HYDROLOGY OF THE BRITANNIA MINE

by

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Abstract

The Britannia Mine is located on the east shore of Howe Sound approximately 50 kilometers north of Vancouver, British Columbia. During its 73 years of operation (1902-1974), the Britannia Mine evolved into a vast network of shafts and tunnels with numerous stopes and open pits at the surface. Acid Rock Drainage (ARD) has been issuing from the portals and waste rock dumps since the early stages of development. The ARD problem has not been properly dealt with due to questions of ownership and liability. Now, however, the initiative has been taken by Environment Canada and the BC Ministry of Environment, Lands & Parks (BC MOELP) to reduce the contaminant loading into Howe Sound and into Britannia Creek by treating the ARD. To aid in the design of a wastewater treatment plant, the hydrologic properties of the Britannia Mine area were investigated and a design flow rate was calculated.

Monitoring of flows at two major outflow points of the mine and two affected creeks has been carried out on a regular basis since 1995 with various random measurements taken before 1995. Water samples at the same locations were taken on a weekly basis by the BC MOELP since 1995 and analyzed for pH, dissolved and total metals, sulphate concentration, acidity, and conductivity. Other water samples had been taken and analyzed by various individuals before 1995 and the results have been recorded. Meteorological data have been collected at six precipitation gauges near the Britannia Mine from as early as 1932.

To determine a design flow rate for the proposed treatment plant the following steps were performed. The precipitation data were analyzed to determine the precipitation event magnitude for a given return period. The flow data were analyzed to determine the flow rate associated with a given return period. A 10 year return was selected as a basis for design. A relationship between precipitation and mine outflow was established and a suitable year's worth of flows was used as the design flow through the treatment plant. To reduce the peak flows, the possibility of storing water inside the mine workings was examined and an available storage volume was estimated. The required storage for a given constant treatment plant flow rate was calculated and compared with the available storage. A design flow rate with a 10 year return was calculated based on the available data. In addition to this, an attempt was made to model the Britannia Mine outflow given precipitation and temperature for flow forecasting purposes.

Forty-two years of record were available to generate return period graphs for mine outflows and precipitation events. The data indicated that a strong relationship exists between the annual precipitation volumes and the annual mine outflow volumes. An average year was chosen as the design flow and the required storage was calculated. The storage volume could not be determined accurately due to insufficient data however, estimates suggest that approximately one million cubic meters are available. A storage of one million cubic meters would allow the treatment plant design flow rate to be reduced to 40% of the average annual maximum flow. This would result in a considerable reduction in the costs of building and operating the treatment plant.

Further testing is needed to determine the storage available inside the mine with greater accuracy as well as the ability of the mine to hold this amount of water before a wastewater treatment plant is designed. The routing mechanism of the mine workings should be examined in more detail so that a better precipitation - flow model can be developed for flow forecasting.

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1. INTRODUCTION

Unlike today, in 1902 when the Britannia Mine began operations, mining regulations concerning pollution control were minimal. Today, pollution prevention and control are addressed before mining commences. However, no such consideration was given to the Britannia Mine and the result is continuing acid rock drainage (ARD) flowing from the disturbed ground into the receiving waters. Now, remediation measures must be taken to eliminate the threat the contaminated water poses to the receiving waters and repair the damage it has already done.

1.1 Contaminated Site

This project was initiated by Robert McCandless of Environment Canada, Pollution Abatement Branch. Several previous studies have been performed on the water quality in the receiving waters of the Britannia Mine outflow and have prompted remediation measures at this site. These include the reports by:

- Drake and Robertson, 1973
- Goyette and Ferguson, 1985
- Moore and van Aggelen, 1986
- Steffen, Robertson, and Kirsten Inc. (SRK), 1991
- Price, Schwab, and Hutt, 1995

1.1.1 The Britannia Mine

The Britannia Mine is located at Britannia Beach approximately 50 km north of Vancouver, British Columbia, see Figure 1.1. The mined ore bodies are located in a ridge between Furry Creek and Britannia Creek. Figure 1.2 shows the various portals and creeks and the pit complex. Mining took place at various elevations of the ridge from 1300 meters (4300 feet) above sea level to 450 meters (1400 feet) below sea level. A network of shafts and tunnels comprised the 80 km of mine workings that were excavated during the operation of the mine. Figure 1.3 shows an East - West section through the Britannia Mine. During the Britannia Mine's operational life, 47 million tonnes of ore were processed (Price, Schwab, and Hutt, 1995). Operations began in 1902 under the Britannia Mining and Smelting Company Ltd. In 1963, ownership was sold to the Anaconda Mining Company which ran the mine until 1974. The main product of the Britannia Mine was copper (500,000 tonnes), but zinc (125,000 tonnes), lead (15,000 tonnes), gold, and silver were also recovered (McCandless, 1997).

Drainage exits the mine from several portals on either side of the ridge, however, two contribute the majority of the contaminated effluent. These are the 2200 Level portal which drains into Jane Creek, a tributary of Britannia Creek and the 4100 Level portal which drains into Howe Sound. The levels of the Britannia Mine are numbered in feet below the top of the ridge which is 4300 feet above sea level. Therefore the 2200 Level portal is 2200 feet below the top of the ridge, 640 meters above sea level. The major levels and their respective elevations are listed in Table 1.1.

Table 1.1 Elevations of the Britannia Mine Portals and Levels

	Elevation above sea level	
Portal	*in meters*	*in feet*
4150 Level	45	150
4100 Level	60	200
3250 Level	320	1050
3100 Level	370	1200
2700 Level	490	1600
2200 Level	640	2100
Daisy	1100	3600
Beta	780	2550
1200 Level	940	3100
1050 Level	990	3250
Barbara	1160	3800

(Price, Schwab, and Hutt, 1995)

1.1.2 Previous Control Measures

Acid rock drainage has been a problem at Britannia Beach since the early stages of operation. The existing discharge requirements based on a Pollution Abatement Order (1981) produced by the Ministry of Environment, Lands and Parks state that the 4100 Level portal drainage is to be treated in the precipitation plant when the copper concentration exceeds 15 mg/l (Price, Schwab, and Hutt, 1995). The Pollution Abatement Order also required that a submerged outfall be built to carry the 4100 Level portal drainage into Howe Sound bypassing Britannia Creek.

Restoration efforts to date included two precipitation plants, a sedimentation pond, and a deep outfall into Howe Sound. The precipitation plants, a series of troughs conveying the drainage past scrap iron, aided in the removal of copper from the 4100 and 2200

Level portal drainage by way of replacement reaction. Tin cans comprised the majority of the scrap iron and removal of the precipitated copper was done by diverting the precipitation plant outflow to the sedimentation pond and shaking the cans so that the copper flocks would get washed downstream (Price, Schwab, and Hutt, 1995). The copper removal was greatest when the dissolved copper concentration was greater than 20 mg/l (Goyette and Ferguson, 1985). Price, Schwab, and Hutt conclude that even when the dissolved copper concentration exceeds 20 mg/l, only 30% removal is achieved. The overall copper removal was 19% (Price, Schwab, and Hutt, 1995).

Currently, the precipitation plant at the 2200 Level is not in operation and the 2200 Level portal discharge is flowing directly into Britannia Creek via Jane Creek. The copper concentration in the 2200 Level portal drainage is approximately 70 mg/l (Zabil, 1998). The copper concentration in the 4100 Level portal drainage fluctuated between 11 and 16 mg/l during the period from January to May, 1998 (Zabil, 1998). Even though the copper concentration fluctuates above 15 mg/l, the precipitation plant is not being maintained at present. Portions of the troughs contain no tin cans and the tin cans are not being replaced or shaken.

1.2 Objectives and Scope

This thesis is concerned with the hydrological and hydraulic properties of the Britannia Mine and surrounding area. The results are specific to this area and will be used for the purpose of designing a wastewater treatment plant which will treat the ARD from the 2200 and 4100 Level portals (Simons, 1998). The main objective of the study was to determine the treatment plant design flow rate. In order to achieve this, the following steps were performed:

- The precipitation data were analyzed to determine the precipitation event magnitude for a given return period
- The flow data were analyzed to determine the flow rate associated with a given return period
- A relationship between precipitation and mine outflow was established
- The amount of available storage inside the mine was estimated
- The required storage for a given treatment plant flow rate was calculated

In addition to this, an attempt was made to model the Britannia mine outflow given precipitation and temperature for flow forecasting purposes.

