increased downstream from Borland Creek, whereas the suspended P concentration decreased (Site 0600317 versus site 0600316 -Table 19, Figure 37).

5.6.10 Phosphorus Loading in San Jose River

Table 19 shows P loading at two locations (site 0600021 and site 0600317) in the San Jose River. The P loading increased by more than an order of magnitude from site 0600021 at the Lac La Hache outlet to site 0600317 upstream from Borland Creek (the monitoring period for site 0600021 was about two months shorter, but the final conclusion will not change even if an appropriate correction is applied to the loading estimates). The results also indicate that the suspended P loading in the river at site 0600021 was similar to the dissolved P loading, but it increased by about 70% over the dissolved loading at site 0600317.

The P loading from the San Jose River to Williams Lake will even be higher, since the contribution from Borland Creek, a major tributary with regard to P loading to San Jose River, was not included in the estimated loading for site 0600317 located upstream from the creek (From Apr. 12 to Dec. 31, 91, the dissolved and suspended P loadings from Borland Creek to the San Jose River were estimated at 921 kg DP and 1081 kg SP, respectively - Table 9).

TABLE 5

1978 DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK (FROM STITT ET AL., 1979)

		Average dissolved P concentration (mg/L)*		*Average suspended P concentration* (mg/L)*	
Station	***Site***	***Non-Freshet***	***Freshet***	***Non-Freshet***	***Freshet***
Above 150 Mile House	0600183	0.051	0.053	0.003	0.010
At Highway 97	0600085	0.044	0.265	0.014	0.076
Above Valley Creek	0600322	0.046	0.225	0.012	0.049
Below Valley Creek	0600330	0.070	0.121	0.017	0.037
At Sugar Cane	0600105	0.107	0.237	0.010	0.039

*based on monthly samples, but the analysis for individual samples and standard deviation were not given in the publication

TABLE 6

1985 DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK (THE MINISTRY OF ENVIRONMENT, LANDS AND PARKS DATA BASE)

	Dissolved Phosphorus		***Suspended Phosphorus***	
SITE	***Average Concentration* (mg/L)***	***# of samples***	***Average Concentration* (mg/L)***	***# of samples***
0600183	0.047±0.016	14	0.027±0.076	14
0600085	0.046±0.027	14	0.050±0.096	14
0600322	0.044±0.021	14	0.052±0.111	14
0600330	0.064±0.036	13	----	----
0600105	0.139±0.102	14	0.035±0.053	14

*average concentration ± standard deviation

TABLE 7

CHARACTERISTICS OF CATTLE OVERWINTERING SITES IN THE BORLAND CREEK WATERSHED AND THEIR RELATIONSHIP TO MELP WATER QUALITY SITES(FROM HART AND MAYALL, 1990)

*Agricultural/ Overwintering Site**	*Livestock density*	*Surface runoff potential*	*Livestock access to creek*	*Potential Impact*	*Water quality Site+*
A47	moderate	high(to ditch)		low to moderate	
A48	moderate	moderate to high		low to moderate	
A49	moderate	low to moderate		low	0600183
A50	low	low to moderate		low	
A51	low	low to moderate		low	0600085
A52	moderate	moderate to high	feeding	moderate	0600322
A53	moderate	low to moderate	watering and feeding	low to moderate	0600330
A54	moderate	moderate to high	watering	moderate to high	0600105
A46	moderate	low to moderate	watering and bedding	low to moderate	

+ Ministry of Environment, Lands and Parks (MELP) water quality sites from Table 6;
* in decreasing order of elevation (A47 is the most upstream site whereas A46 is downstream from all sites).

TABLE 8

SUMMARY OF 1990 DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK (FROM HART AND MAYALL, 1990)

Water Quality Site+	*Site Description*	*Sample Date*	*Dissolved Phosphorus (mg/L)*	*Suspended Phosphorus (mg/L)*
W32	Borland Creek u/s site 48	27/3/90	0.040	0.036
W33	Runoff from site 47	27/3/90	0.063	0.193
W34	Borland Creek at HWY 97	18/3/90	0.090	0.026
W35	Borland Cr. u/s Valley Cr.	18/3/90	0.108	0.049
W38	Borland Cr. d/s Valley Cr.	18/3/90	0.083	0.046
W39	Borland Cr. d/s site 53	18/3/90	0.091	0.024

+ These water quality sites were established by Hart and Mayall during their study and were not entered on SEAM.

TABLE 9

BORLAND CREEK PHOSPHORUS LOADING ESTIMATES FOR THE JAN. 30-MAY 28, 1985 AND APR. 12-DEC. 31, 1991 PERIODS

Variable	*Water Quality Site* ←upstream — downstream→				
	0600183	*0600085*	*0600322*	*0600330*	*0600105*
	-loading in kilograms-				
				Valley Creek ↓	*Five Mile Creek* ↓
Dissolved Phosphorus	405	395	400	650	920 (921)*
Suspended Phosphorus	1 190	1 680	1 880	----	1 200 (1 081)*

* The phosphorus loadings in parentheses are from April 12 to December 31, 1991.

TABLE 10

DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS IN VALLEY CREEK

Water Quality Site	*Dissolved Phosphorus*		*Suspended Phosphorus*	
	Concentration (mg/L)	*Loading (kg)*	*Concentration (mg/L)*	*Loading (kg)*
0600319: at the mouth		344+ (April 12, 1991 to March 28, 1992)		90 (April 12, 1991 to March 28, 1992)
•1978	0.106 (Nonfreshet)*		0.012 (Nonfreshet)*	
	0.098 (Freshet)*		0.016 (Freshet)*	
•1985	0.096±0.044**(n=14)		0.028±0.047**(n=14)	
•1991	0.095±0.043**(n=36)		0.025±0.028**(n=36)	
E215850: back-ground		35 (May, 1991 to March, 1992)		24 (May, 1991 to March, 1992)
•1991	0.035±0.018**(n=9)		0.012±0.008**(n=9)	
•1992	0.017±0.003**(n=9)		0.007±0.006**(n=9)	

* average concentrations: the analysis for individual samples and standard deviation were not given in the publication (from Stitt *et al.*, 1979), ** average±standard deviation

TABLE 11

1991/92 PHOSPHORUS CONCENTRATIONS AND LOADINGS IN THE FIVE MILE CREEK BASIN

Site # and description	*Dissolved Phosphorus*		*Suspended Phosphorus*	
	Conc. (mg/L)	*Loading (kg)*	*Conc. (mg/L)*	*Loading (kg)*
E215830: Dugan Lake outlet		9 (May 8-Dec. 19/91)		4 (May 8-Dec. 19/91)
•1991	0.022±0.008 (n=16)		0.014±0.006 (n=16)	
•1992	0.026±0.012 (n=16)		0.012±0.011 (n=16)	
E215831: 5 Mile Lake inlet				
•1991	0.192±0.107 (n=14)		0.090±0.095 (n=13)	
•1992	0.160±0.121 (n=17)		0.032±0.017 (n=17)	
E213126: Five Mile Lake outlet		208 (May 1-Jul 10/91 + Nov. 12-Dec. 19/91)		40 (May 1-Jul 10/91 + Nov. 12-Dec. 19/91)
•1991	0.164±0.046 (n=9)		0.051±0.041 (n=9)	
•1992	0.211±0.062 (n=17)		0.053±0.034 (n=17)	
E216690: Five Mile Creek above 153 Yearlings -•1992	0.500±0.572 (n=21)		0.069±0.062 (n=21)	
E216606: Five Mile Creek below 153 ranch - •1992	0.599±0.780 (n=30)		0.143±0.184 (n=30)	
E213046: Five Mile Creek at Hwy 97		745 (Jan. 24-Dec. 19/91)		103 (Jan. 24-Dec. 19/91)
•1991	0.252±0.074 (n=47)		0.026±0.029 (n=47)	
•1992	0.242±0.101 (n=25)		0.019±0.018 (n=25)	

TABLE 12

AGRICULTURAL SITES ADJACENT TO JONES CREEK (FROM HART AND MAYALL, 1990)

Site	***Livestock Density***	***Potential Surface Runoff***	***Livestock Access to Creeek***	***Potential Impact***
A27	moderate	mod. to high	watering	low to moderate
A28	moderate	mod. to high	watering	moderate
A29	moderate	low to moderate	watering	low to moderate
A30	low	low to moderate		low
A31	low	high		moderate
A32	low	moderate		low
A33	low	low		low
A34	low	mod. to high	watering and bedding	mod. to high
A35	moderate	moderate	watering	low to moderate
A36	moderate	high	watering and bedding	high

TABLE 13

AGRICULTURAL SITES ADJACENT TO KNIFE CREEK (FROM HART AND MAYALL, 1990)

Agricultural Site	*Livestock Density*	*Potential Surface Runoff*	*Livestock Access to Creek*	*Potential Impact*	*MELP Water Quality Site*
A9	moderate	low to moderate		low	0600320
A10	low	low to moderate		low	0600314
A11	moderate	low		low	
A12	moderate	moderate		low to moderate	
A13	moderate	moderate		moderate	
A14	low	low		low	0600313
A15	moderate	low		low	
A16	low	moderate	watering	low to moderate	
A17	low	moderate		low to moderate	
A18	low	moderate		low to moderate	
A19	low	high	watering	low to moderate	0600227
A20	low	moderate to high	watering	low to moderate	
A21	low	low to moderate	watering	low	
A22	low	low		low	0600124

TABLE 14

1978 DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS IN THE KNIFE CREEK WATERSHED

		Average dissolved P concentration* (mg/L)		Average suspended P concentration* (mg/L)	
Water Quality Site	*Station*	*Non-Freshet*	*Freshet*	*Non-Freshet*	*Freshet*
Coldspring Creek	0600320	0.060	0.046	0.014	0.014
Knife Creek @ Squawk Lk	0600315	0.033	0.030	0.011	0.034
Knife u/s Coldspring Creek	0600314	0.043	0.043	0.007	0.010
Knife Creek @ 1st Bridge	0600313	0.044	0.048	0.009	0.024
Knife Creek @ Dump	0600227	-----	0.053	----	0.012
Knife Creek @ 141 Mile	0600124	0.056	0.142	0.012	0.016

*the analysis for individual samples and standard deviation were not given in the publication (from Stitt *et al.*, 1979)

TABLE 15

1990/92 AVERAGE PHOSPHORUS CONCENTRATIONS IN THE KNIFE CREEK WATERSHED

Site Description	*Site #*	*Dissolved P (mg/L)*	*Suspended P (mg/L)*	*Phosphorus Loading (kg)*
Coldspring Creek at the confluence with Knife Creek	E213047			
•1991		0.040±0.011* (n=15)	0.014±0.011* (n=15)	
•Jan-May/92		0.028±0.003* (n=9)	0.019±0.025* (n=9)	
Knife Creek u/s K. Smith Hobby Ranch	E213042			
•1991		0.045±0.015* (n=15)	0.024±0.018* (n=15)	
•Jan-May/1992		0.027±0.007* (n=11)	0.026±0.009* (n=11)	
Knife Creek at the mouth	0600124			
•1990/92		0.047±0.015* (n=66)	0.027±0.028* (n=66)	
•Jan-May/92		0.046±0.015* (n=28)	0.024±0.020* (n=28)	
•Apr. 9/91-Mar.28/92				623 (dissolved) 580 (suspended)
Apr.12/91-Dec.31/91				393 (dissolved) 420 (suspended)

* average ± standard deviation (n = number of measurements)

TABLE 16

SUMMARY OF AGRICULTURAL SITES ALONG THE MAINSTEM SAN JOSE RIVER*

Agricultural site	*Livestock Density*	*Potential Surface Runoff*	*Livestock Access to Creek*	*Potential Impact*	*Water Quality Site*
A1	high	high	watering & bedding	high	0600021
A2	moderate	high		moderate	0600102
A3	low-moderate	moderate		moderate	
A4	moderate	high		high	
A5	moderate	moderate	bedding	moderate	
A6	low	low-moderate		low	0600103
A7	low	low		low	
A8	low	low		low	0600107
A23	moderate	high	watering & bedding	high	
A24	low	low		low	
A25	low	low-moderate		low	
A26	low	low-moderate		low	
A36	moderate	high	watering & bedding	high	
A37	low	moderate		low-moderate	0600312
A38	moderate	high		high	
A39	moderate	high		high	
A40	low	low		low	
A41	cultivation			low	
A42	high	low		low	
A43	low	low		low	
A44	low	low-moderate		low-moderate	
A45	moderate	mod. to high		mod. to high	0600106
A46	moderate	low-moderate	watering & bedding	low-moderate	0600317

*Most of the high and moderate sites have now been upgraded (see Section 4.2)

TABLE 17

SUMMARY OF THE 1978 DISSOLVED AND SUSPENDED PHOSPHORUS CONCENTRATIONS FROM SEVERAL SITES ON THE SAN JOSE RIVER (FROM STITT ET AL., 1979)

		Average dissolved P concentration (mg/L)*		*Average suspended P concentration* (mg/L)*	
San Jose River at	***Water Quality site***	***Non-Freshet***	***Freshet***	***Non-Freshet***	***Freshet***
Lac la Hache outlet	0600021	0.010	0.006	0.006	0.007
133 Mile	0600102	0.015	0.009	0.001	0.009
Enterprise Road	0600103	0.014	0.030	0.007	0.010
Above Knife Creek	0600107	0.016	0.043	0.006	0.010
Below Knife Creek	0600312	0.035	0.045	0.006	0.016
Above Residence	0600123	0.037	0.090	0.010	0.024
Onward	0600106	0.043	0.099	0.011	0.031
Above Borland Creek	0600317	0.048	0.100	0.008	0.028
Mouth	0600316	0.052	0.106	0.012	0.030

*the analysis for individual samples and standard deviation were not given in the publication (from Stitt *et al.*, 1979)

TABLE 18

SUMMARY OF THE 1990 DISSOLVED AND SUSPENDED PHOSPHORUS RESULTS COLLECTED ON THE SAN JOSE RIVER BY HART AND MAYALL (1990)

Water Quality Site	*Description*	*Date (d/m/y)*	*Dissolved Phosphorus (mg/L)*	*Suspended Phosphorus (mg/L)*
W1	SJR at Lac la Hache	15/3/90	0.006	0.004
W2	SJR above Site A1	18/3/90	0.022	0.005
W3	Runoff from Site A1	26/3/90	0.660	0.420
W4	SJR below Site A1	18/3/90	0.116	0.043
W5	SJR at 133 Mile	18/3/90	0.039	0.021
		26/3/90	0.021	0.020
		5/4/90	0.018	0.022
W6	SJR at 134 Mile	18/3/90	0.050	0.068
		26/3/90	0.035	0.034
		5/4/90	0.023	0.051
W7	SJR at Enterprise Rd.	18/3/90	0.045	0.026
		26/3/90	0.036	0.023
		5/4/90	0.030	0.025
W15	SJR d/s Site A23	18/3/90	0.127	0.060
W16	SJR u/s Site A36	17/3/90	0.134	0.076
W17	Runoff from Site A36	17/3/90	2.600	0.030
W18	SJR d/s Site A36	17/3/90	0.292	0.398
W26	SJR d/s Site A35	17/3/90	0.275	0.082
W27	SJR u/s Site A38	17/3/90	0.182	0.091
W28	Runoff from Site A39	17/3/90	6.700	5.700
W29	SJR d/s Site A39	27/2/90	0.028	0.021
		17/3/90	0.183	0.069
W30	SJR at Onward Bridge	26/3/90	0.088	0.072
W31	Runoff from Site A45	26/3/90	2.560	0.540

TABLE 19

SUMMARY OF THE MELP DISSOLVED AND SUSPENDED PHOSPHORUS RESULTS COLLECTED ON THE SAN JOSE RIVER

San Jose River at	*n*#	*Average concentration (± standard deviation) (mg/L)*		*Phosphorus loading (kg)*	
		Dissolved P	*Suspended P*	*Dissolved P*	*Suspended P*
0600021: Lac La Hache outlet				152 (Jun. 13/91 - Mar. 13/92)	153 (Jun. 13/91 - Mar. 13/92)
•1976-79	32	0.008±0.002	0.008±0.005		
•1980-85	82	0.015±0.019	0.012±0.018*		
•1987-92	54	0.010±0.006**	0.012±0.012**		
•Jan-Apr/91	7	0.006±0.002	0.005±0.002		
0600103: Enterprise Rd					
•1990-91	20	0.026±0.014	0.030±0.017		
•Feb-Apr/91	18	0.025±0.014	0.028±0.015		
0600317: above Borland Creek				2 092 (Jan. 23 - Dec. 17/91)	3 543 (Jan. 23 - Dec. 17/91)
•1991	33	0.042±0.031	0.055±0.036		
•Jan-Apr/91	21	0.046±0.037	0.061±0.039		
•Jan-Apr/92	29	0.042±0.031+	0.038±0.025		
0600316: below Borland Creek					
•1985-89	43	0.080±0.046++	0.029±0.029		
•1990-91	18	0.054±0.033	0.041±0.036		
•Jan-Mar/91	5	0.078±0.052	0.041±0.033		

* excluding the anomalous value of 0.441 mg/L on March 13, 1984;
** excluding the anomalous value of 0.78 mg/L (dissolved P) and 0.17 mg/L (suspended P) on March 14, 1989;
+ excluding the anomalous value of 0.276 mg/L on Jan. 30, 1992;
++ excluding the anomalous value of 0.490 mg/L on Feb. 27, 1986;
# number of samples