The results of the analysis suggest that the storage volume inside the mine is on the order of one million cubic meters. This is approximately equal to the storage volume required given a 10 year return period as the design flow. The wastewater treatment plant will be able to operate at a constant flow rate of 0.179 CMS (the 10 year return annual average flow) with the higher flow peaks being stored in the mine for release during low flow periods.

1.3 Summary

This thesis consists of five sections. Section 1 defines the scope of this thesis and provides information on the study site. Background information on acid rock drainage, neutralization / precipitation water treatment, and the qualifications of the Britannia

Mine to be a rehabilitation candidate are contained in Section 2. Section 3 contains the data used in this thesis and details the processing of it. The results and their consequences are presented in Section 4. Conclusions are drawn and recommendations are made in Section 5. Flow records from various locations at the Britannia Mine and records of pressure behind the 4100 Level plug are contained within Appendix A.

2. BACKGROUND

The Britannia Mine ARD problem was introduced in the previous section and the objectives of this thesis were defined. This section gives background information which is required in the coming sections. This section consists of a brief definition of ARD and its prevention, background information on neutralization / precipitation water treatment, and a discussion of the suitability of the Britannia Mine site for rehabilitation.

2.1 Acid Rock Drainage

The most important environmental concern associated with the mining industry is acid rock drainage (McCandless, 1995). Acid rock drainage is the term used for the water that carries oxidation products from ores or waste rock with a high sulphur content. The associated reactions are extremely complex and involve the following ingredients: oxygen, water, sulfide minerals, and sulfide-oxidizing bacteria.

Methods of eliminating acid rock drainage fall into three categories:

Primary Control: control of the reactions which generate acid

Secondary Control: control of the transport of contaminated water

Tertiary Control: collection and treatment of contaminated water

If possible, primary control should be applied as it is the most desirable option. In certain situations, as with old abandoned mines, tertiary control needs to be implemented along with primary and secondary control. Primary control involves removing a necessary ingredient for acid generation. Removing the exposed sulphide mineral, covering the waste rock to remove oxygen and/or water access, and using bactericides to eliminate the sulphide-oxidizing bacteria. Secondary control involves preventing water entry into the waste rock by diversion, interception, application of covers over the waste rock, and locating waste in a manner that will minimize infiltration. Tertiary control involves collecting and treating already contaminated water using a lime precipitation treatment plant and tailings pond disposal of precipitates or a passive treatment system such as wetlands. (Filion, Sirois, and Ferguson, 1992)

2.2 Neutralization / Precipitation Water Treatment for Rehabilitation

Neutralization / precipitation water treatment is a form of tertiary ARD control and requires a treatment plant employing chemical and mechanical processes to partially remove target contaminants. The processes involved in neutralization / precipitation water treatment are designed to:

- neutralize the pH of the acidic water entering the plant.
- reduce the concentrations of metals in the water.

2.2.1 Neutralization of pH

The pH of the mine drainage is acidic. Based on 1998 data, the 2200 Level portal drainage pH fluctuates between 3.01 and 3.13 and the 4100 Level portal drainage pH fluctuates between 3.43 and 4.18 (Zabil, 1998). The first step in the neutralization / precipitation water treatment is to neutralize the pH of the water entering the plant. This can be done with the addition of an alkaline compound such as lime, soda ash, or pulp mill residue (Simons, 1998). The amount of the alkaline compound added is a function of the pH of the inflow and the flow rate. The pH of the mine drainage varies slightly and will affect the alkaline reagent dosage but is independent of flow rate. The flow rate through the treatment plant will determine the quantity of alkaline reagent needed. It will also determine the physical treatment plant size as larger flow rates will increase the size of the mixing tank, the reactor tank, and the clarifier.

2.2.2 Reduced Metals Concentration

A neutralization / precipitation water treatment plant utilizes chemical precipitation, flocculation, and settling to remove the metals from solution. In a neutralization / precipitation reaction, the pH of the mine drainage is raised to a level at which the target metals are less soluble and therefore precipitate out. A flocculant may be desirable as it will increase the precipitated particle size and increase the settling rate. This allows for a smaller clarifier or a higher flow rate through the clarifier. The products of the neutralization / precipitation treatment are an effluent with characteristics that make it suitable for release into receiving waters and a sludge consisting of water, the alkaline reagent, and the precipitated metals (Simons, 1998). The sludge must be disposed of by placing it in a sludge pond or otherwise processing it to recover the metals if profitable (SRK, 1991).

2.2.3 Neutralization / Precipitation Treatment Options

There are several options in chemical reagents for the neutralization / precipitation reaction. These include hydrated lime, caustic soda, magnesium hydroxide, soda ash, limestone, dolomite, magnesite, and alkaline pulp mill residue. All of these reagents may be used to raise pH in order to promote metal precipitation, however, the drainage water properties, site conditions, and reagent availability will determine which reagent is most suitable. (Simons, 1998)

A high or low density sludge process may also be used. The high density sludge process requires partial recirculation of sludge through the plant. With this process a denser, more stable sludge and a higher quality effluent are produced. (SRK, 1991)

2.3 The Need to Rehabilitate the Britannia Mine Site

Several studies have been performed on the properties of the Britannia Mine outflow, as well as, on the properties of the mine itself (Goyette & Ferguson,1985, SRK, 1991, Price, Schwab, and Hutt, 1995, Simons, 1998). The acid rock drainage problem has been described as being the worst point source of pollution in the province (McCandless, 1995). Water quality data records have been kept on a regular basis by the BC Ministry of Environment, Lands & Parks (BC MOELP) since 1995 and also periodic measurements were taken during mine operation. The discharge poses a threat to juvenile salmon in Howe Sound by destroying habitat along the coastline. A multi year study of the fate of metals entering Howe Sound is under way as part of a

Ph.D. thesis in the Department of Oceanography at UBC (Price, Schwab, and Hutt, 1995).

Rehabilitation action has been delayed due to ownership and liability disagreements between the province, the Anaconda Mining Company, and Copper Beach Estates. It has been decided, by Environment Canada and BC MOELP, to go ahead with the pre-feasibility design and cost estimate of a treatment plant and continue to resolve liability issues (McCandless, 1998).

The Britannia Beach properties are situated between Squamish and the fast-growing community of Furry Creek. The land at Britannia Beach, if cleaned up, may have similar potential in terms of development as the Furry Creek community. Because of the acid rock drainage clean-up responsibility associated with land ownership, land developers are reluctant to invest. A wastewater treatment plant would eliminate the acid rock drainage problem and potentially create the opportunity for growth at Britannia Beach.

2.3.1 Outflow Properties

The Britannia Mine drainage exceeds water quality standards for discharge into the environment, as set by the Department of Fisheries and Oceans and the Ministry of Environment. The target metals for removal by the neutralization / precipitation treatment process are listed in Table 2.1.

Table 2.1. Metals Concentrations in Drainage and Post Treatment

Metal in Mine Drainage	*Annual Average Concentration in Mine Drainage**	*Target Concentration in Treatment Plant Effluent*
Copper (Cu^{2+})	28 mg/l	0.2 mg/l
Iron (Fe^{2+})	15 mg/l	0.5 mg/l
Zinc (Zn^{2+})	25 mg/l	0.3 mg/l
Aluminum (Al^{3+})	31 mg/l	0.5 mg/l
Manganese (Mn^{2+})	4.8 mg/l	1.0 mg/l
Cadmium (Cd^{2+})	0.12 mg/l	0.05 mg/l

* Flow weighted average of 4100 and 2200 Level portal concentrations (Simons, 1998)

2.3.2 Britannia Creek

A large part of the contamination in Britannia Creek is due to the 2200 Level portal drainage which discharges into Britannia Creek via Jane Creek. The iron in the water leaves rocks in Britannia Creek stained. The water then flows into Howe Sound contaminating the brackish water along the coastline which is favored by juvenile salmon as rearing habitat (McCandless, 1995). The 4100 Level portal drainage did enter Britannia Creek in the past, but in 1978 a submerged outfall into Howe sound was built and Britannia Creek was bypassed (SRK, 1991).