FIGURE 9

BORLAND CREEK STREAM PROFILE AND WATER QUALITY SITES

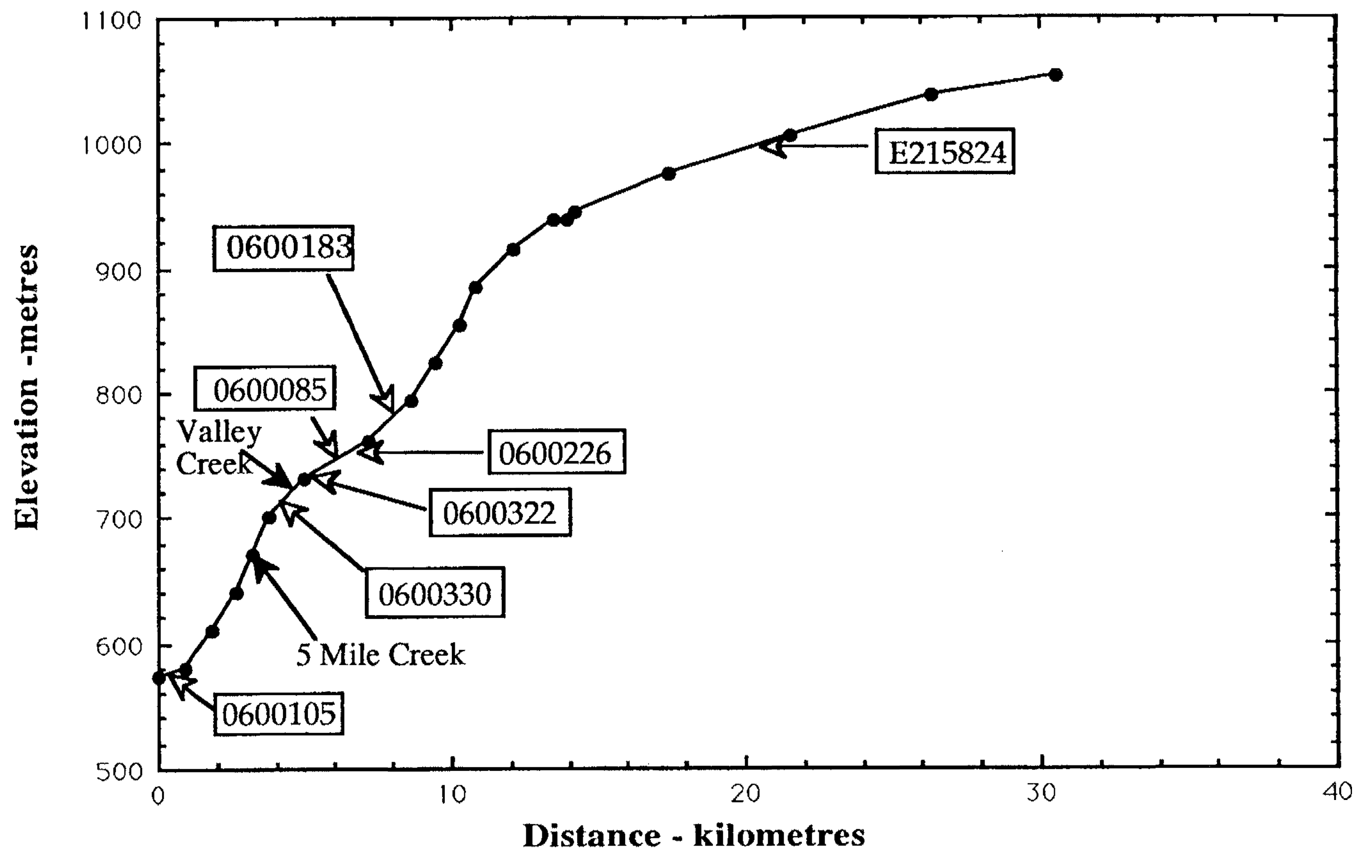


FIGURE 10

1990/92 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK ABOVE ALL AGRICULTURAL SITES

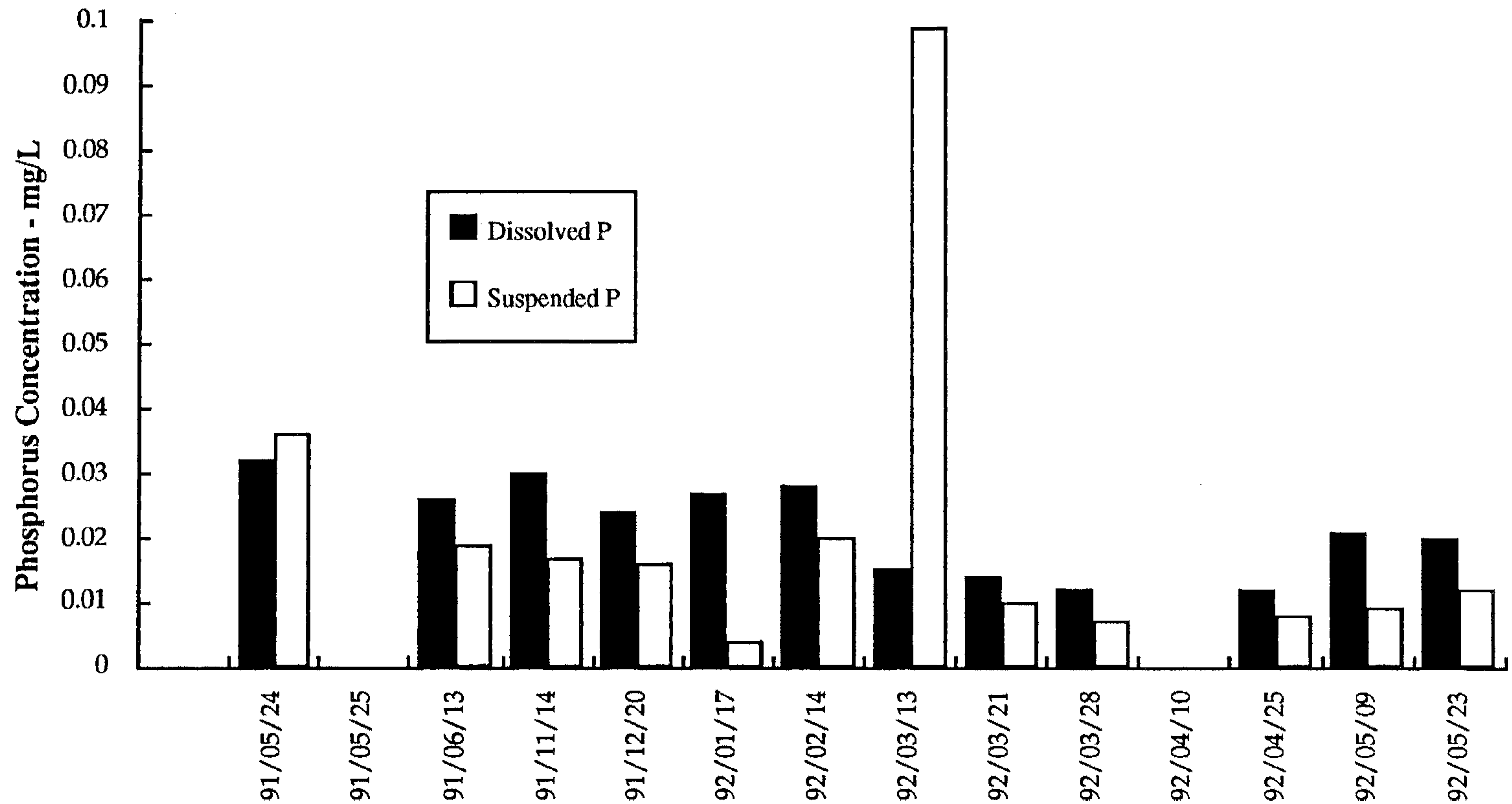


Figure 11

1985 Flow and Phosphorus Concentrations in Borland Creek at Site 0600183

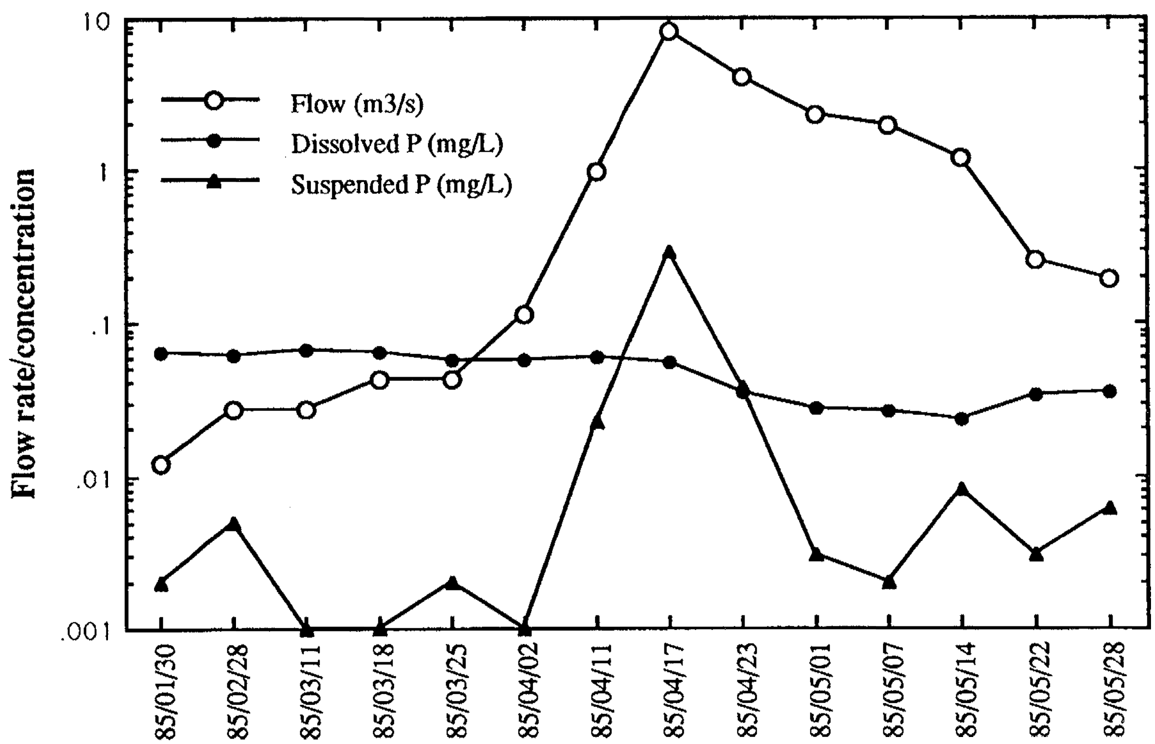


FIGURE 12

1985/91 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK AT HWY 97 (SITE 0600085)

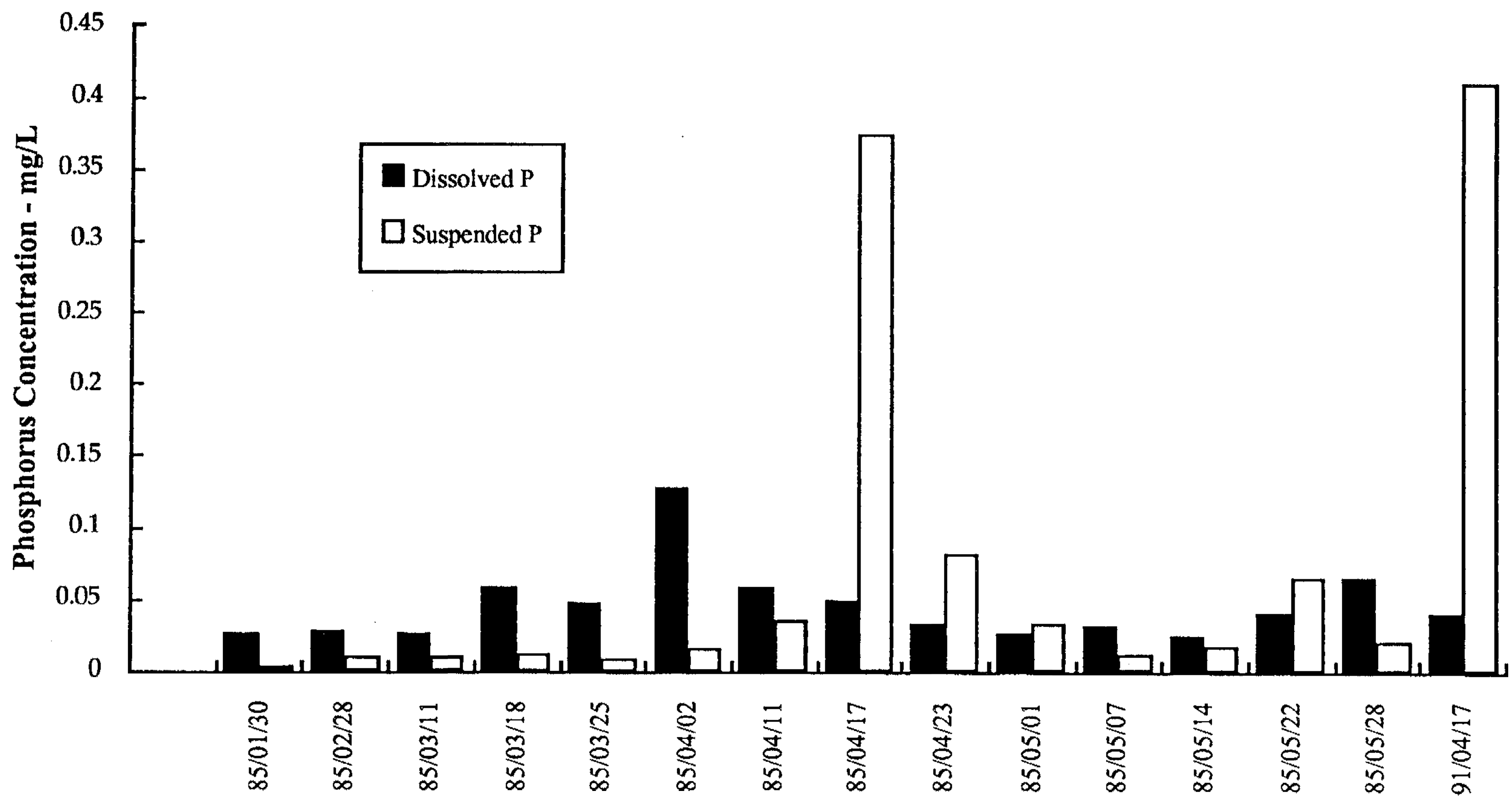


FIGURE 13

1985 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK ABOVE VALLEY CREEK (SITE 0600322)

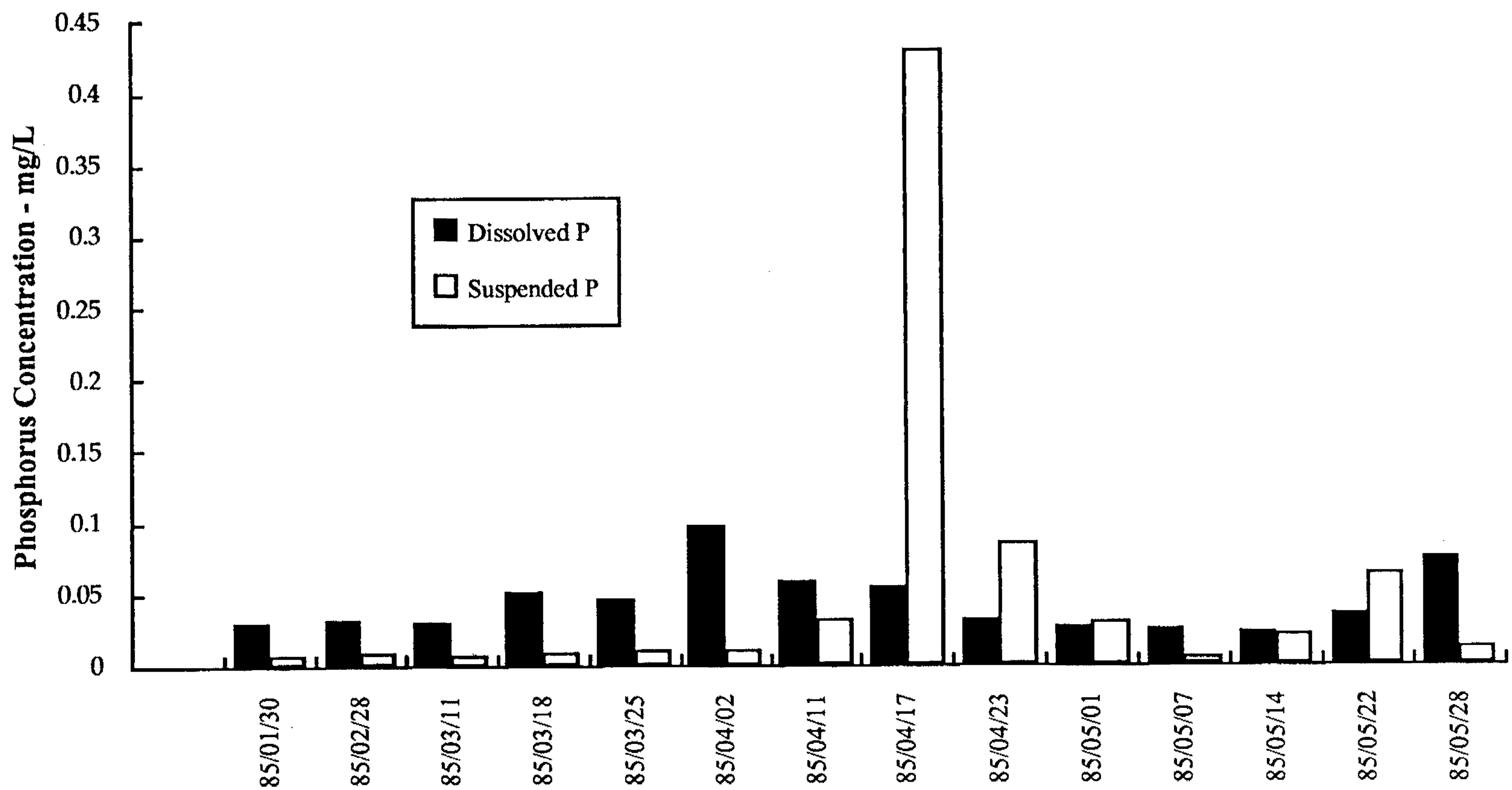


FIGURE 14

1985 AND 1991 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK BELOW VALLEY CREEK (SITE 0600330)

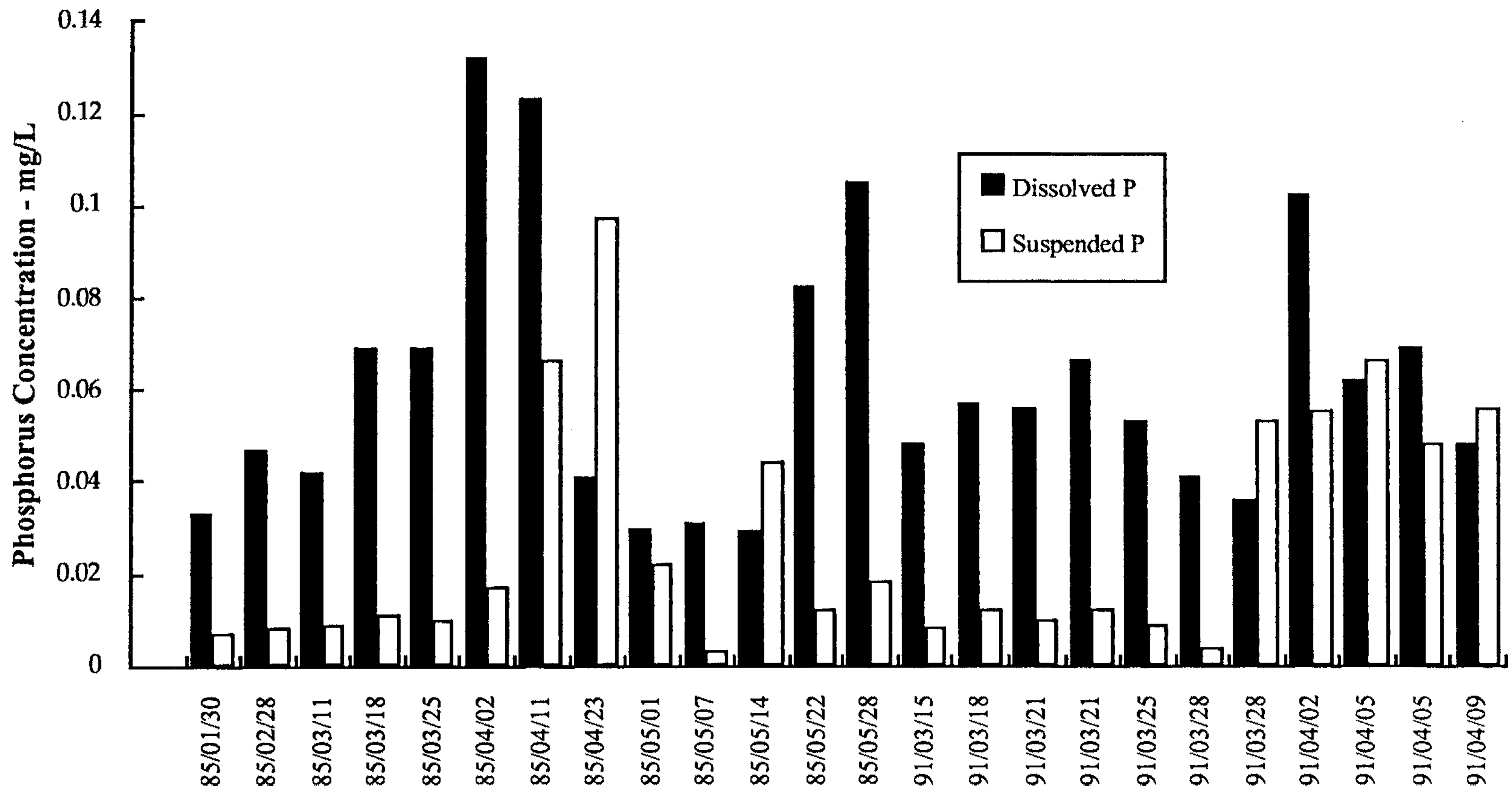


FIGURE 15

1985 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK AT SUGAR CANE RESERVE (SITE 0600105)

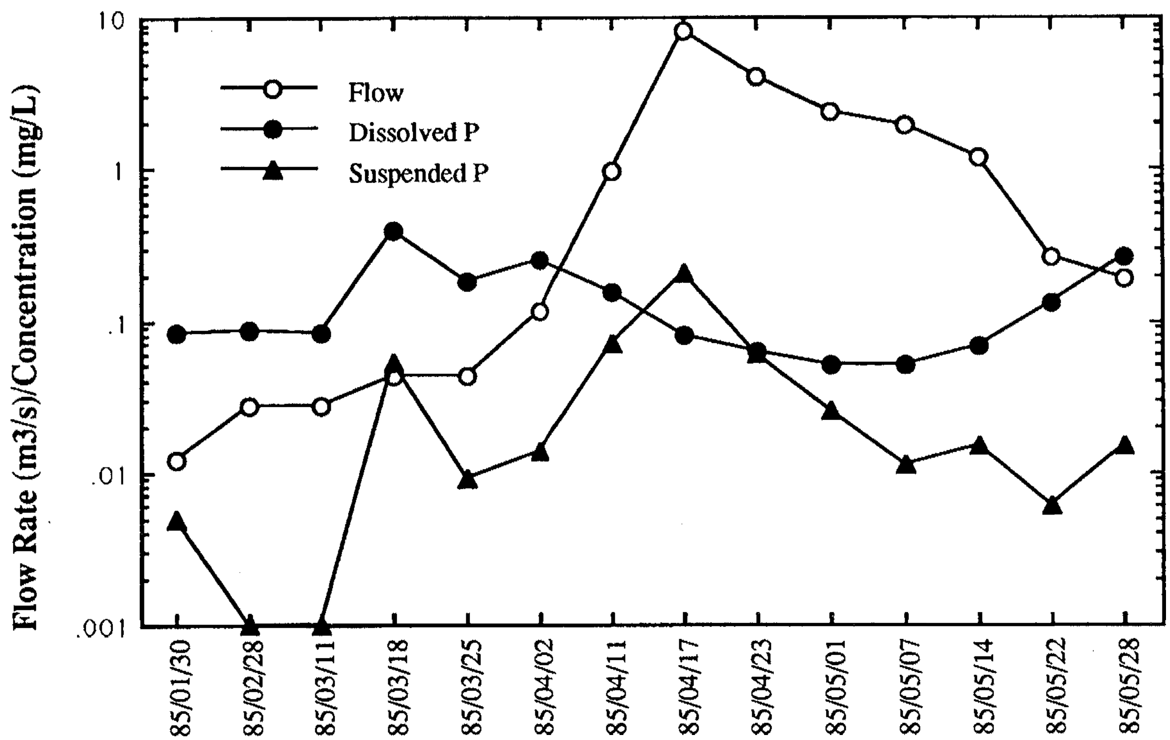


FIGURE 16

1985/92 PHOSPHORUS CONCENTRATIONS IN BORLAND CREEK AT SUGARCANE (SITE 0600105)

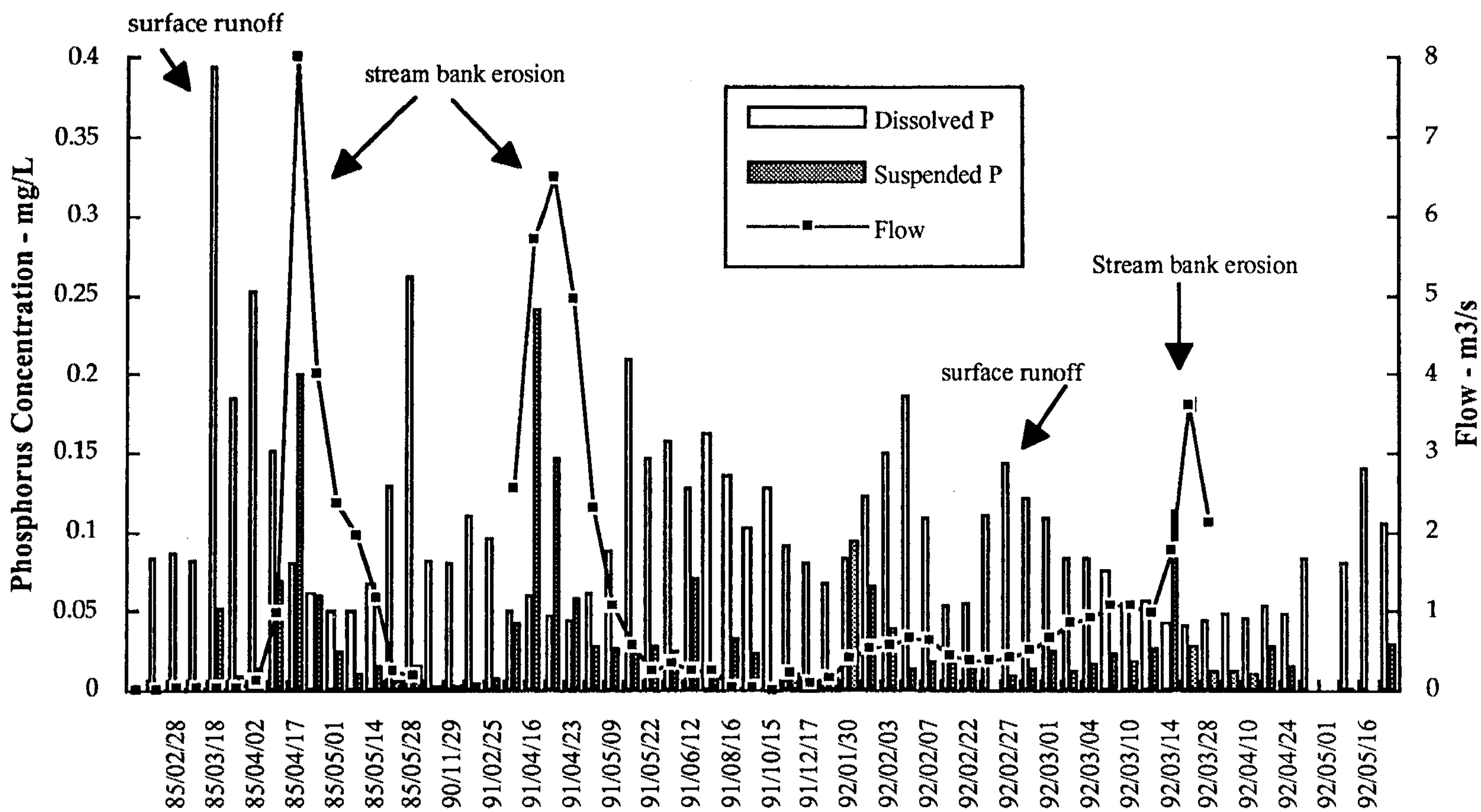


FIGURE 17

VALLEY CREEK STREAM PROFILE AND WATER QUALITY SITES

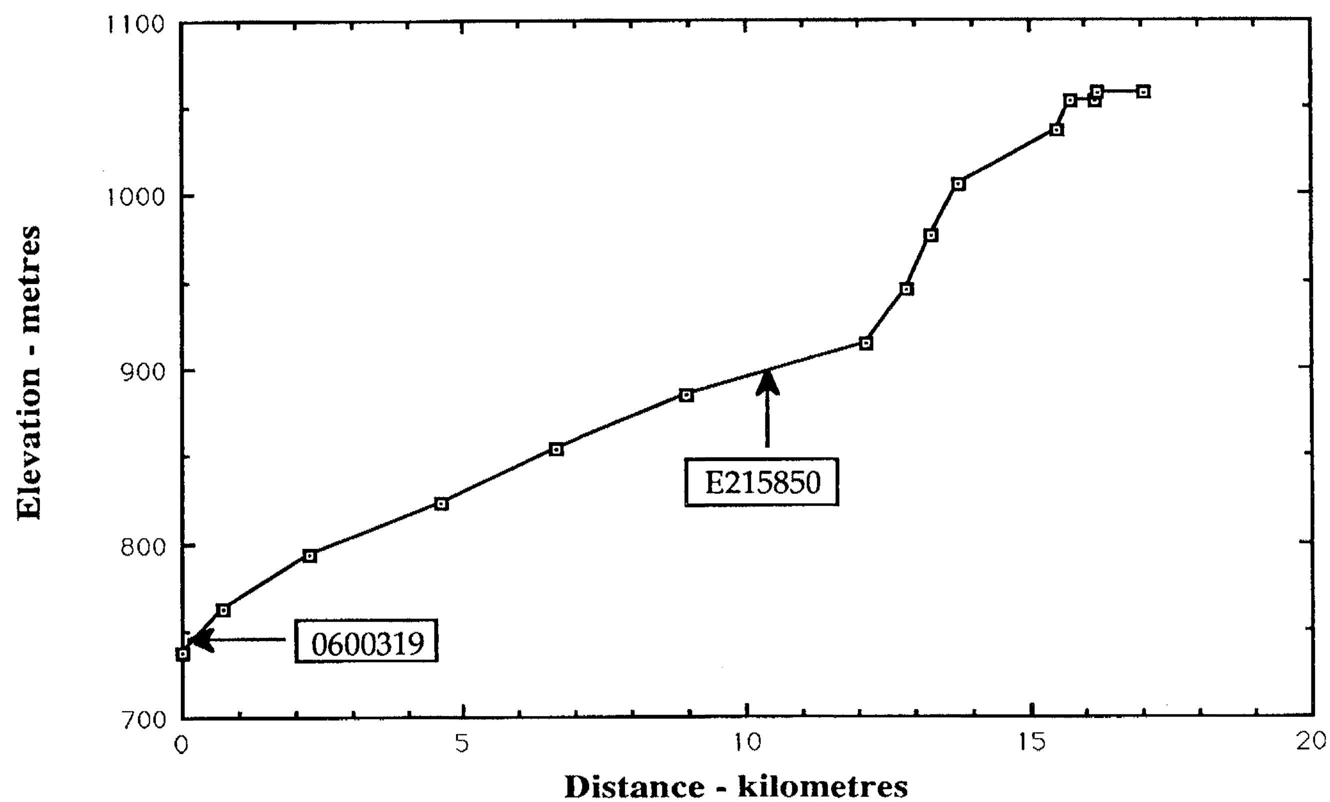


FIGURE 18

1991/92 PHOSPHORUS CONCENTRATIONS IN VALLEY CREEK ABOVE TURCOTTE'S (SITE E215850)