2.3.3 Mine Portals

There are several portals into the mine on both the Britannia and Furry Creek sides of the ridge. On the Furry Creek side, there are four portals; the Barbara, Empress Camp 1050 Level, 1200 Level, and Beta portals. Water samples were taken at several locations in the Furry Creek watershed between October 1992 and January 1993. The water quality properties of each portal's drainage are listed in Table 2.2. No flow out of the Barbara portal was observed, nor was any expected since the portal declines into the mine. The channel carrying the Beta portal drainage is stained a blue-green color resulting from the precipitation of malachite due to the higher pH and the low concentrations of aluminum and iron (Price, Schwab, and Hutt, 1995). All three portals drain into Portal Creek which exhibited similar water properties as the portals. Empress Creek also contained elevated copper and zinc concentrations and a pH of 4. Both the Portal and Empress Creeks drain into Furry Creek. Samples from Furry Creek show acceptable copper and zinc levels. With a flow rate three orders of magnitude larger than the Empress and Portal Creeks combined, Furry Creek water quality is ensured by dilution (Price, Schwab, and Hutt, 1995).

Table 2.2. Water Quality of Drainage in the Furry Creek Watershed

Site	*Flow Rate (l/s)*	*pH*	*Cu (mg/l)*	*Zn (mg/l)*	*Cd (µg/l)*	*Fe (mg/l)*	*SO_4 (mg/l)*
1050 Level portal	0.8	3.4	33	9.6	100	5.2	280
1200 Level portal	0.2		0.22	0.045	5.0	0.23	12
Beta portal	1.0	5.4	2.8	3.2	47	0.18	160
Portal Creek	0.5	3.9	1.7	1.2	14	2.3	97
Empress Creek	4.0	4.1	0.40	0.31	2.0	0.17	50
Furry Creek	3000	7.0	0.018	0.020	5.0	0.049	5.0

(Price, Schwab, and Hutt, 1995)

On the Britannia Creek side, there are several portals including the Daisy, the 2200 Level, the 2700 Level, the 3100 Level, the 3250 Level, and the 4100 Level portals. The Daisy portal, the two 2700 Level portals, and the 3100 and 3250 Level portals all drain into Mineral Creek. The flow from each is less than 1 l/s (Price, Schwab, and Hutt, 1995). Water samples were taken at several locations in the Britannia Creek watershed in November 1992. The water quality properties of each portal's drainage are listed in Table 2.3.

Table 2.3. Water Quality of Drainage in the Britannia Creek Watershed

Site	*Flow Rate (l/s)*	*pH*	*Cu (mg/l)*	*Zn (mg/l)*	*Cd (µg/l)*	*Fe (mg/l)*	*SO_4 (mg/l)*
Daisy portal	0.5	5.8	0.002	0.20	1.0	0.020	14
2700 Level portal A	0.5	4.3	0.26	1.24	7.0	8.9	260
2700 Level portal B	<1.0		0.046	0.15	1.0	0.010	9.0
3100 Level portal	<1.0						
3250 Level portal	<1.0						
Jane Creek*	45	5.8	28	13	78	16	545
Mineral Creek*	130	7.9	0.012	0.032	6.0	0.060	31
Britannia Creek*	1500	4.3	2.7	2.6	17	1.2	180

* at mouth of creek (Price, Schwab, and Hutt, 1995)

The two portals that contribute the majority of contaminated flow are the 2200 and 4100 Level portals. The 2200 Level portal is located at the former Mt. Sheer townsite and its outflow drains into Jane Creek. Jane Creek flows into Britannia Creek which flows out into Howe Sound, see Figure 1.2. The 2200 Level portal drainage is highly acidic with a pH of 3. The 2200 Level portal drainage properties are listed in Table 2.4. The average flow rate out of the 2200 Level portal based on the 1996 record is 30 l/s (Zabil, 1998).. An attempt was made to divert the 2200 Level portal flow down through the mine to the 4100 Level by building a dam inside the 2200 Level tunnel. The success of this attempt was only temporary until the dam started overtopping and flow out of the 2200 Level portal resumed. A rectangular weir was built at the entrance to the portal and water surface elevation is measured on the upstream side. Waste rock piles at the 2200 Level also contribute ARD into Britannia Creek (Price, Schwab, and Hutt, 1995).

Table 2.4. Water Quality of Drainage from the 2200 and 4100 Level Portals

Parameter	*2200 Level portal*	*4100 Level portal*
Average Flow Rate (l/s)	30	115
pH*	3.01 - 3.13	3.43 - 4.18
Copper (mg/l)*	45 - 78	11 - 16
Zinc (mg/l)*	27 - 39	16 - 30
Cadmium (μg/l)*	160 - 250	60 - 100
Iron (mg/l)*	22 - 44	3.5 - 8.6
Sulphate (mg/l)*	980 - 1270	1320 - 1580

* based on 1998 data (Zabil, 1998)

The 4100 Level portal is located at the foot of the ridge at Britannia Beach. A concrete plug 400 meters inside the 4100 Level tunnel holds back the flow. Three pipes (4", 6", and 10") convey water through the plug, see Figure 2.1. The water flows out of the pipes and into a ditch which runs along one side of the tunnel towards the entrance. Four hundred and seventy meters from the concrete plug, the ARD in the ditch falls down a shaft to the 4150 Level. The path that the 4100 Level portal drainage takes from there is illustrated in Figure 2.2. The water emerges out of the mine and flows towards the Parshall flumes located several meters from the 4150 Level portal. The ARD enters a splitter box where it is split into two directions. Part of the flow enters a Parshall flume where its flow rate is measured and drains towards the powerhouse building. From there it flows underground towards the submerged outfall in Howe Sound. The remainder of the ARD flows into two side by side Parshall flumes where its flow rate is measured. Currently, one of the flumes is blocked off forcing all the flow into the other. From the flume the ARD flows down a wooden trough, falls into a culvert, and emerges in the precipitation plant. The ARD flows down the concrete troughs of the precipitation plant, into a manhole where it merges with the powerhouse flow component, and is carried to the submerged outfall. The 4100 Level portal drainage is highly acidic with a pH of 3.5. The drainage characteristics are listed in Table 2.4. The average flow rate out of the 4100 Level portal based on the 1996 record is 115 l/s (Zabil, 1998).

3. METHODS, MATERIALS, and DATA PROCESSING

The previous section gave background information on ARD generation and prevention and described the use of a neutralization / precipitation reaction for water treatment. It also described the Britannia Mine site and the need for its rehabilitation. This section focuses on the data and the tools used for collection and processing of the data. In Section 3.1 the meteorological, hydrologic, and pressure data that were used in this study are presented. The information regarding the mine workings is discussed in Section 3.2. The required topographical maps are listed in Section 3.3 And the data processing is described in Section 3.4.

3.1 Electronic Data

The electronic data consist of meteorological data from climate stations near the Britannia Mine area, flow data from the two major outflow points of the mine, flow data from a small creek near one on the portals, and records of pressures behind the 4100 Level plug. The data were supplied by BC MOELP and Environment Canada.

3.1.1 Meteorological Data

Meteorological data consisted of total daily precipitation and minimum, average, and maximum daily temperature. Meteorological data for the period of flow record (1930 to present) were collected at six stations near the Britannia Mine. Each station has an individual period of record with numerous gaps in the data. The six stations are:

- Squamish A CS (4947N 12310W)
- Squamish STP Central (4942N 12310W)
- Furry Creek station (4935N 12313W)
- Cypress Bowl - West Vancouver CS (4924N 12312W)
- Gambier Harbour station (4927N 12326W)
- 2200 Level station (4937N 12308W)

The Squamish A CS (Automatic Climate Station) is located at the Squamish airport at an elevation of 59 meters above sea level. The available data at this station are from May 1982 to September 1996. The Squamish STP Central station is located at an elevation of 39 meters above sea level. The available data at this station are from September 1996 to March 1998. The Furry Creek station is located at an elevation of 9 meters above sea level. The available data for this station are from January 1932 to October 1974 and from January 1994 to April 1998. The Cypress Bowl - West Vancouver CS is located on Hwy. #1 near the Cypress Bowl exit at an elevation of 850 meters. The available data for this station are from December 1984 to December 1995. The Gambier Harbour station is located on Gambier Island at an elevation of 53 meters above sea level. Only precipitation data are available for this station from August 1962 to May 1997. The 2200 Level station is located near the 2200 Level portal at an elevation of 640 meters above sea level. The available data for this station are from October 1997 to January 1998.