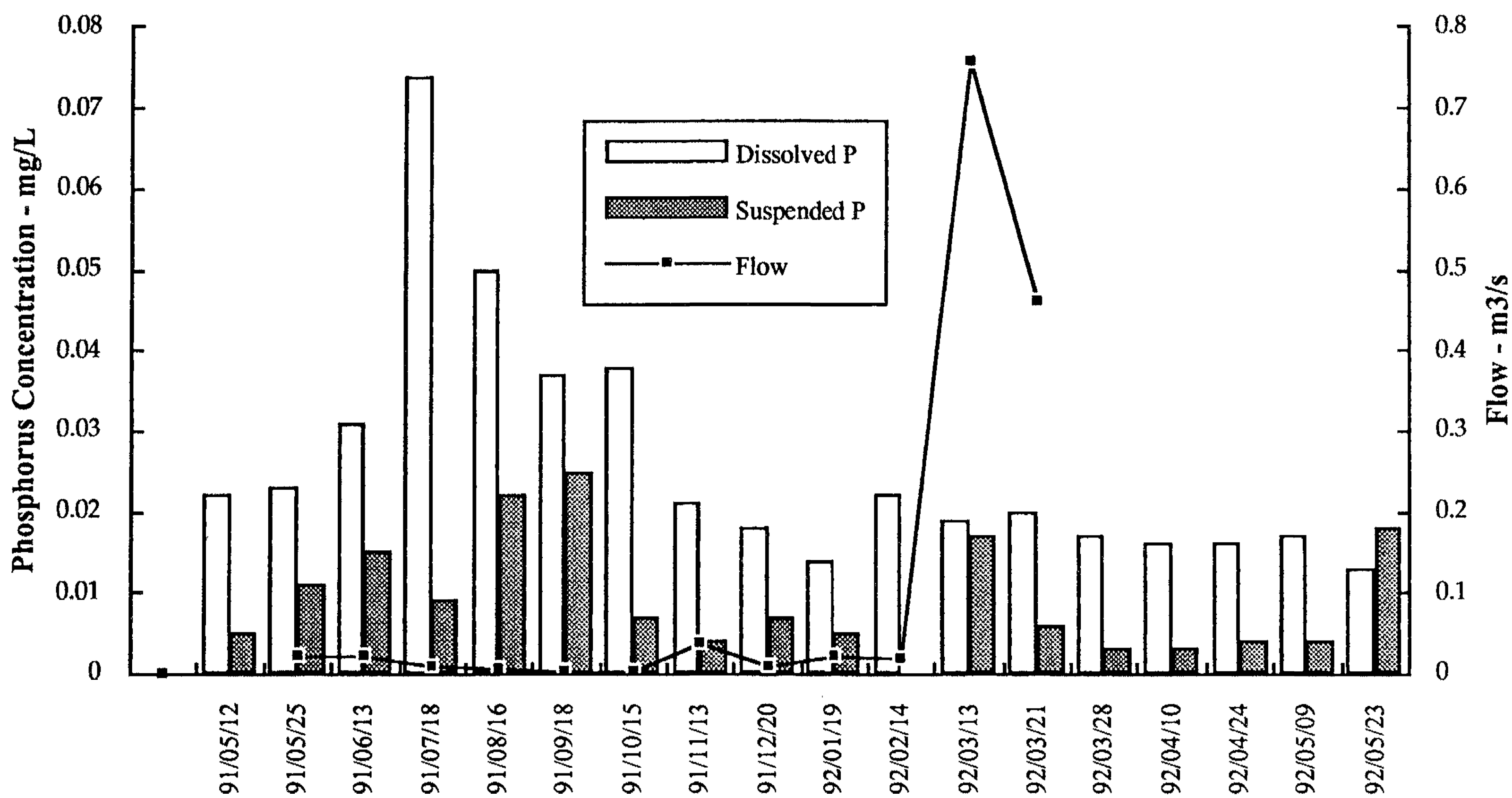


Figure 19

1985 Phosphorus Concentration in Valley Creek above Borland Creek (Site 0600319)

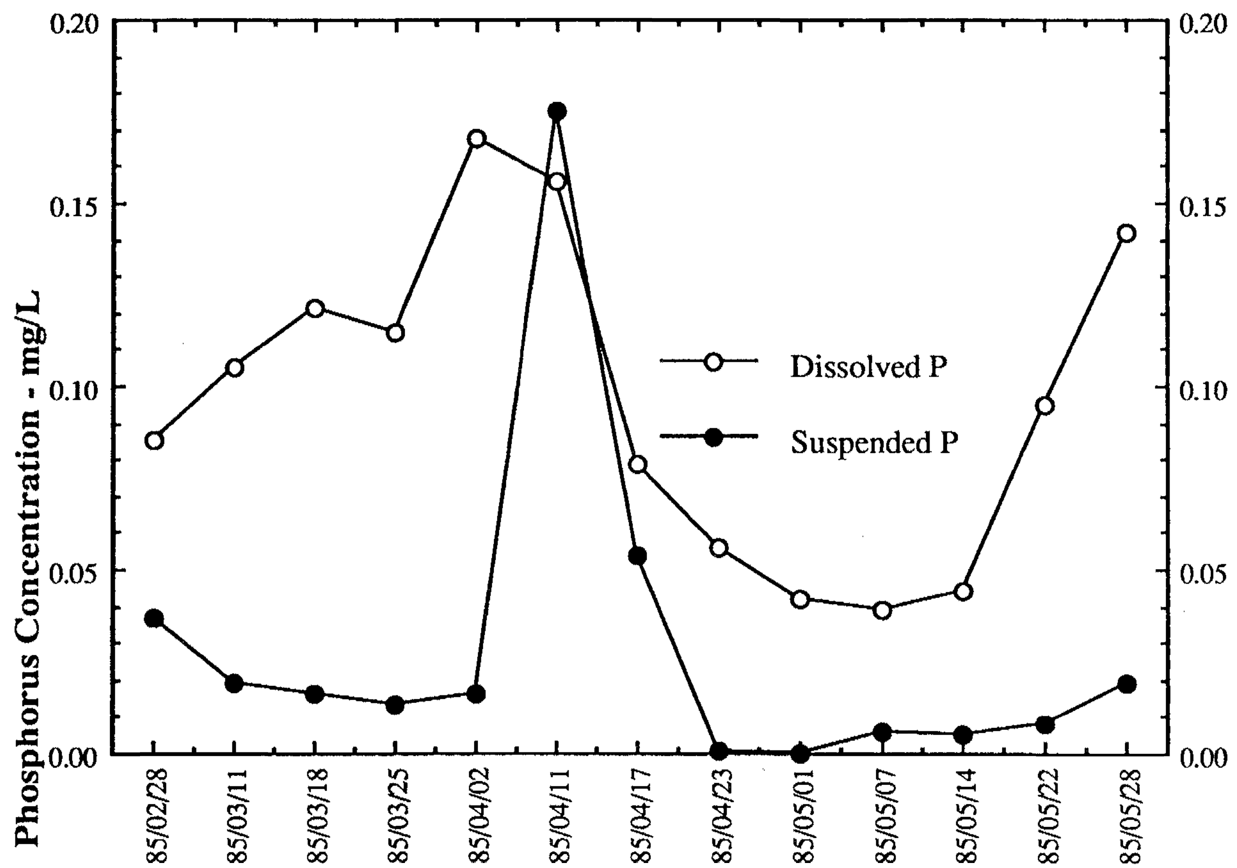


FIGURE 20

1985/92 PHOSPHORUS CONCENTRATION IN VALLEY CREEK ABOVE BORLAND CREEK (SITE 0600319)

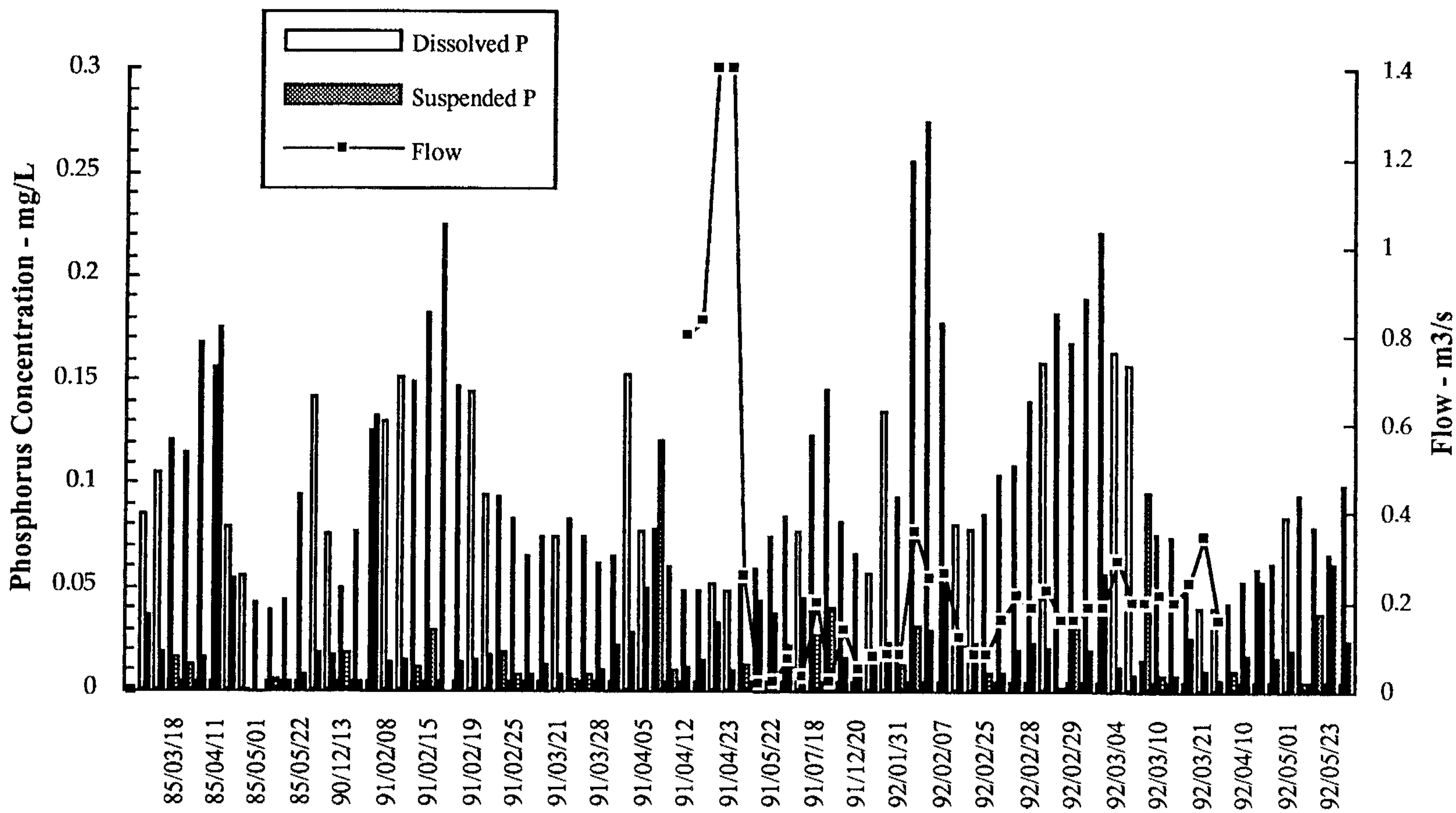


FIGURE 21

FIVE MILE CREEK STREAM PROFILE AND WATER QUALITY SITES

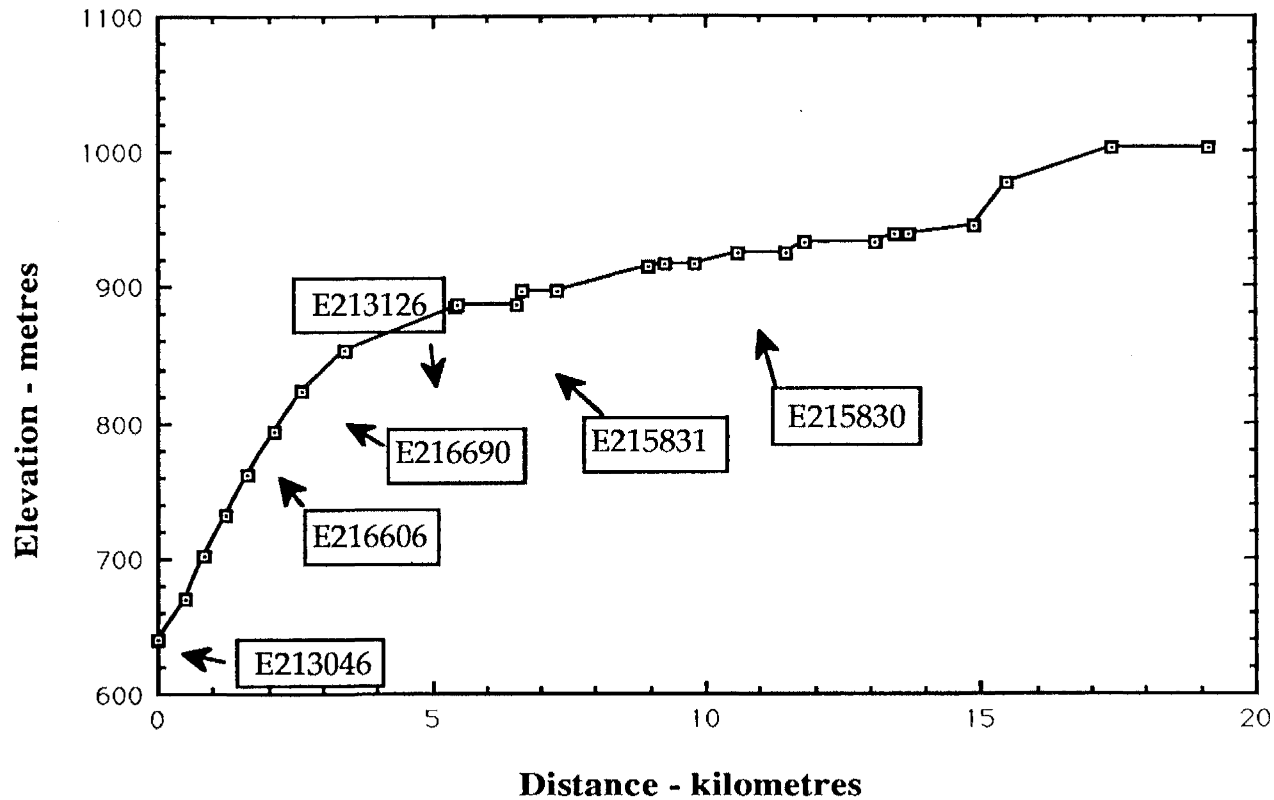


FIGURE 22

1991/92 PHOSPHORUS CONCENTRATION IN THE CREEK AT THE DUGAN LAKE OUTLET AT HORSEFLY ROAD (SITE E215830)

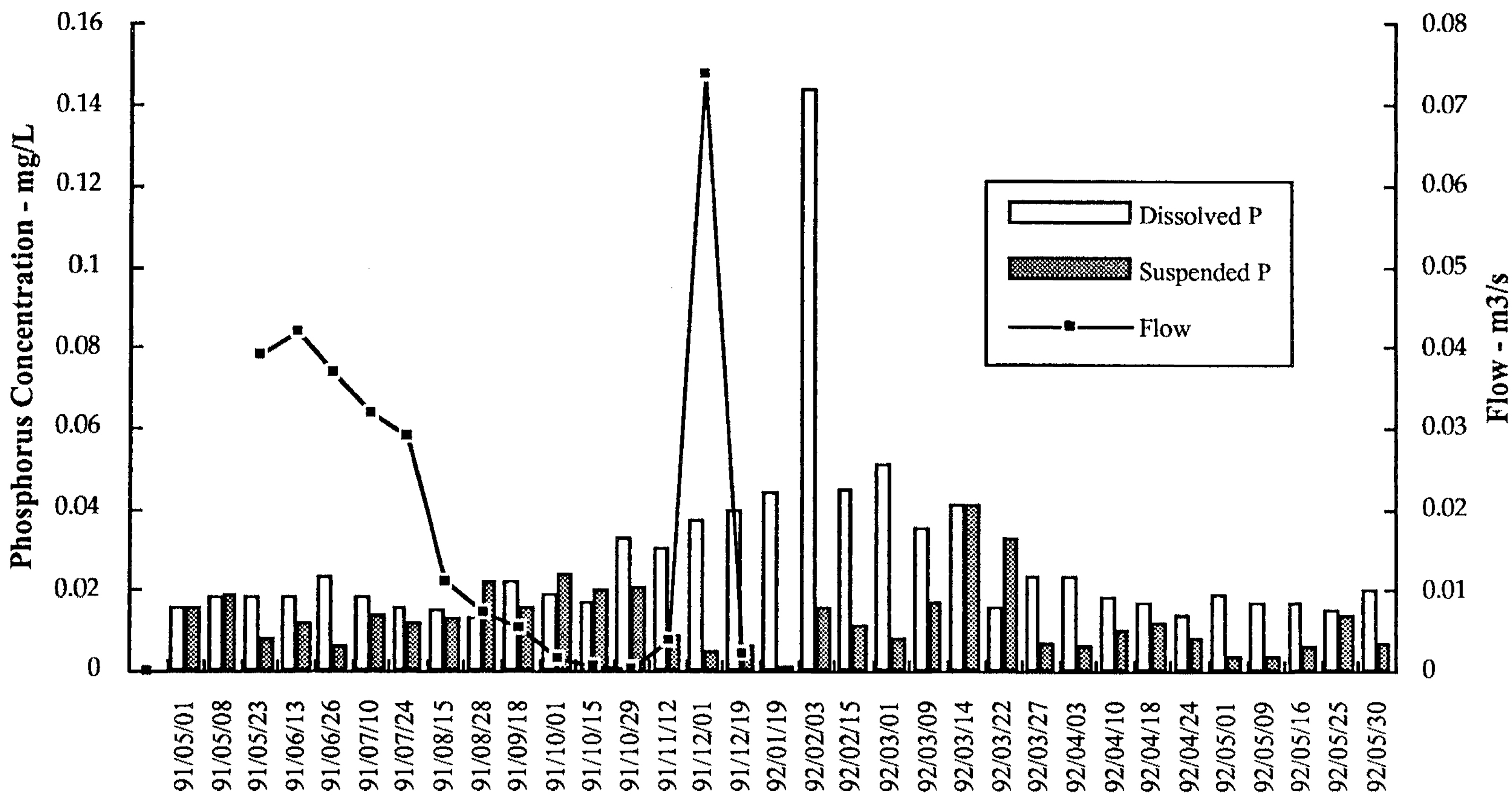


FIGURE 23

1991/92 PHOSPHORUS CONCENTRATIONS IN THE CREEK AT THE FIVE MILE LAKE INTLET AT LIKELY ROAD (SITE E215831)