3.1.2 Hydrologic Data

Hydrologic data consisted of flows measured at four locations at the Britannia Mine. Each of these locations has an individual period of record with numerous gaps in the data. The four locations are:

- 2200 Level portal
- 4100 Level portal (flow to powerhouse)
- 4100 Level portal (flow to precipitation plant)
- Jane Creek

Flow emerging from the 2200 Level portal is measured at a rectangular weir located at the entrance to the 2200 Level tunnel. A staff gauge is installed to measure the water surface elevation upstream of the weir. The crest of the weir is at an elevation that coincides with a staff gauge reading of 0.186 meters. The weir is 0.911 meters wide and has a weir coefficient of 0.637. Flow over it is governed by the equation:

$$Q = (1.714 - 0.376 * (S - 0.186)) * (S - 0.186)^{1.5} \tag{3.1}$$

where Q is the flow rate in cubic meters per second, and S is the staff gauge level in meters (Triton,1997). Equation 3.1 was derived from the equation for discharge over a rectangular weir:

$$Q = 2/3 * C_w * (L - 0.2 h) * (2 g)^{0.5} * h^{1.5} \tag{3.2}$$

where Q is the flow rate over the weir in cubic meters per second, C_w is the weir coefficient, L is the width of the weir in meters, h is the depth of water over the crest of the weir in meters, and g is the gravitational constant, 9.81 m/s^2 (Triton, 1997). The 2200 Level portal discharge was measured at three different flow rates and compared to the flow rate calculated using Equation 3.1. The values agreed to within 9%. There is insufficient data to determine whether this error is associated with the flow measurement or with the inaccuracy of Equation 3.1.

The depth of water upstream of the weir is measured automatically by a nitrogen gas bubbler water level sensor. A data logger stores the water level values every fifteen minutes and stored data are periodically downloaded to free up memory. The 2200 Level portal flow records are available from January 1930 to December 1956 on a semi monthly basis. From January 1996 to March 1997 and from October 1997 to January 1998 records are available on an hourly basis.

Flow from the 4100 Level portal is measured at two Parshall flumes located at the 4150 level. Both Parshall flumes are 12 inches wide and flow through them is governed by the equation:

$$Q = 4.0 * W * H_a^{1.522 * W^{0.26}} \qquad (3.3)$$

where Q is the flow rate in cubic feet per second, W is the flume width in feet, and H_a is the depth of flow measured in feet at a point two-thirds of the length of the sidewall of the converging section back from the crest (Triton, 1997). The flow through each flume was measured at three different flow rates and compared to the flow rate calculated using Equation 3.3. The values agreed to within 12%. Since the 4100 Level portal contributes approximately 90% of the treatment plant flow, the equation should be refined as more flow measurements are made. Currently, there is insufficient data to determine whether this error is associated with the flow measurement or with the inaccuracy of Equation 3.3.

The depth of water in the Parshall flumes is measured automatically by a nitrogen gas bubbler water level sensor. A data logger stores the water level values from each Parshall flume every fifteen minutes and stored data are periodically downloaded to free up memory. The 4100 Level portal flow records are available from October 1977 to December 1993 on a weekly basis. From September 1995 to March 1997 and from October 1997 to January 1998 records are available on an hourly basis.

Flow in Jane Creek is measured at a rectangular weir located near the 2200 Level portal. A staff gauge is installed to measure the water surface elevation upstream of the weir. The crest of the weir is at an elevation that coincides with a staff gauge reading of 0.212 meters. The weir is 0.916 meters wide and has a weir coefficient of 0.637. Flow over it is governed by the equation:

$$Q = (1.723 - 0.376 * (S - 0.212)) * (S - 0.212)^{1.5} \tag{3.4}$$

where Q is the flow rate in cubic meters per second, and S is the staff gauge level in meters (Triton,1997). Jane Creek flow was measured at two flow rates and compared to the flow rate calculated using Equation 3.4. The values agreed to within 15%. There is insufficient data to determine whether this error is associated with the flow measurement or with the inaccuracy of Equation 3.4.

The water level upstream of the weir is measured by a Stevens chart recorder. The Stevens chart recorder uses a float which is mechanically attached to a pen plotter. As the float moves up and down, the pen moves across the paper. The pen scribes a continuous line as the paper moves by. The roll of paper is periodically replaced and the data are digitized into computer files. Jane Creek flow records are available from January 1996 to January 1997 and from May 1997 to June 1998 on an hourly basis.

3.1.3 Pressure Data

The water level behind the 4100 Level plug has fluctuated a great deal since the plug was installed. From 1980 to 1986, the pressure behind the plug was recorded on a weekly basis. Each of the three pipes conveying water through the plug had a pressure gauge installed on it between the plug and the valve, see Figure 2.1. During the six year period (1980 to 1986), the valves were regulated. For extended periods of time, only one of the three valves would be open and the pressure was recorded on at least one of the closed valves. The measurements were recorded in 5 psi increments in a ledger provided by Robert McCandless of Environment Canada. The data were entered into Microsoft Excel for analysis.

3.2 Mine Workings

The mine workings of the Britannia Mine consist of tunnels, shafts, stopes, and pits. An incomplete set of drawings of the mine workings, made available by Robert McCandless of Environment Canada, includes an elevation view showing the numerous levels and shafts and plan views showing each level. The elevation view indicates the positions of the stopes, however, the plan views do not. These 1:2400 scale drawings were used to estimate the volume of storage available between the

4100 Level portal and the next portal above it, the 3250 Level portal. The major shafts, tunnels, and ore bodies are shown in Figure 1.3.

3.3 Topography

Various topographical maps were used to estimate catchment areas. A 1:20000 scale map obtained from the University of British Columbia Map Library (No. 92G.065 Digital) was used to estimate the catchment area of Jane Creek and the open pit complex. A 1:4800 scale map, made available by Robert G. McCandless of Environment Canada, was used to revise both estimates. In addition, a visual inspection of the terrain around the open pits was performed from a helicopter and also on foot.

3.4 Data Processing

The electronic data were imported into Microsoft Excel 7.0 for processing. The temperature, precipitation, and flow records were manipulated to produce graphs showing correlation between sets of data. Meteorological data from the six climate stations were analyzed for similar weather patterns. The precipitation and flow records were used to generate return period plots and establish a precipitation-flow relationship. A volume inside the mine between the 4100 and 3250 Levels was estimated. A design flow based on the 10 year return flow rate and available storage was calculated. The 10 year return period was agreed on by HA Simons and Environment Canada.

In order to achieve a numerical relationship between precipitation, temperature, and mine outflow for possible flow forecasting, the UBC Watershed model was applied. The UBC Watershed model was developed to describe the behavior of streams in mountainous areas (Quick, 1995). The model has the ability to model groundwater flow and flow through a series of reservoirs. The model was used to estimate the relative quantities of fast runoff and slow groundwater flow. It was also used because of its ability to model snow accumulation and melt using only precipitation and maximum and minimum temperature as input.

It was never the intention of the developers for the UBC Watershed model to be used for flow though mine workings. Attempting to apply it to flow through a mine was done to test whether or not it could be applied with reasonable success. Successful modeling would allow the flow out of the mine to be predicted given precipitation and temperature data. The storage reservoir could be better managed, draining it down when high flow rates are predicted and storing more water during dryer periods.

4. OBSERVATIONS and RESULTS

The previous section described the sources of data and processing methods applied to acquire meaningful results. This section covers the results and associated observations. The results of the meteorological data analysis are presented in Section 4.1. In order to determine a design flow rate for the wastewater treatment plant the following results were obtained. The results of the return period analysis which were used to determine the 10 year return flow rate are presented in Section 4.2.1. The precipitation - flow relationship that is required to determine what a design year of flow should look like is discussed in Section 4.2.2. The available storage volume inside the mine is estimated in Section 4.2.3 and the design flow is calculated in Section 4.2.4. Flow modeling for forecasting purposes is discussed in Section 4.3.

4.1 Meteorological Data

The meteorological data that were collected at the six stations near the Britannia Mine were compared to determine whether or not each station experienced similar weather patterns.

4.1.1 Regional Weather

The stations with overlapping records were compared by temperature and precipitation. Figure 4.1 shows the temperature relationships between the Squamish A CS, Cypress Bowl - West Vancouver CS, and Furry Creek stations for the period of record. All three locations experienced similar temperature fluctuations and therefore the temperature at any station may be expressed as a function of the temperature at another. The following relationships were observed:

$$T_{FC} = 0.90 \times T_{Sq} + 2.3 \qquad (4.1)$$

$$T_{Cy} = 0.88 \times T_{Sq} - 2.8 \qquad (4.2)$$

where T_{FC} is the temperature at the Furry Creek station (in Celsius), T_{Sq} is the temperature at the Squamish A CS (in Celsius), and T_{Cy} is the temperature at the Cypress Bowl - West Vancouver CS (in Celsius). The Cypress Bowl - West Vancouver CS recorded lower temperatures than the Squamish A CS or the Furry Creek station. This is due in part to the fact that the Cypress Bowl gauge is at an elevation of 850 meters above sea level while the Squamish and Furry Creek gauges are at 59 meters and 9 meters above sea level, respectively.