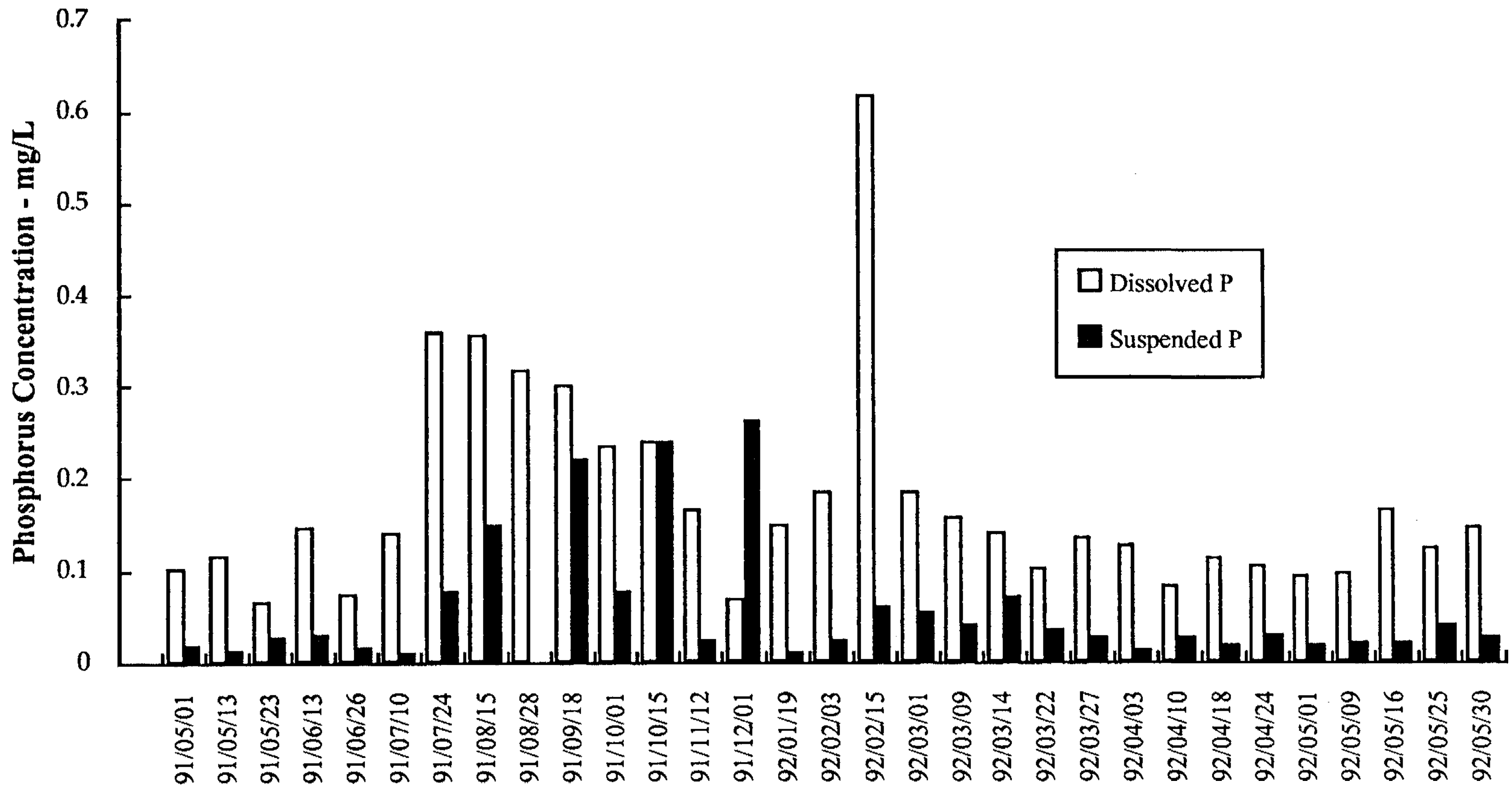


FIGURE 24

1990/92 PHOSPHORUS CONCENTRATIONS IN FIVE MILE CREEK AT THE FIVE MILE LAKE ONTLET (SITE E213126)

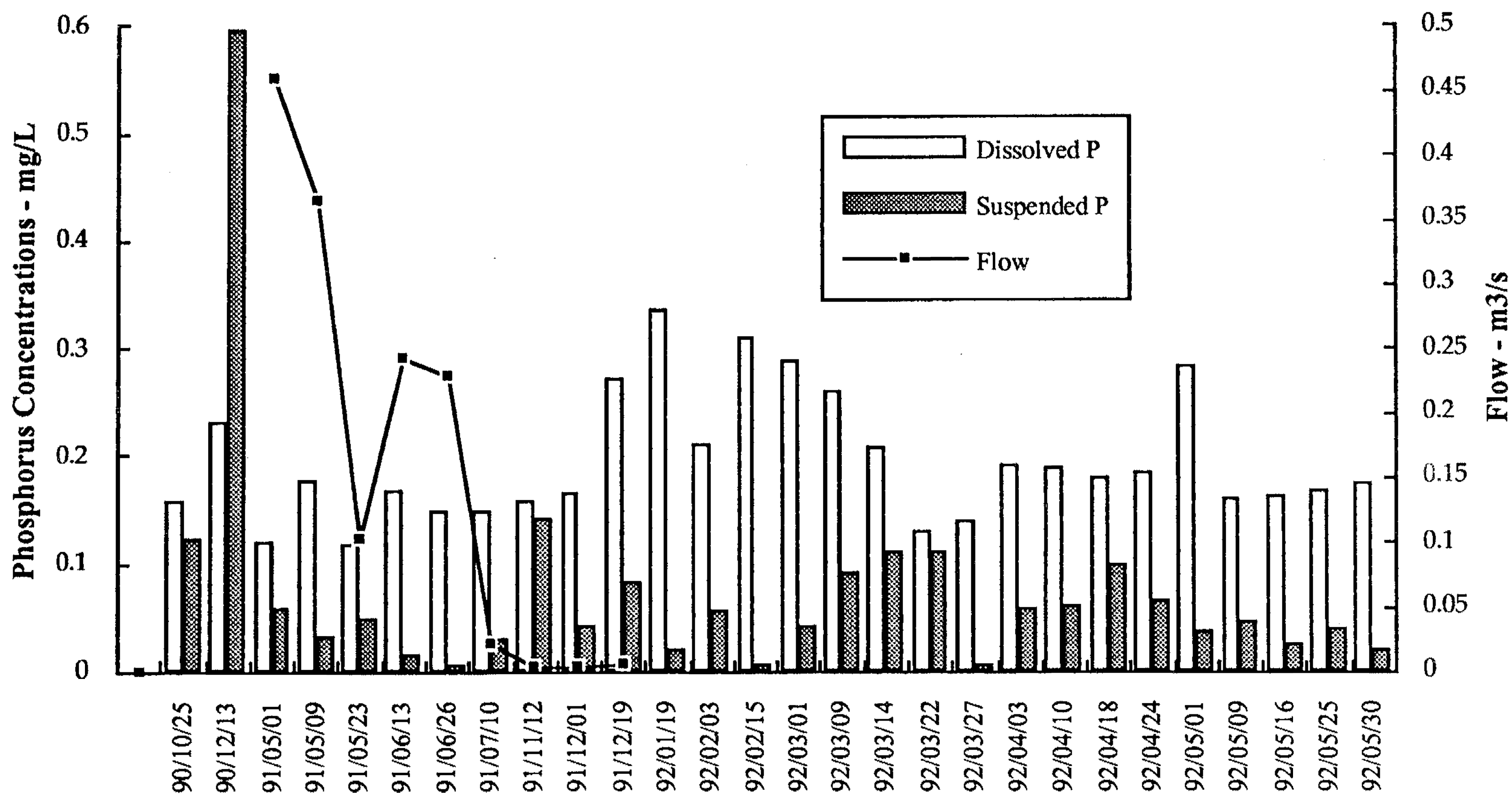


FIGURE 25

1992 PHOSPHORUS CONCENTRATIONS IN FIVE MILE CREEK ABOVE YEARLINGS (SITE E216690)

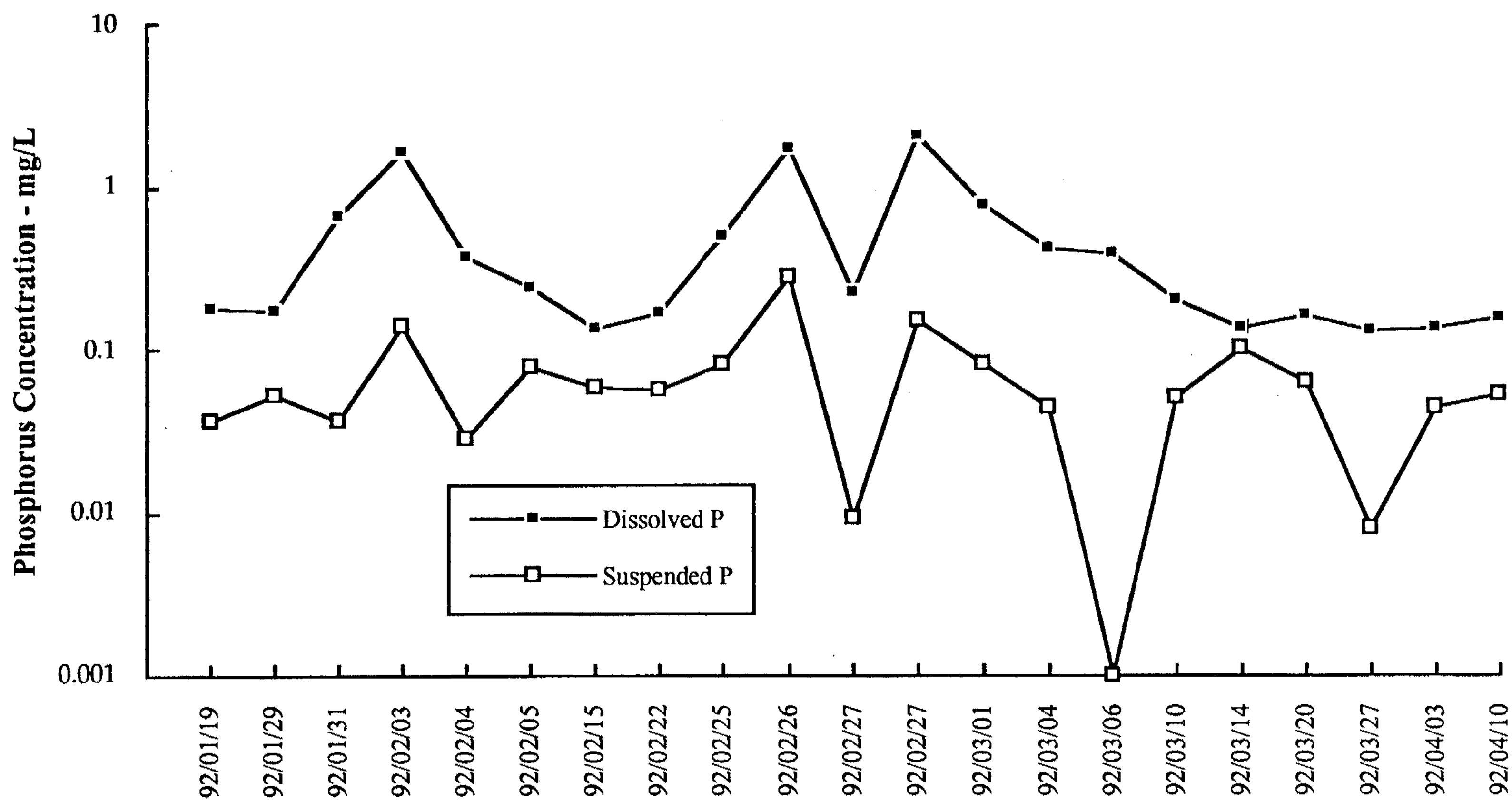


FIGURE 26

1991/92 PHOSPHORUS CONCENTRATIONS IN FIVE MILE CREEK BELOW 153 MILE RANCH (SITE E216606)

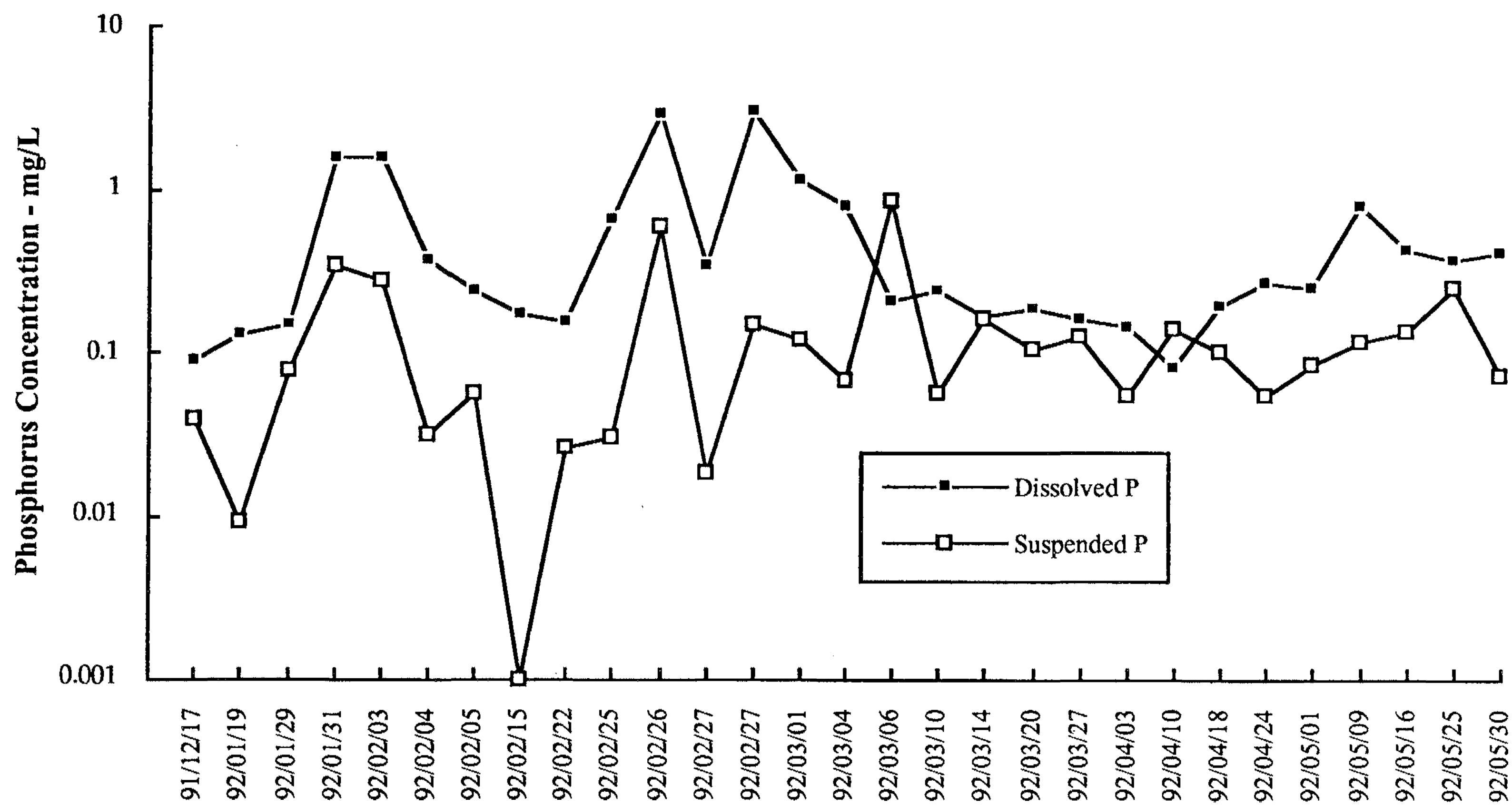


FIGURE 27

1991/92 PHOSPHORUS CONCENTRATIONS IN FIVE MILE CREEK AT HIGHWAY 97 (SITE E213046)

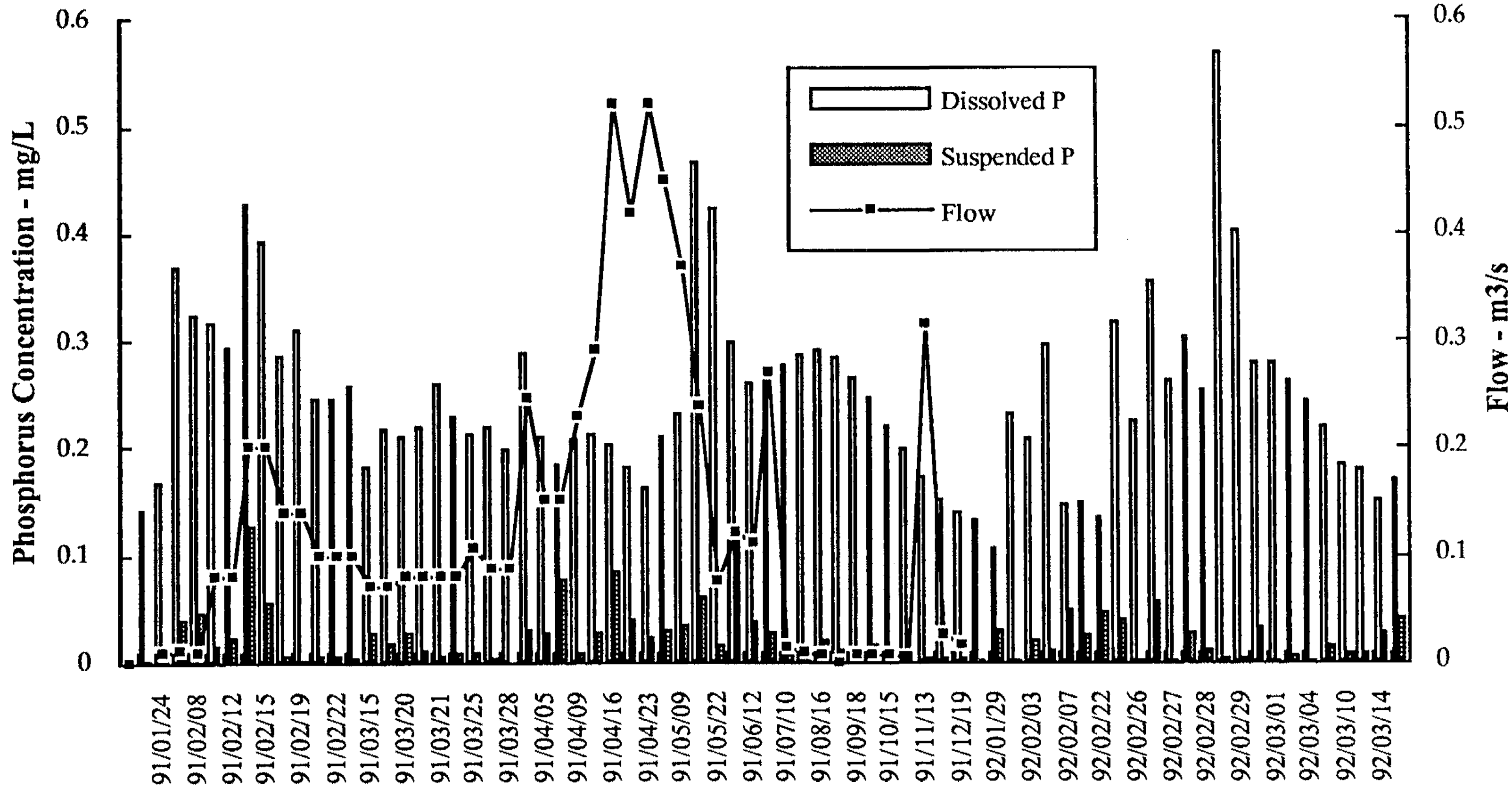


FIGURE 28

JONES CREEK STREAM PROFILE AND WATER QUALITY SITES

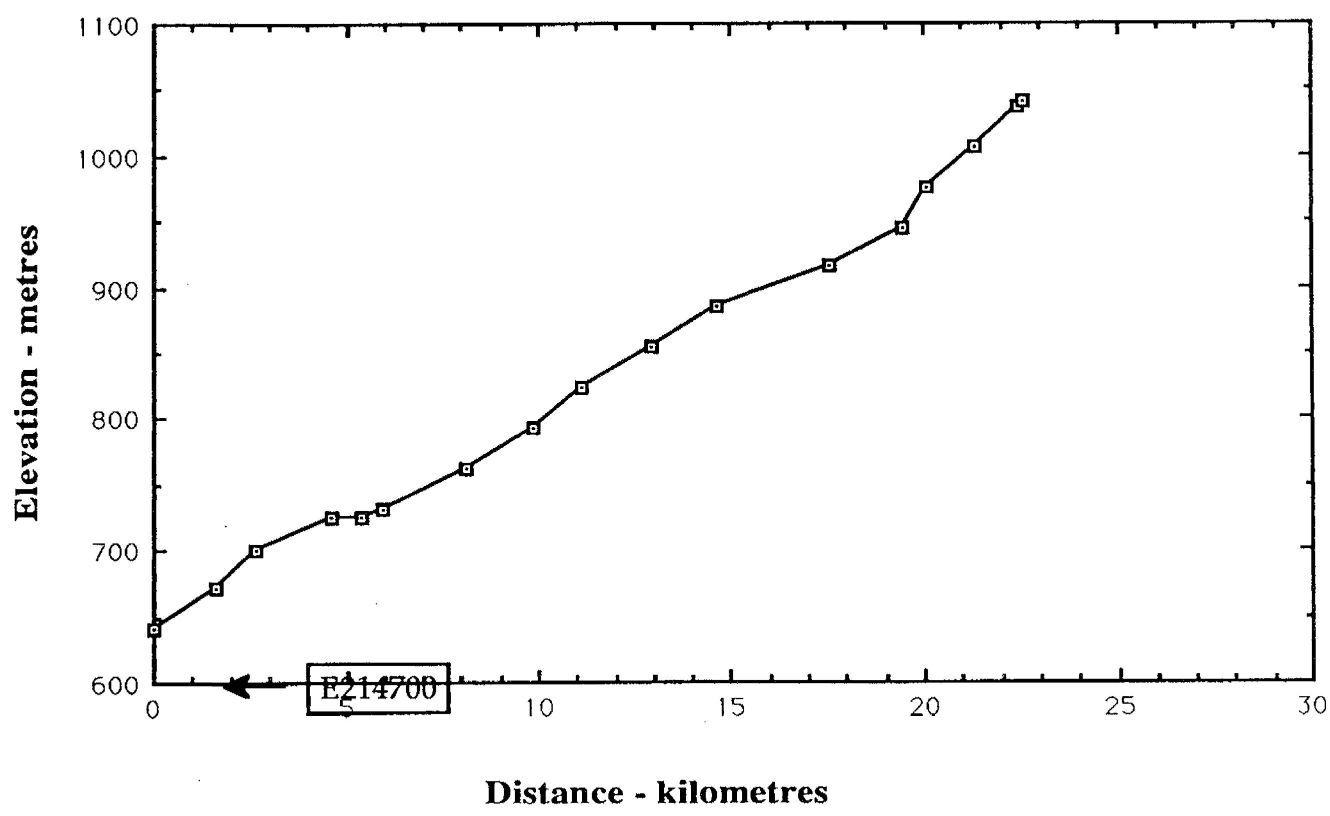


FIGURE 29

1991/92 PHOSPHORUS CONCENTRATIONS IN JONES CREEK AT HIGHWAY 97 (SITE E214700)

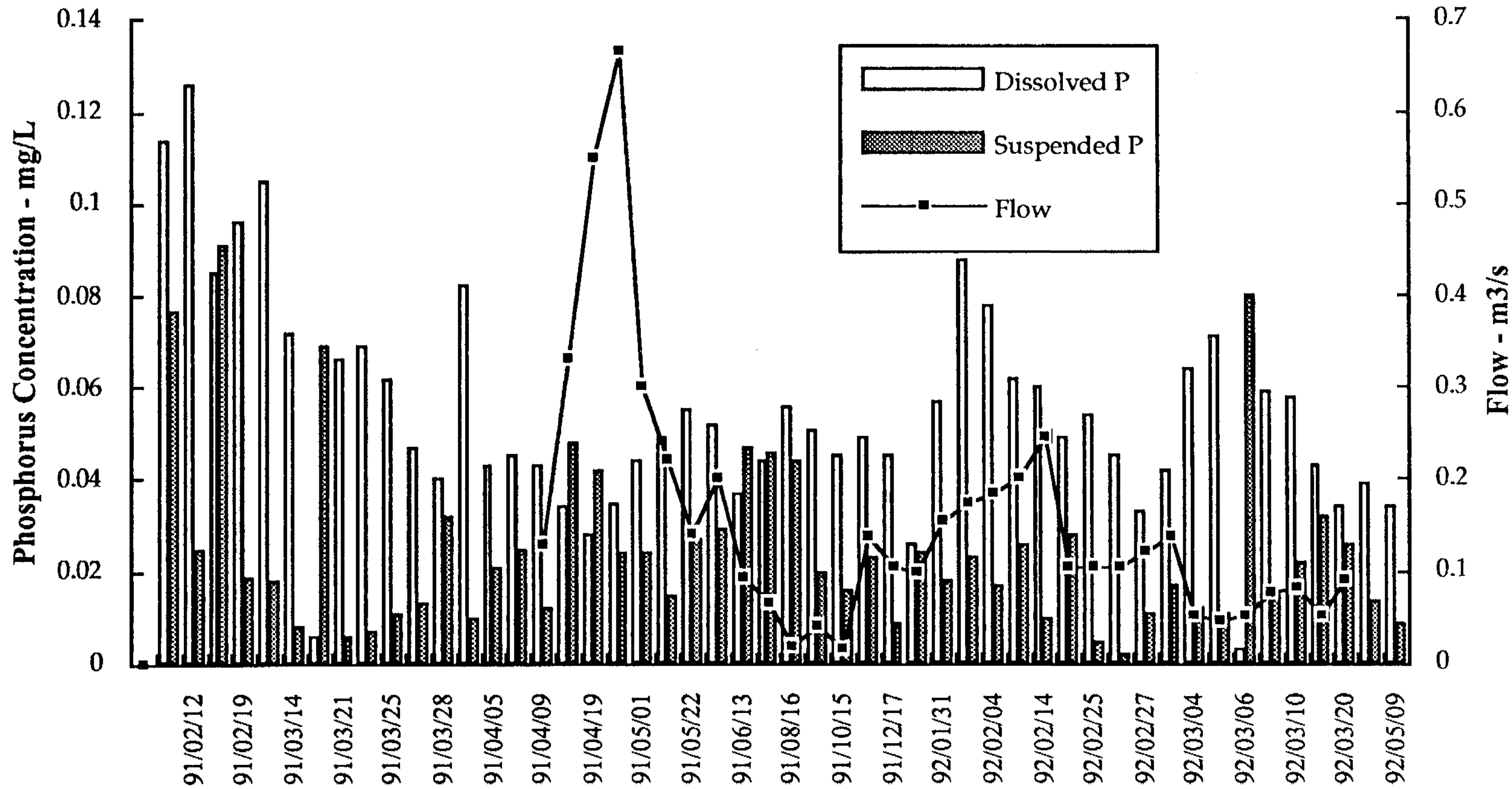


Figure 30

Knife Creek Stream Profile and Water Quality Sites

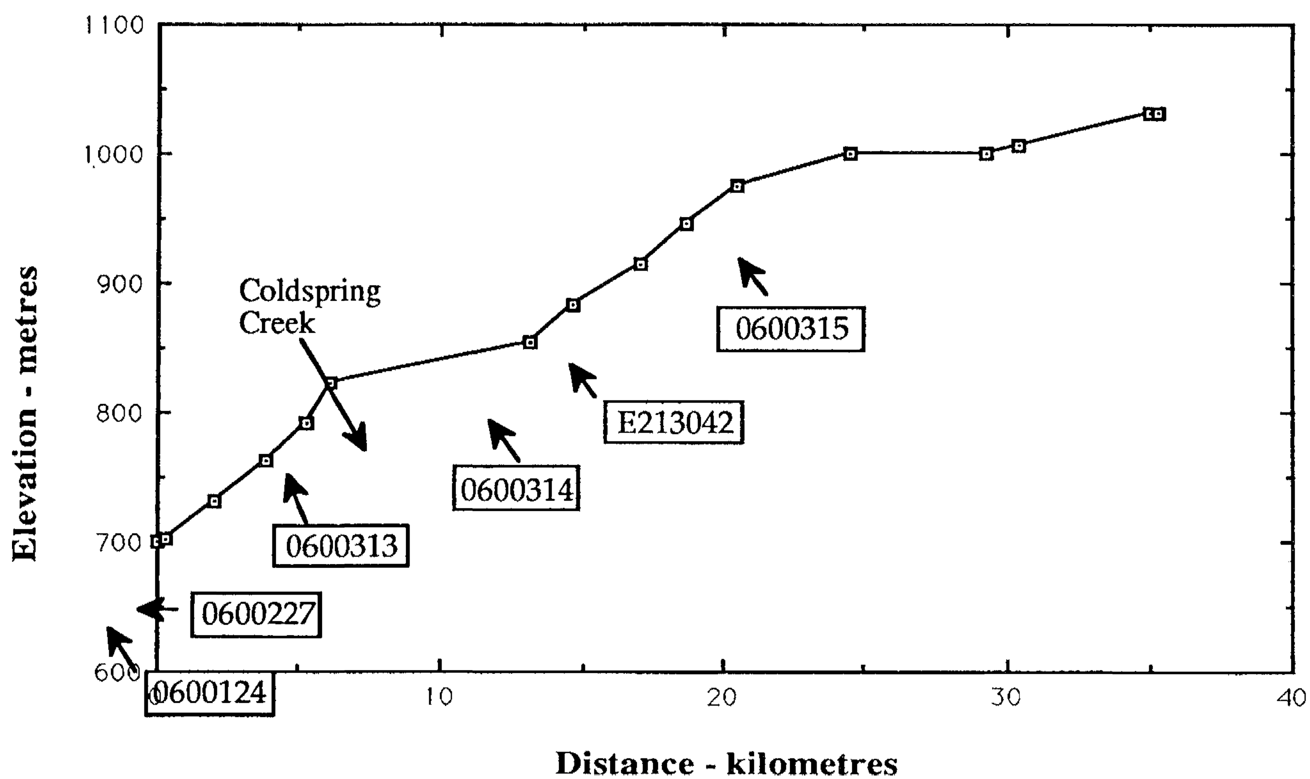


FIGURE 31

1990/92 PHOSPHORUS CONCENTRATIONS IN KNIFE CREEK UPSTREAM FROM K. SMITH RANCH (SITE E213042)

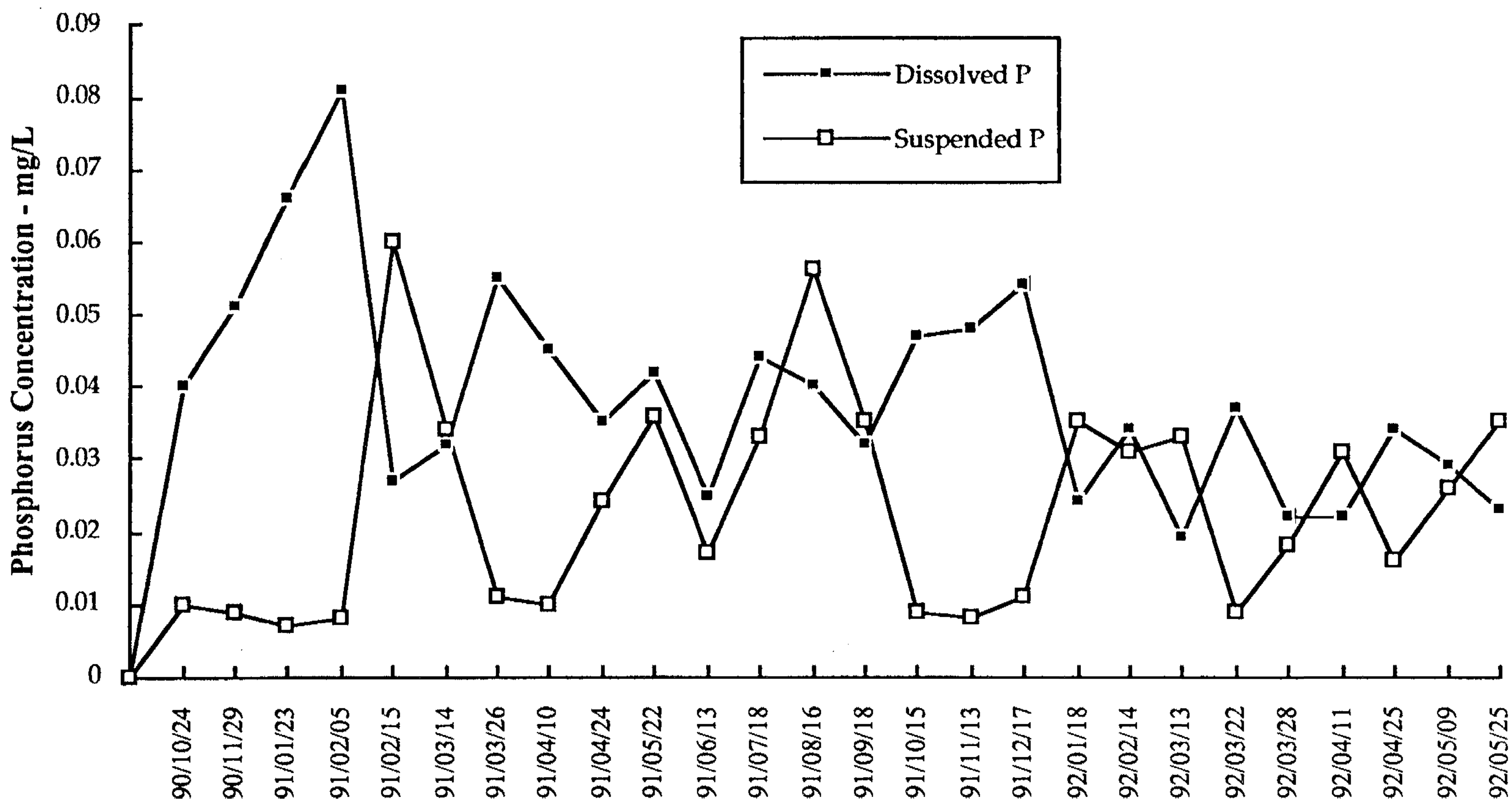


FIGURE 32

1990/92 PHOSPHORUS CONCENTRATIONS IN KNIFE CREEK ABOVE SAN JOSE RIVER AT 141 MILE HOUSE (SITE 0600124)