A cumulative precipitation comparison of the Squamish A CS, Cypress Bowl - West Vancouver CS, Furry Creek, and Gambier Harbour stations for the period January 1994 to February, 1997 was performed. Each location exhibits a similar precipitation pattern as can be seen in Figure 4.2. The Furry Creek and Gambier Harbour stations consistently recorded lower precipitation values than the Cypress Bowl or Squamish A CS stations. The Cypress Bowl station consistently recorded the highest precipitation values. This is due, in part, to the precipitation gradient resulting in higher precipitation values at higher elevations. Regional variation may also be a factor in the precipitation difference between stations. The precipitation at one station can be expressed as a function of the others. The precipitation at the Cypress Bowl station is on average 11% greater than that at the Squamish A CS and the precipitation at the Squamish A CS is, on average, 22% greater than that at the Gambier Harbour station. The Gambier

Harbour station precipitation is, on average, 3% greater than that at the Furry Creek station. Figure 4.3 shows these relationships.

Each station recorded similar weather patterns suggesting that the data from any one of the four stations is representative of the precipitation and temperature occurring in the Britannia Mine catchment.

4.1.2 Local Meteorological Record

In October 1997, a precipitation and temperature gauge was installed near the 2200 Level portal to obtain a local weather record. Data recorded at this station were compared to the regional weather patterns. Figure 4.4 shows the temperature comparison between the Squamish STP Central, Cypress Bowl - West Vancouver CS, and the 2200 Level stations for the period of October to November, 1997. The 2200 Level temperature did not fluctuate as much as the temperature at the Cypress Bowl and Squamish stations. All three locations experienced similar temperature fluctuations with a period of 24 hours. Larger temperature fluctuations generally occurred on days without precipitation. This is reasonable since higher fluctuations occur on cloudless days.

The cumulative precipitation at the Squamish STP Central, Cypress Bowl - West Vancouver CS, and the 2200 Level stations was compared for the period of October to November, 1997. The 2200 Level station precipitation values were significantly lower than all the other stations in the area. The record at this station however is believed to be incorrect as it is unlikely that the precipitation at the base of the ridge (Furry Creek station) would be higher than that at the 2200 Level. It was suggested that the precipitation may have been recorded in inches instead of millimeters. A factor of 25.4 would increase the 2200 Level precipitation to a value consistent with the other precipitation gauges. The datalogger's programming has since been erased and it cannot be confirmed or denied that the precipitation was recorded in inches. The precipitation gauge was calibrated in April, 1998, however, the datalogger's memory was already full at that time and the data were lost.

On the assumption that the 2200 Level station precipitation was recorded in inches, the precipitation values were multiplied by a factor of 25.4 to convert them to millimeters. Figure 4.5 shows the cumulative precipitation comparison. The Squamish and Cypress stations recorded precipitation totals of 449 mm and 296 mm, respectively, while the 2200 Level gauge recorded a total precipitation of 340 mm (13.4 x 25.4). All three gauges did experience similar precipitation events. For this short period (one month), the Squamish STP Central precipitation is greater than the Cypress Bowl precipitation even though the Cypress Bowl station is 811 meters higher than the Squamish station. Short-term regional weather patterns may account for this discrepancy.

4.2 Treatment Plant Design Flow Rate

In order to design the treatment plant, a flow rate must be determined. The wastewater treatment plant is going to treat both the 4100 and 2200 Level portal drainage, therefore both flows must be considered.

The 4100 Level portal contributes 90% of the total flow. A complete year of flow records on a daily basis is available within the period from September 20, 1995 to September 20, 1996. However it is not know whether this year of data is typical or atypical. To determine this, the other 4100 Level portal flow data must be examined. The available data are readings taken on a weekly basis between 1977 and 1993.

A complete year of daily flows beginning in September does not exist for the 2200 Level portal. The reason for dividing the years in September is discussed in Section 4.2.1. The daily flow data begins on January 1st, 1996 and continues through to March 4th, 1997. Flow readings were taken on a semi-monthly basis between 1931 and 1956.

Both the 4100 and the 2200 Level portal sets of flow data were analyzed to determine average and maximum flows. The flow and precipitation data were compared and an effective catchment area was calculated. The available storage volume in the mine was estimated in order to determine the reduction in flow rate through the treatment plant offered by peak flow attenuation by storage.

4.2.1 Return Period Analysis

A return period analysis was performed to determine the average and maximum flow rates of discharge out of the 4100 and 2200 Level portals for 10, 20, 50, and 100 year events.

All available Furry Creek station precipitation data and all 2200 and 4100 Level portal outflow data were compiled to develop return period plots. A Normal distribution was used for analysis of total or average values and a Gumbel distribution was used for maximum values. Both precipitation and flow data are divided into years starting at the beginning of September and ending at the end of August. This division is preferred over a calendar year division since summer flows are actually driven by melting snow which accumulated during the late fall and winter of the previous year. Figure 4.6 shows the annual average and maximum outflow from the 4100 and 2200 Level portals plotted against return period.

Only Furry Creek gauge precipitation data were analyzed because it has the longest record and its location is nearest to the Britannia Mine catchment. The Furry Creek data can be multiplied by a factor to give estimates of Squamish or Cypress precipitation values. This was discussed in Section 4.1.1. Total annual precipitation and 24-hour maximum precipitation are plotted against return period in Figure 4.7. The values of the flows and precipitation for a number of return periods are listed in Table 4.1.

The average and maximum 2200 Level portal flows presented in Table 4.1 are relatively low when compared to recent data. The peak 2200 Level portal flow recorded in 1996 is 0.090 CMS which is greater than the 100 year return annual maximum flow. 1996 was an above average year for precipitation, however, it was only approximately a 1 in 10 wet year. During the period of record for the 2200 Level portal flows (1931 to 1956), the mine was still being developed and the flow rates were therefore changing. A closer look at the flows and precipitation reveals this in the following section.

Table 4.1. Flows and Precipitation for Various Return Periods

Return Period	Mean	10 years	20 years	50 years	100 years
Annual average 4100 flow	0.136 CMS	0.160 CMS	0.166 CMS	0.174 CMS	0.179 CMS
Annual maximum 4100 flow	0.326 CMS	0.413 CMS	0.451 CMS	0.499 CMS	0.536 CMS
Annual average 2200 flow	0.0131 CMS	0.0190 CMS	0.0207 CMS	0.0226 CMS	0.0239 CMS
Annual maximum 2200 flow	0.0273 CMS	0.0371 CMS	0.0413 CMS	0.0467 CMS	0.0508 CMS
Total annual Furry Cr. precipitation	2100 mm	2480 mm	2580 mm	2700 mm	2780 mm
Annual 24 hour maximum Furry Cr. precipitation	74 mm	97 mm	107 mm	120 mm	129 mm

4.2.2 Precipitation – Flow Relationship

In order to determine what a typical year of flows may look like, past flow records were plotted, along with precipitation records, for inspection. General trends were identified and a relationship between precipitation and flow was established in the form of an effective catchment area.

4.2.2.1 General Patterns

The inspection of flow and precipitation pattern was done by first focussing in on a short time scale during which data were collected frequently. Then a longer time scale with less frequent data was examined. And lastly, a longest time scale with very coarse data was examined. Jane Creek flow is included as a reference flow of a typical creek within the Britannia Mine catchment.

For a short period of time, precipitation and flows were recorded on an hourly basis. The period of October 24th, 1997 to November 28th, 1997 is plotted in Figure 4.8. As can be seen in the figure, Jane Creek responds very well to precipitation events. A spike in Jane Creek flow follows each precipitation event recorded at the 2200 Level station. At the end of the summer when there is no snow, Jane Creek does not dry up during periods of no precipitation. This suggests that Jane Creek is fed by groundwater flow. Catchment area of Jane Creek was determined from a topographical map to be approximately 0.50 km^2. Multiplying this value by the average annual precipitation at the Furry Creek station (1960 mm) yields a total annual precipitation volume of 0.98 x 10^6 m^3. The total annual volume from measured flows in Jane Creek was 1.79 x 10^6 m^3, a value almost twice that of the calculated precipitation volume. This discrepancy can be attributed to both a precipitation gradient between the Furry Creek precipitation gauge and the Jane Creek basin and the fact that Jane Creek is fed by groundwater flow. The groundwater flow in Jane Creek is believed to be seepage from the mine workings as it contains elevated metals concentrations (Price, Schwab, and Hutt, 1995).

The 2200 Level portal flow is not as responsive to precipitation events as Jane Creek flow. The spikes in 2200 Level portal flow do correspond to precipitation events. However, the spikes are much smoother with smaller precipitation events being attenuated and therefore not causing a rise in flow. The flow out of the 2200 Level portal appears to be routed through some form of reservoir. The mine workings and rectangular weir combine to cause this attenuation. The catchment of the 2200 Level portal drainage cannot be clearly defined on a map. The flow out of the 2200 Level portal is affected by water entering the shafts that surface in the pits at the top of the mine. Like Jane Creek, the 2200 Level portal does not dry up and is also most likely fed by groundwater. Its base flow, however, is approximately one third that of Jane Creek.

The 4100 Level portal flow shows very little response to precipitation events. Individual precipitation events combine to increase the flow much more gradually. Detention in the upper levels of the mine and behind the plug smoothes out the inflow peaks making a precipitation-flow relationship visually imperceptible. At the beginning of the October to November 1997 period, the valve on the 10 inch pipe at the plug was only half open. The flow spiked as the valve was fully open on October 10th, see Figure 4.8. The flow quickly returned to just above its previous value.

Since January 1st, 1996, flow in Jane Creek and the discharge from the 2200 Level portal have been recorded on an daily basis. The daily 4100 Level portal discharge records have been kept since September 20th, 1995. The period of September 20th, 1995 to March 3rd, 1997 is plotted in Figure 4.9. As can be seen in this figure, the relationships between precipitation and flow based on the hourly data discussed above hold for the most part, however, snowmelt and snow accumulation alters the flow response. All three flows exhibit a recession flow during the summer period (June to September), characteristic of snowmelt dominated flow with precipitation peaks appearing as short-lived spikes on the flow curve.

The response of the 4100 Level portal flow is more apparent than in Figure 4.8. High intensity and long duration precipitation events combine to cause large spikes in the flow as can be seen at the end of 1995 and 1996, as well as in May, 1996. Other high intensity precipitation events cause spikes in the flow as can be seen around January 20th, February 20th, and March 14th of 1996 and February 2nd, 1997. The large flow peak in mid June 1996 is a result of the combination of snowmelt and rainfall events. Smaller precipitation peaks alone do not cause spikes in the 4100 Level portal flow. Complicated routing and storage mechanisms along with snow accumulation are likely to be responsible for these observations.

In order to determine whether the more recent data (daily) is representative of the typical flows, the weekly flow data from 1977 to 1993 were plotted and examined. The 4100 Level concrete plug was installed in 1978 and since then the valves on the three pipes that carry the flow through the plug were regulated until February 1st, 1991 at which time all three were fully opened and remained so for the remainder of this period. For this reason, during the 1977 to 1991 period, the same precipitation events would result in differing outflows from the 4100 Level portal today than the flows recorded in that year. Nevertheless, Figure 4.10 shows the 4100 Level portal flows from 1977 to 1993 overlaid over a one year period with the average flows plotted as a darker curve. Also plotted in Figure 4.10 is the average precipitation at the Squamish A CS. The Squamish station precipitation was chosen because it was more complete than the other precipitation records available for this period (Cypress Bowl and Gambier Harbour). The 4100 outflow follows the same pattern for the entire sixteen year period. The flow peaks twice during the year, once in the fall and once in the late spring or early summer. The spring peaks are the highest as they are a combination of snowmelt and rain. The fall peaks vary from year to year as a function of temperature and precipitation. Low temperatures cause snow accumulation and therefore a lower peak flow in the fall.

In order to determine whether the trends observed in the more recent 2200 Level portal flow data (daily) are typical, the semi-monthly flow measurements taken between 1931 and 1956 were examined. As the Britannia Mine was still being developed during these and following years, the 2200 Level portal outflows may not be representative of the mine behavior today. It is still worthwhile to examine these flow records for general trends. For this period, only the Furry Creek station records were available. Similar patterns as were observed in the 4100 outflows can be seen in Figure 4.11. The peak flows occur in the late spring or early summer, during periods of low precipitation. The second annual peak, most often lower than the spring peak, occurs in the fall. A semi-monthly sampling period is too coarse because the 2200 Level portal flows change very rapidly. It is likely that peak flows are missed and the data are not representative of actual flows, average or maximum. However, no complete daily sampled year's worth of flow is available for the 2200 Level portal. The return period analysis of the 2200 Level portal flows may be an underestimate. The limited recent flow data support this hypothesis.

4.2.2.2 Effective Catchment Area

Because the route the water takes through the mine workings is unknown, it is difficult to measure the catchment area for either the 2200 or 4100 Level portal flows from a topographical map. Instead, total annual flow volumes and total annual precipitation values were compared. An effective catchment area (in square meters) was calculated by dividing the total annual outflow volume (in cubic meters) by the total annual precipitation (in meters). Figure 4.12 shows that the effective catchment area of the 4100 Level portal flow remains very much constant at approximately 2,000,000 square meters (200 ha) over the 12 year period. A similar plot was developed for the 2200 Level portal outflow and the Furry Creek station precipitation data, see Figure 4.13. The effective catchment area for the 2200 Level portal outflow appears to be high in the 1930s and then settles down to approximately 170,000 square meters (+/- 20,000 square meters) An explanation of the drop in effective catchment area may be that between 1938 and 1940, some of the 2200 Level portal outflow was intercepted by a new shaft which diverted the flow to the lower workings (McCandless, 1998).

The effective catchment areas calculated will become useful when estimating inflows into the mine and for flow modeling. Both of these analyses will be presented in following sections.

4.2.3 Mine Volume and Storage

Storage is an important factor in determining the treatment plant size. Storage allows peak flows to be attenuated thereby reducing the flow through the plant. Storage would also allow the plant to shut down for maintenance or in case of emergency without having to spill untreated water (Simons, 1998). The mine workings may possibly serve the purpose of a storage reservoir. Water can be allowed to build up behind the 4100 Level plug up to the 3250 Level, 260 meters above. The volume between these two level is estimated by various methods. Direct measurement of the volume is not possible.

4.2.3.1 Volume Based on Drawings

The storage volume of the Britannia Mine between the 4100 Level and the 3250 Level is estimated at 200,000 cubic meters. This value was calculated by measuring the length of tunnels and shafts and multiplying it by a cross-sectional area of 10.5 square meters (the area of the 4100 tunnel at the plug). Plan views were not available for four small levels which appeared on the cross-sectional view of the mine and were therefore not taken into account. Also, any stopes in the mine where ore was removed were not accounted for. This additional volume may be offset by any material that may have slumped in from higher levels. The value of 200,000 cubic meters is believed to be a lower bound for the available storage volume.

Based on experience with mines of Britannia's type, Brennan Lang of Ground Control Consulting Engineers believes that the shafts and tunnels would only account for 15% of the total volume, the stopes accounting for the remainder (Simons, 1998). This would suggest that approximately 1.3 million cubic meters of storage are available.

4.2.3.2 Volume Based on Pressure Records

To obtain an upper bound for the mine volume, the pressure records were examined. During the six years that pressure was recorded, the pressure rose once to 305 psi in July 1982. This value corresponds to a height of 215 meters above the 4100 Level.

Then the pressure steadily declined to a value of 12 psi (8.5 meters above the 4100 Level). During this period, 1.42 million cubic meters of water flowed out of the 4100 Level portal. This peak pressure event occurred in mid-July during snowmelt and therefore no snow accumulation was occurring. Any precipitation that occurred during this period would enter the mine workings almost immediately. Multiplying the precipitation that occurred during the drawdown by the effective catchment area for the 4100 Level portal flow (200 ha) results in 0.49 million cubic meters of water entering the mine workings. This value takes into account the groundwater component of flow. This inflow volume value does not take into account snowmelt and is therefore a lower bound for inflow. The difference between the outflow and inflow volumes (930,000 cubic meters) is therefore an estimate of the storage volume available between the 4070 Level (8.5 meters above the 4100 Level) and 3400 Level (215 meters above the 4100 Level). This volume accounts for 206.5 of the 260 vertical meters of height available for storage. Assuming a linear height versus storage relationship, the 930,000 cubic meters of storage calculated accounts for approximately 80% (100% $\times$ 206.5 m $\div$ 260 m) of the entire volume between the 4100 and 3250 Levels. This suggests that an estimate for the entire volume is 1.16 million cubic meters. In reality, the storage volume may not be directly proportional to elevation. It appears that the ore body around the No. 2 shaft contributes increasingly larger volumes with increasing elevation, see Figure 1.3. If this is the case, the 930,000 cubic meters calculated may account for less than 80% of the total volume and therefore, the total volume estimate would be greater than 1.16 million cubic meters . In any case, the estimate is consistent with Brennan Lang's estimate of 1.3 million cubic meters.