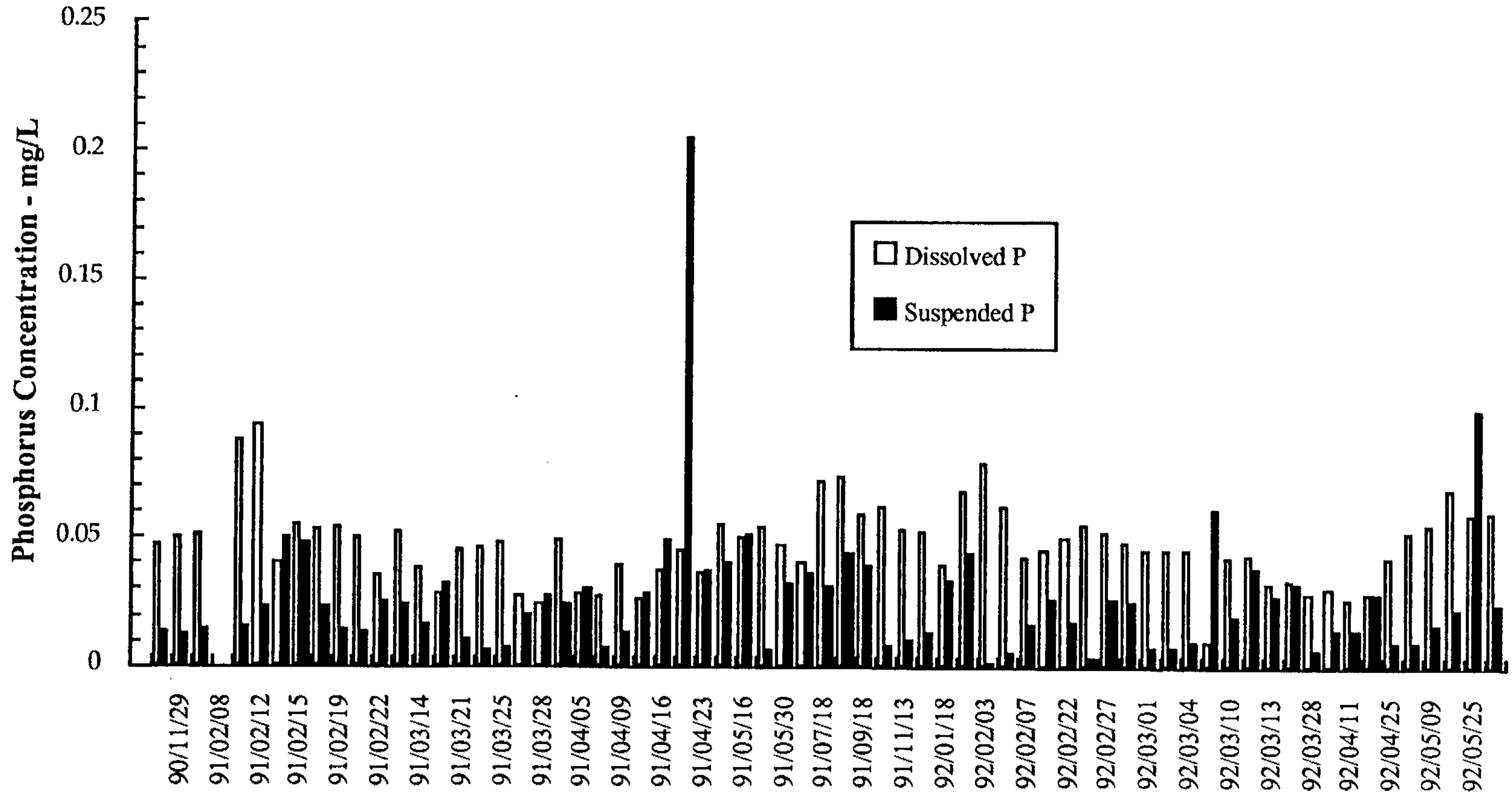


FIGURE 33

1990/92 PHOSPHORUS CONCENTRATIONS IN COLDSPRING CREEK AT SQUAWK LAKE ROAD (SITE E213047)

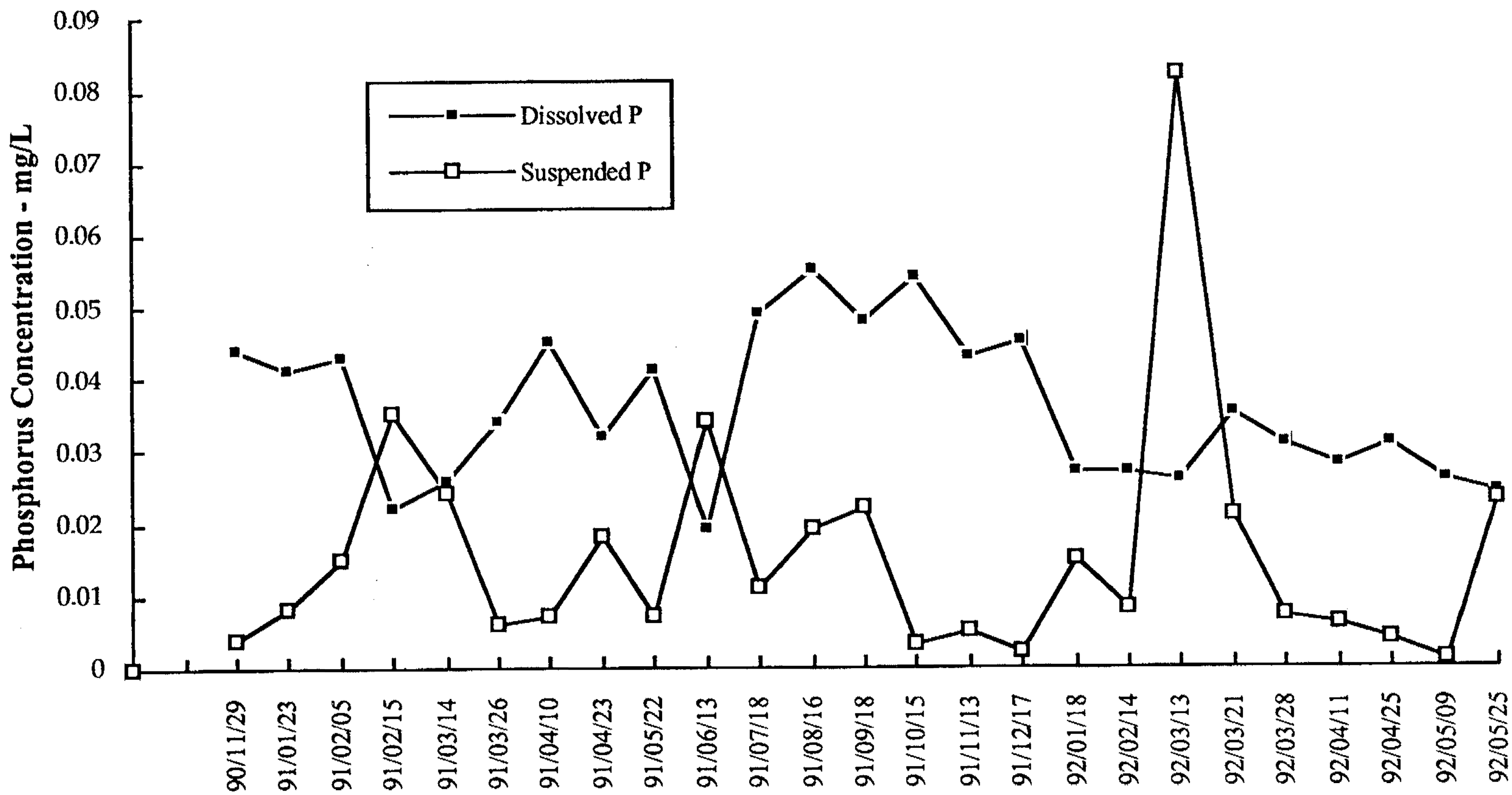


FIGURE 34

SAN JOSE RIVER PROFILE AND WATER QUALITY SITES

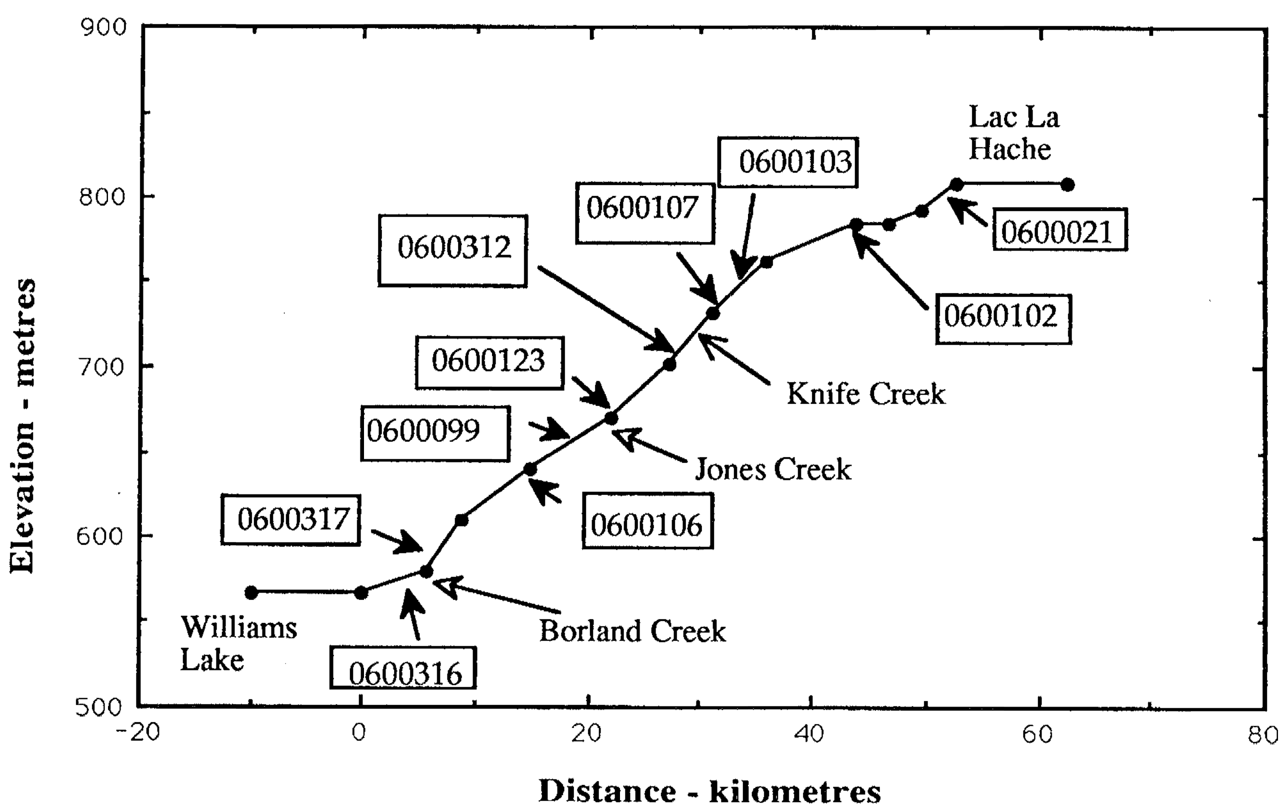


FIGURE 35a

1976/80 PHOSPHORUS CONCENTRATIONS IN THE SAN JOSE RIVER AT LAC LA HACHE (SITE E0600021)

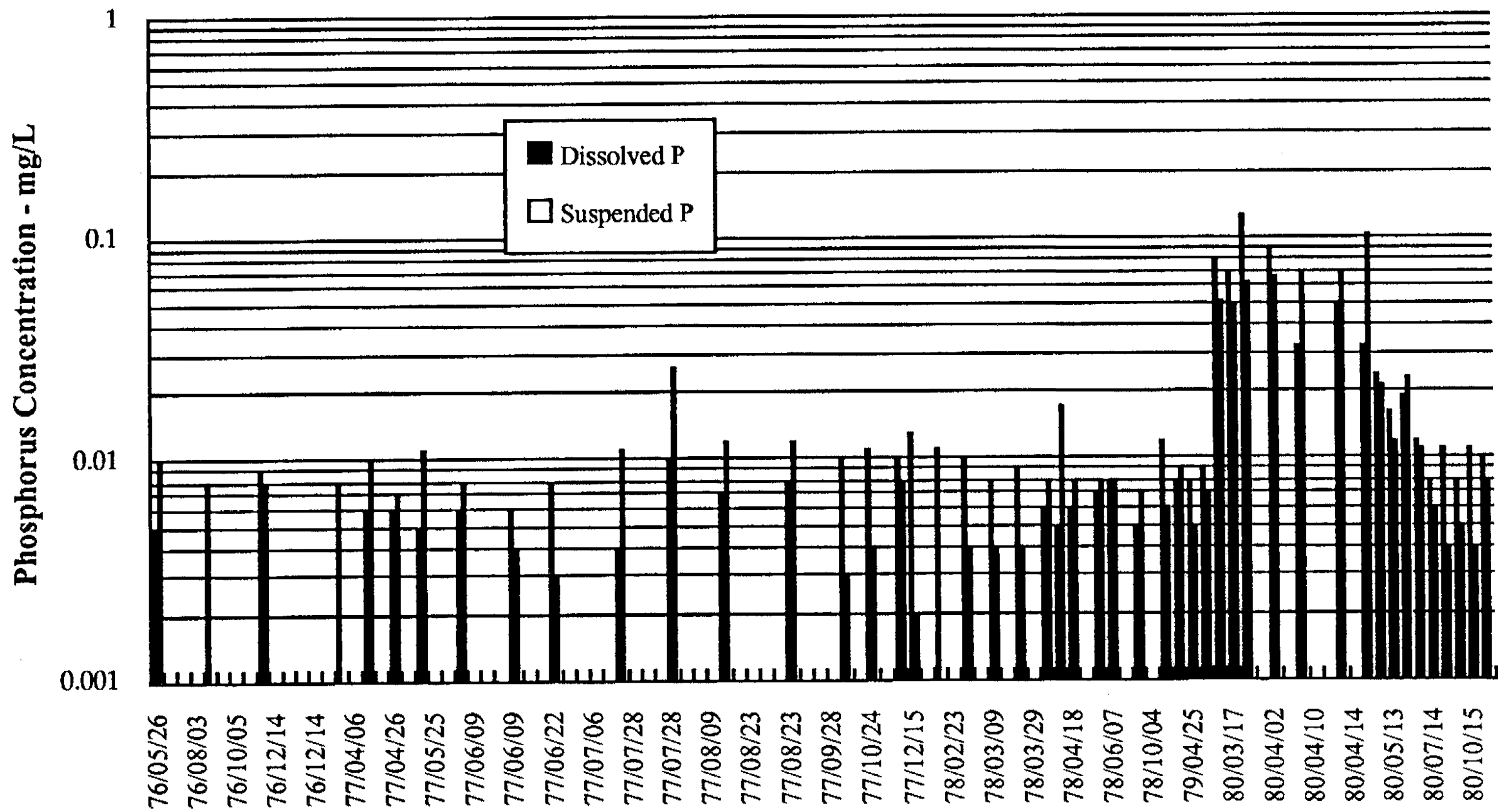


FIGURE 35b

1981/92 PHOSPHORUS CONCENTRATIONS IN THE SAN JOSE RIVER AT LAC LA HACHE (SITE E0600021)