The two bounds for volume are 0.20 and 1.3 million cubic meters. The range of possible volume values is great and the bounds must be refined if possible. To refine the upper bound, a better estimate of inflows needs to be calculated. To do this, snowmelt is taken into account.

There are five years of pressure record for which precipitation and temperature was also recorded. The peak recorded pressure event (305 psi), a second peak of 280 psi, and three lower peaks are available for analysis. The highest of the three lower peaks is 130 psi. All peaks occurred in either June or July when snow was melting. Precipitation and outflow volumes were calculated from September of the previous year up to the start of the pressure peak. The precipitation volume was calculated using the effective catchment area method. The difference in precipitation and outflow volumes gave the volume of water stored as snowpack. Snowmelt was simulated by a simple model relating melt to temperature.

$$\text{Melt} = \text{constant} \times \text{Temperature} \tag{4.3}$$

The constant was varied from year to year in order to achieve complete melt of the snowpack volume by the end of the melting period. During the melting period, a tally of melt volume, precipitation volume and outflow volume was kept. The difference between inflows (snowmelt and precipitation) and outflow was recorded as the storage. Cumulative storage values were recorded and compared to the pressure rise, peak, and fall. The melting period was adjusted so that the cumulative storage curve followed the pressure curve. Figure 4.14 shows the three highest pressure peaks and the best fit storage values. The pressure and storage peaks lined up very well in the first year and fairly well in the second year. The third year pressure and storage peaks did not coincide as well. The best fit that could be achieved is that shown in Figure 4.14. In these three years during which the pressure rose to 305 psi, the storage reached 790,000 cubic meters. Figure 4.15 shows the storage versus pressure plot for these three pressure peaks. Plotted on the figure is the estimated shaft and tunnel volume curve which should be the lower bound for storage and therefore all the storage data resulting from the pressure record analysis should plot higher. In fact, a majority of the storage data does exceed this lower bound, see Figure 4.15. A linear fit was applied to the pressure data that exceeded 150 psi. Extrapolating this line up to the 3250 Level (384 psi) gave an estimate of the total storage of 1.03 million cubic meters. Once again referring to Figure 1.3, it appears that the ore body around the No. 2 shaft starts contributing to the volume at approximately the 3800 Level (130 psi). It contributes increasingly larger volumes with increasing elevation, therefore a linear extrapolation may be a lower estimate for the storage using this analysis. It may be possible that 1.3 million cubic meters of storage is available in the mine, see Figure 4.15. The estimate is consistent with the previous estimates (1.16 and 1.3 million cubic meters).

It is difficult to make any further refinements on the mine volume without additional data. In order to obtain a better estimate of the mine volume, inflows into the mine need to be determined with greater certainty. For now, the limits of 200,000 and 1,300,000 cubic meters suffice, but before a treatment plant is built, further testing and data acquisition are necessary if the treatment plant flow is to be minimized.

4.2.4 Design Flow

To determine a design flow for the treatment plant, the following need to be determined:

- Which drainage is going to be treated
- What return period is going to be used
- What is a typical year of flows for the drainage
- How much storage is available

These issues have been addressed in the preceding sections. To summarize, only the 2200 and 4100 Level portal drainage will be treated; a 10 year return period is going to be used for design; a typical year will be selected based on annual average and maximum flows for the period of record; and the storage will be left as a variable with 1.3 million cubic meters as a maximum.

The 1995-96 year for which daily 4100 Level portal flow data exist is not a good candidate for a design year's worth of flows. The flow peak in the fall is unusually high. It is nearly twice as high as the spring peak. The annual maximum flow rate to annual average flow rate ratio is high (3.33) compared to the average ratio of all 17 years of record (2.39). For these reasons, the 1995-96 year is unsuitable for use as a typical year for treatment plant design. Instead, the September 1984 to August 1985 year's worth of 4100 Level portal outflow data was used in developing the flow design year. This year's worth of flows had the same annual maximum flow to annual average flow ratio as the entire 17 years of record that the return periods are based on. Since the response of the 4100 Level portal flows to precipitation is dampened and the flow rate changes gradually, weekly readings are not likely to result in missed peaks. Therefore the frequency of the record should not disqualify it from use in this analysis. The 1984-85 4100 Level portal outflows were scaled up so that the annual average flow matched the calculated 10 year value of 0.160 cubic meters per second. Scaling the annual average up resulted in an annual maximum flow of 0.410 CMS which is only slightly lower than the 10 year annual maximum flow (0.413 CMS). Figure 4.16 shows the 4100 Level portal contribution to design flow.

No complete year of daily data exist for the 2200 Level portal flow. The 1953-54 year was selected because both scaling factors, to bring the annual maximum and average flow up to the 10 year return values, were the same for that year. The result was a 10 year average flow of 0.019 CMS and a 10 year maximum flow of 0.037 CMS. The 2200 Level portal contribution to design flow is plotted in Figure 4.16. Figure 4.16 also shows the combined flow for a 10 year return period design year. The 10 year return average combined flow is 0.179 CMS and the 10 year return maximum combined flow is 0.447 CMS.

The maximum required storage, using the 10 year return flow design year and a treatment plant flow of 0.179 CMS (the annual average flow rate), will be 1.02 million cubic meters. This value matches the best estimate of storage volume (1.03 million cubic meters). The required storage for a particular treatment plant flow was calculated based on the 10 year return design year shown in Figure 4.16. Figure 4.17 shows the required storage versus treatment plant flow curve. The required storage for various flow rates was calculated by integrating over time the difference between the 10 year return flow (as shown in Figure 4.16 - combined flow) and the proposed constant flow through the treatment plant. The highest storage reached is the required storage for that particular treatment plant flow rate. If the available volume was only 200,000 cubic meters (the lower bound for mine volume), the treatment plant flow would have to be approximately 0.36 CMS. The best estimate of storage volume (1.03 million cubic meters) yields a treatment plant flow of 0.18 CMS.

The error associated with flow measurement will affect the design flow. The difference between the measured 4100 Level portal flow and the flow given by Equation 3.3 is as much as 12%. An error of this magnitude in the 10 year return average flow (0.160 CMS) would either increase the flow to a 100 year return (0.179 CMS) and decrease it to a 2.5 year return (0.141 CMS). The flow through the Parshall flumes should be determined to a greater accuracy before the treatment plant is sized. Because of the smaller contribution to total plant flow, the need to refine the 2200 Level portal flow measurement accuracy is a lower priority.

4.2.5 Summary

The physical treatment plant size depends on several factors. The two that are most uncertain are the design flow year and the available storage. The design flow year may be one that requires less storage as the flow peaks may be of shorter duration. It is difficult to predict what the 10 year return year of flows will be like. To deal with this uncertainty, a higher return period could be selected. However, the 10 year return was selected with this in mind. The plant may be operated above capacity during higher flows with a possible decrease in performance (Simons, 1998).

Given a design flow year, the available storage will significantly affect the flow rate through the treatment plant and therefore its size. From the analysis in the preceding sections, the flow rate may need to be as high as 0.36 CMS, a value twice that of the average flow rate. Or the flow rate may be 0.179 CMS (the 10 year annual average flow) or lower if more storage is available. The best estimate for storage volume is 1.03 million cubic meters. With this available storage, the treatment plant design flow is 0.18 CMS. It is clear that storage will affect the capital cost of the wastewater treatment plant and therefore needs to be estimated with greater certainty.

4.3 Flow Modeling

An attempt to model the outflow out of the 4100 Level portal was made to determine the possibility of modeling the Britannia Mine outflows. If successful, the model would allow forecasting of flows given meteorological data and storage reservoir management. Two models were used with limited success.