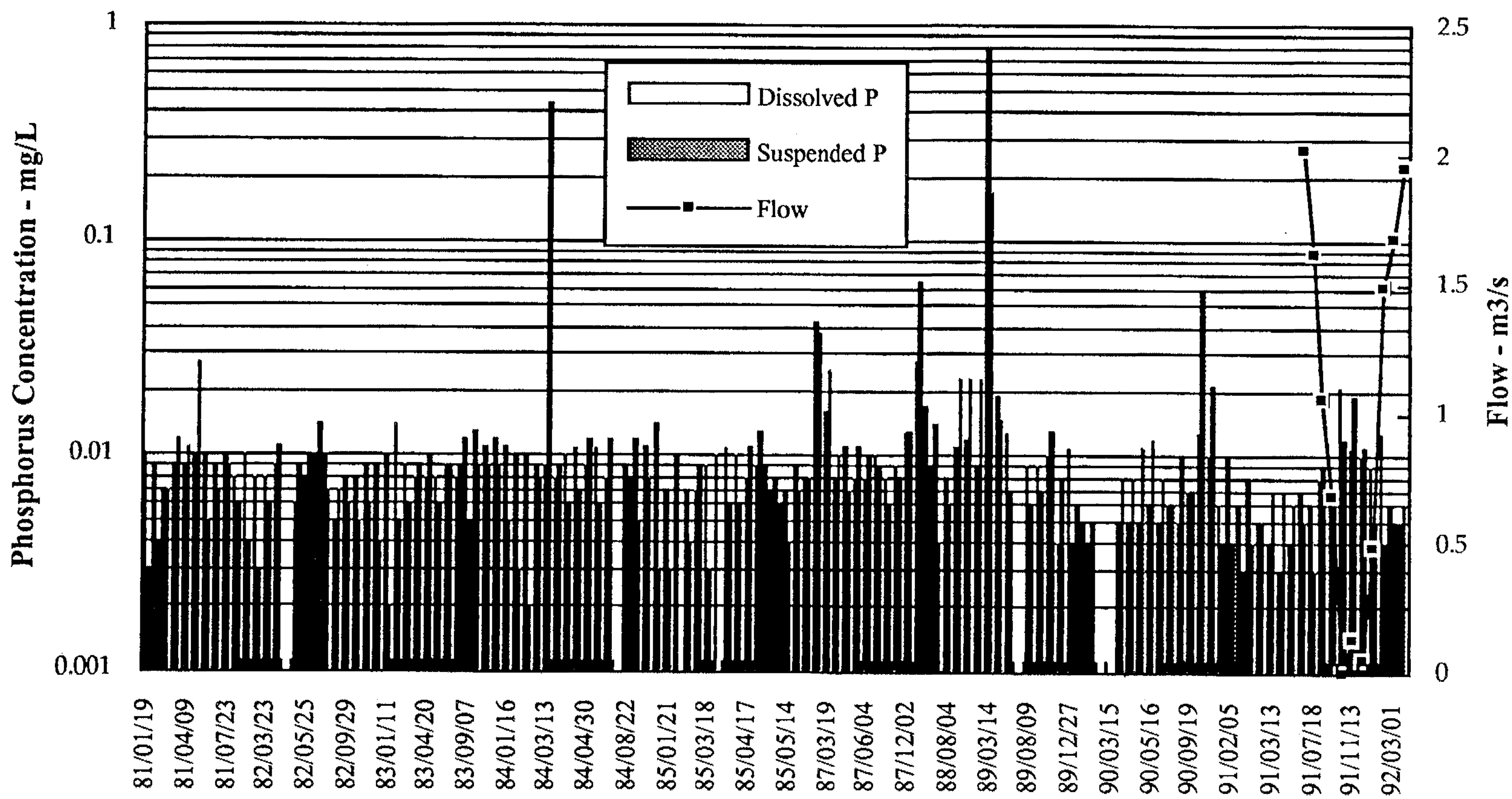


FIGURE 36

1991/92 PHOSPHORUS CONCENTRATIONS IN THE SAN JOSE RIVER ABOVE BORLAND CREEK (SITE E0600317)

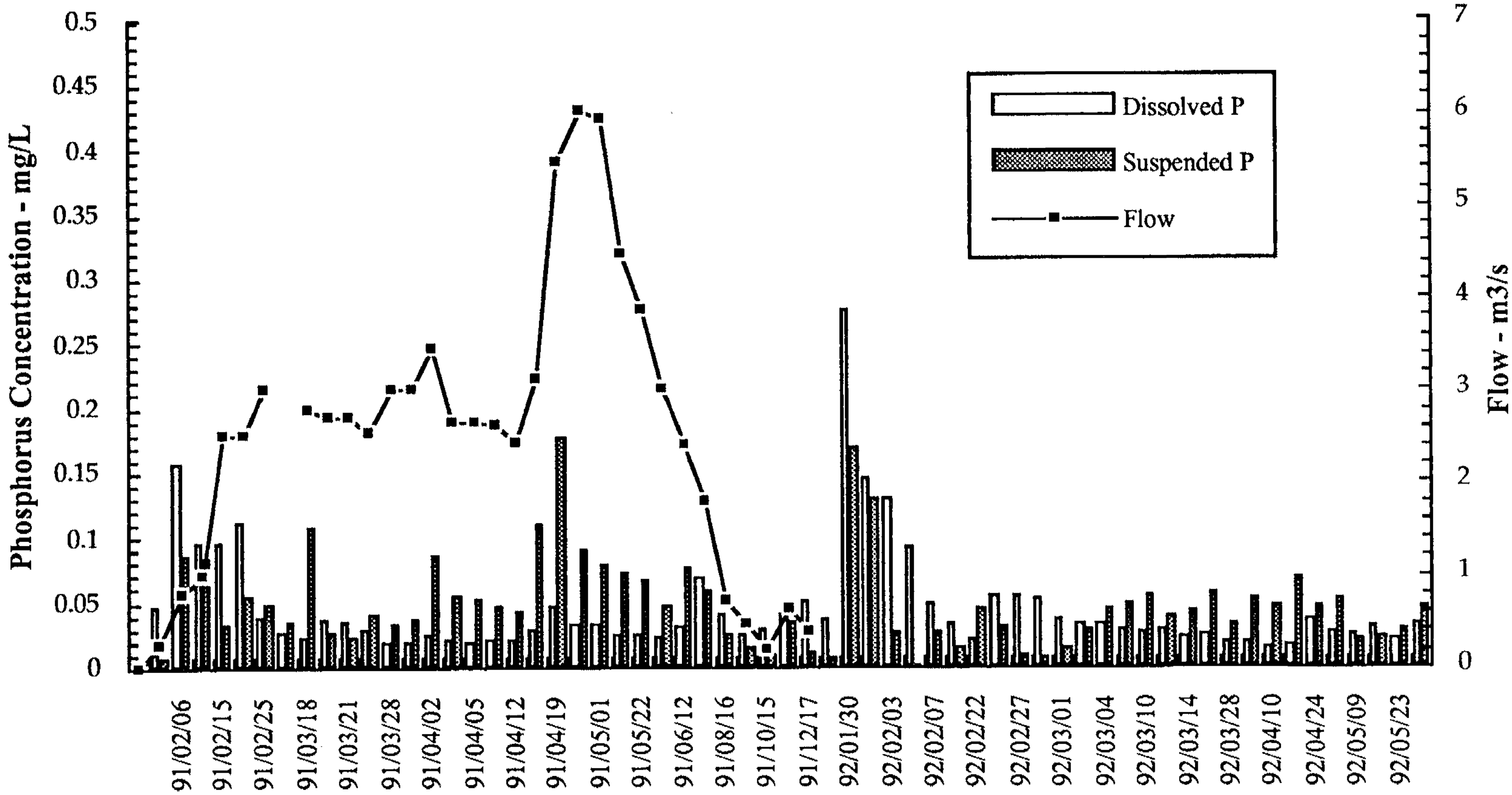
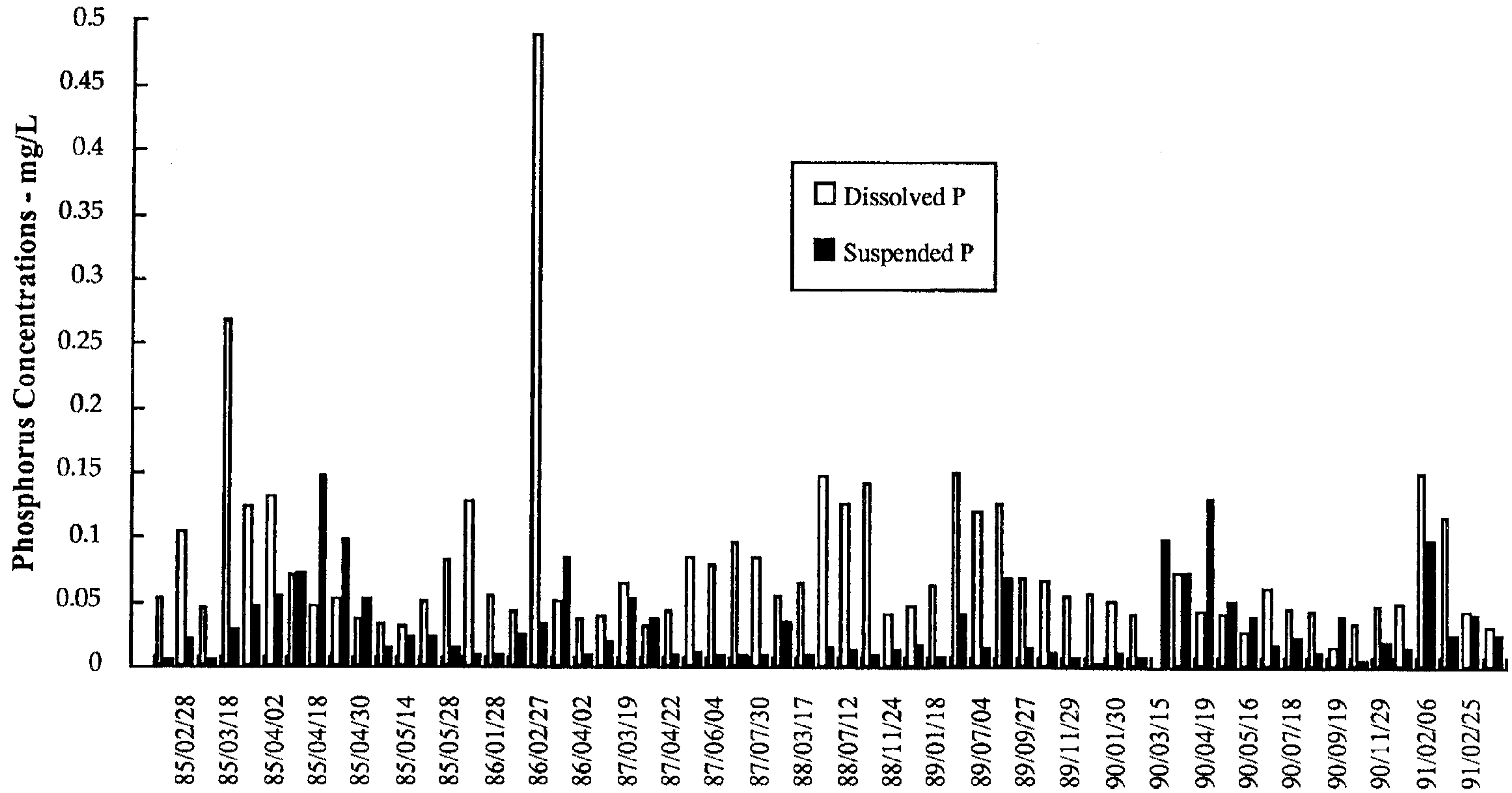


FIGURE 37

1985/91 PHOSPHORUS CONCENTRATIONS IN THE SAN JOSE RIVER BELOW BORLAND CREEK (SITE E0600316)



6. WATER QUALITY OBJECTIVES

Several assumptions are made in setting water quality objectives in the San Jose River basin:

(a) the allowable maximum annual total P loading from the San Jose River and its tributaries to Williams Lake is 2 500 kg. At this rate of P loading from San Jose River, the phosphorus concentration in Williams Lake will meet the current water quality objective (i.e., spring overturn concentration of 0.02 mg/L total P[6], provided input of P from other sources is completely eliminated (Nordin 1992)). The allowable maximum phosphorus loading from the San Jose River basin is 2.4 kg/km^2 when expressed on areal basis (i.e., area of San Jose River basin between Lac La Hache at the outlet and Williams Lake);

(b) the dissolved fraction in the San Jose River is the most important component of the phosphorus loading to Williams Lake. Therefore, the maximum allowable P loading from the San Jose River basin is expressed in terms of the dissolved P and not the total.

(c) the allowable maximum dissolved P loading from a given tributary in the San Jose River basin is on its drainage area and the objective loading from the entire basin as specified in (a) (Table 20);

In addition to the objective P loadings, Table 21 also shows mean annual concentrations at various sites in the San Jose River basin. The mean annual concentration (MAC) was calculated as a ratio between the allowable P loading and the mean annual flow for the site. It can be used to check water quality objectives when flow measurements are not available. However, note that the MACs in Table 21 are for the average year with respect to

---

[6]This is a long-term objective concentration for Williams Lake (McKean *et al.*, 1987)which is contingent on lake and stream restoration being sucessful and based on protecting all designated water uses for the lake (e.g., recreation, aquatic life, drinking water, etc.). Based on 1991 background levels and mean annual discharge at the mouth of 5 Mile Ck, Valley Ck, Borland Ck, Knife Ck, and San Jose River at Lac La Hache outlet, the background average dissolved P concentration in the San Jose River was estimated to be $\leq$ 0.020 mg/L. Given the mean annual discharge of 1.583 m^3/s for San Jose River at the mouth, the background dissolved P loading from the San Jose River to Williams Lake was calculated to be $\leq$ 1000 kg/annum.

water flow. Their dependency on flow means that the acceptable concentrations (i.e., those which indicate that the objectives are met) will be lower for the wetter years and higher for the drier years. It is, therefore, imperative that both flow and P concentration be measured to ensure that the phosphorus objective of a maximum of 2 500 kg/annum (or 2.4 kg/km^2 of watershed from the San Jose River watershed to Williams Lake) is met.

The allowable maximum P loadings (Tables 20 and 21) are long-term objectives contingent on successful control of non-point agricultural sources of phosphorus over time.

TABLE 20

DRAINAGE AREA AND ALLOWABLE MAXIMUM ANNUAL DISSOLVED PHOSPHORUS LOADING FOR VARIOUS WATER BASINS IN THE SAN JOSE RIVER WATERSHED

Water basin	***Drainage area@***		***Allowable dissolved Phosphorus loading***
	(km^2)	***% of total drainage area***	***kg/annum***
Five Mile Creek at the mouth	52.1	4.9*	120#
Valley Creek at the mouth	65.0	6.1*	150#
Borland Creek at the mouth	228	21.5*	540#
Jones Creek at the mouth	82.6	7.9*	200#
Knife Creek at the mouth	234	22.1*	550#
San Jose R. at Lac La Hache	1 110		300+
San Jose R. above Borland Creek	1 940	78.3**	
San Jose R. below Borland Creek	2 170	100	2 500

* drainage area ÷ (2 170-1 110)
** (drainage area-1 110) ÷ (2 170-1 110)
\+ estimated loading coming from Lac La Hache Lake
\# ≈ {% of total drainage area x 2 500 / 100}, includes background for the watershed
@ Chapman (1992)

TABLE 21

DISSOLVED PHOSPHORUS LOADING OBJECTIVES AND MEAN ANNUAL CONCENTRATIONS FOR VARIOUS WATER BASINS IN THE SAN JOSE RIVER WATERSHED

Water basin	***Site***	***Mean annual discharge at the mouth@***	***Allowable maximum dissolved P loading***	***Mean annual concen-tration+***
		(m^3/s)	***kg/annum***	***mg/L***
Five Mile Creek at the mouth	E213046	0.043	120	0.090
Valley Creek at the mouth	0600319	0.054	150	0.090
Borland Creek at the mouth	0600105	0.166	540	0.100
Jones Creek at the mouth	E214700	0.068	200	0.090
Knife Creek at the mouth	0600124	0.148	550	0.120
San Jose River at Lac La Hache	0600021	0.810	300	
San Jose River below Borland Creek	0600316	1.583	2 500	0.050

* Objective Concentration = column 3 ÷ (column 2 x 31536)
@ Chapman (1992)
\+ The mean annual concentrations are for the average (with respect to flow) year; it will be lower for the wetter year and higher for the drier year.

7. MONITORING RECOMMENDATIONS

The following recommendations are based on the observations made during the assessment of the water quality data for the San Jose River basin:

1. The mean annual concentrations in section 6 (Table 21) are based on mean annual flow in the San Jose River and its tributaries. Given that the mean annual flow in the San Jose River basin may vary from year to year, ***it is recommended that both phosphorus concentration and flow[7] are measured simultaneously to ensure that objectives (given in terms of phosphorus loading) are met.***

2. Water quality objectives (i.e., the allowable maximum P loadings) are proposed for several sites in the San Jose River. basin (Table 21). ***It is recommended, however, that only site 0600316[8] in the San Jose River downstream from Borland Creek be monitored.*** The reasons being: (a) the recommended objectives are based on protecting water quality in Williams Lake, (b) water quality in the San Jose River and its tributaries is not a major concern for aquatic life[9], livestock, and/or irrigation water uses, (c) the recommended phosphorus loadings for the San Jose River and its tributaries were apportioned arbitrarily based on size of the drainage area and not on any other watershed characteristics (e.g., soil type, stream sensitivity to phosphorus, instream water uses, etc.); nevertheless, the tributary-wide objectives are useful in delineating problem areas where future action may be warranted[10], and (d) extensive monitoring will yield better estimate of phosphorus loading to Williams Lake.

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[7] Alternatively objectives can be checked based on mean annual concentrations and flow. The services of the Hydrology Section of the Water Management Division can be obtained to estimate annual discharge at the given site.

[8] San Jose River above Borland Creek (0600317) and Borland Creek at the mouth (0600105) together may be used for the purpose if access to site 0600316 is not possible. The corresponding water flow measurement should be obtained from the Water Survey of Canada station (08MC040) located on the San Jose River upstream from Borland Creek in conjunction with water flow measurements to be carried out at the mouth of Borland Creek.

[9] Lack of water is the major concern for fisheries resource in the basin.

[10] B.C. Environment in the region has been working with the farmers in the basin to reduce phosphorus loading to streams by limiting cattle grazing to areas away from the watercourses.

3. The water quality assessment in section 5 indicated a considerable variability in the P concentrations and/or loading during the year. The characteristics of the runoff generated by snowmelt and a storm event amplifies the variability. ***It is, therefore, recommended that the water quality objectives be checked based on samples collected during the entire year. In the late spring, summer and early fall, biweekly samples may be acceptable. The frequency of sampling may be increased to a daily or a weekly interval during snowmelt or a storm event, depending upon changes in flow patterns.***

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