Attempts using simple snow budget and linear reservoir models failed to accurately describe the 4100 and 2200 Level outflows. One such attempt uses Jane Creek flows as being representative of the inflows entering the mine with the effects of snow accumulation, snowmelt, and groundwater flow already incorporated. This flow was routed through various combinations of channels and reservoirs with little success. Figure 4.18 shows on attempt involving modeling the mine as twenty reservoirs in series. Using one reservoir did not sufficiently change the shape of the inflow curve so additional reservoirs were added. The mine workings generate a very complex routing mechanism that could not be reproduced using channel and reservoir routing procedures.

The UBC Watershed model was applied with some success. Figure 4.19 shows an output of the model comparing the observed and calculated flow from the 4100 Level portal. Figure 4.19 also shows the estimated groundwater flow component. The groundwater component of the 4100 Level portal outflow accounts for more than 50% of the annual total flow volume. The model offers optimization for precipitation distribution variables, water budget allocation variables, and routing constants. After optimization of all the variables, the UBC Watershed model was unable to model the mine outflow with much accuracy. The model calculates a modeling efficiency value (based on standard deviation). The best efficiency value was 0.66, 1.0 being perfect agreement between modeled and actual flow. A value of 0.8 suggests good agreement between with the actual and modeled flow (Quick, 1995).

Neither model is sufficient for use in forecasting. Knowing what the inflows into the mine are with more certainty as well as having an accurate storage versus elevation relationship would allow for better mine outflow modeling.

5. CONCLUSIONS and RECOMMENDATIONS

Monitoring of flows at two major outflow points of the mine and two affected creeks has been carried out on a regular basis since 1995. Meteorological data has been collected at six precipitation gauges nearest the Britannia Mine from as early as 1932. The analysis of the data revealed the following. The mine acts to attenuate the outflows from the 2200 and 4100 Level portals. Inflows due to snowmelt and precipitation enter the mine at various rates: as fast speed runoff into shafts, as medium speed fracture flow, and as slow speed infiltration. Regional groundwater table elevations also contribute to both inflow (during high groundwater table periods) and outflow (during low groundwater table periods). The flow that enters the mine workings undergoes a complex form of routing as a result of the network of shafts and tunnels, small dams, a concrete plug, and valves. A more complex model is needed to describe the routing characteristics of the mine workings.

Despite the precipitation record from the 2200 Level station, the stations in the region of Britannia Beach recorded similar weather patterns. Using precipitation records from near-by stations for analysis is justified. It is recommended that the next 2200 Level station check include another set of precipitation gauge calibrations. The tests should be conducted in a way which will determine the effect of rainfall intensity. This can be done by pouring a constant volume of water into the precipitation gauge at various rates. The data recorded by the datalogger should be downloaded immediately following the calibration for analysis.

The possibility of storing water inside the mine and of attenuating the peak flows in order to decrease the treatment plant design flow rate was examined. The maximum required storage, using the 10 year return flow design year and a treatment plant flow of 0.179 CMS (the average flow rate), will be 1.02 million cubic meters. This value is approximately equal to the best estimate of storage volume (1.03 million cubic meters). Given that approximately one million cubic meters of storage are available in the mine, the treatment plant design flow rate would be 0.18 CMS. In order to determine accurate mine storage characteristics for a more cost-effective treatment plant design, a better estimate of volume needs to be made. In order to do this, the inflows into the mine need to be determined. The groundwater table fluctuations need to be recorded. Snowmelt has to be calculated by performing surveys of snow depth. Precipitation needs to be measured near the top of the mine at the pits. Infiltration in non-pit areas needs to be quantified and travel time through the mine workings has to be determined. Once inflow can be calculated with certainty, the storage may be calculated simply by allowing the mine to fill up to the 3250 Level and subtracting total outflow from total inflow.

Before the inflows are determined by collecting the necessary data, an acceptable estimate of volume may be made by allowing the mine to fill rapidly. The test should be performed during a high but relatively steady inflow period such as that during the snowmelt recession. The valves should be adjusted so that the pressure is not rising or falling and therefore inflow is equal to outflow. Then the valves are shut, and the pressure rise is recorded over time. Once the mine fills up to the 3250 Level, the valves can be opened to drain the mine. This test may take several days depending on the inflow rate. The pressure is once again equalized to obtain another inflow value which may be lower than the inflow at the beginning of the test due to the flow recession. The inflow rate can be interpolated from these two values. Inflow integrated over time will yield the storage of the mine. This test would also confirm the mine's ability to hold such a volume of water.

To reduce the error associated with flow measurement, especially that of the 4100 Level portal flow, the stage - discharge relationship must be refined. To achieve this, more flow measurements at various flow rates must be made. With additional stage - flow data, the portion of the total error that can be attributed to flow measurement can be determined and a more precise estimate of flow rate can be made from stage values.

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Figures

Figure 1.1. Location Map of the Britannia Mine

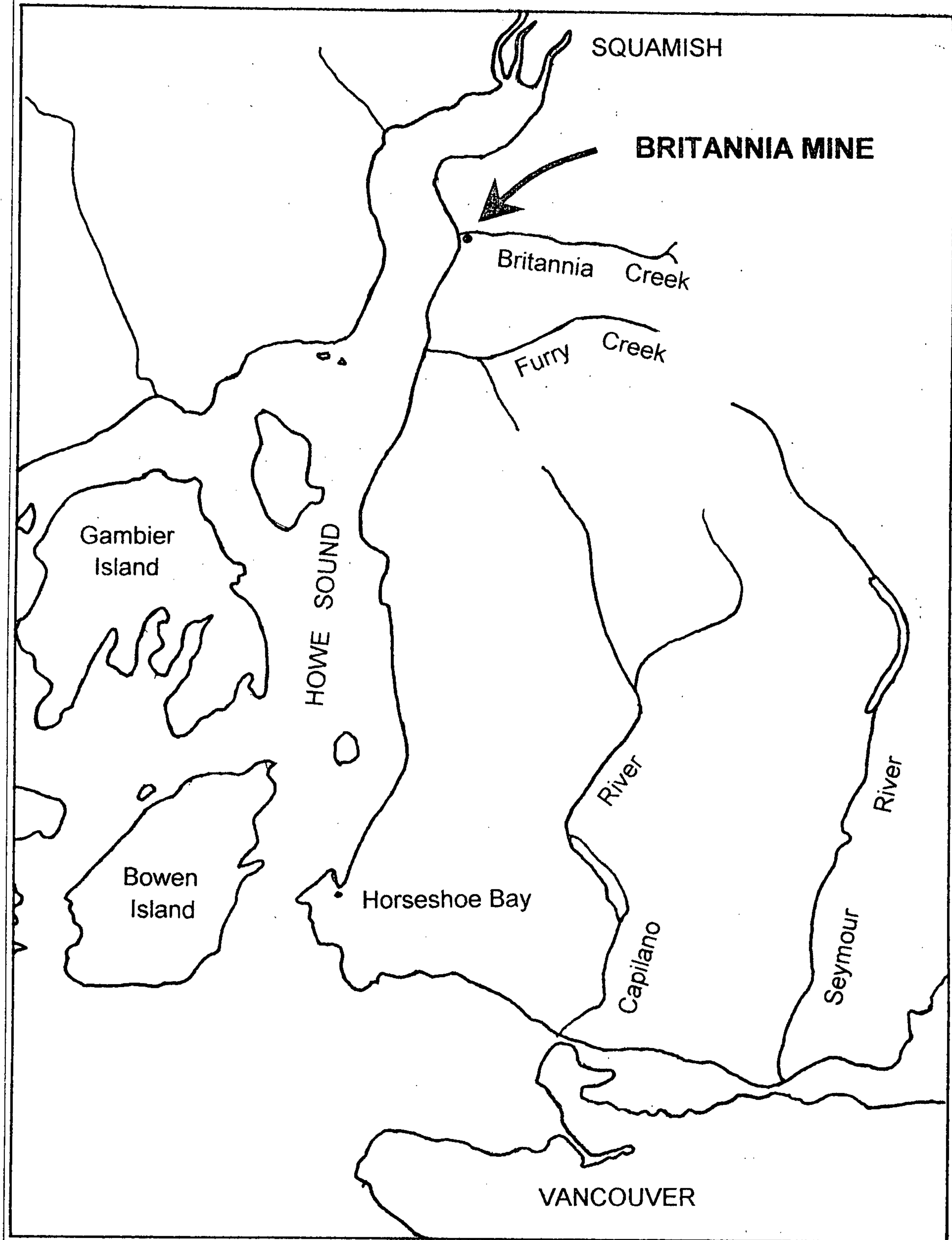


Figure 1.2. Mine Site Schematic

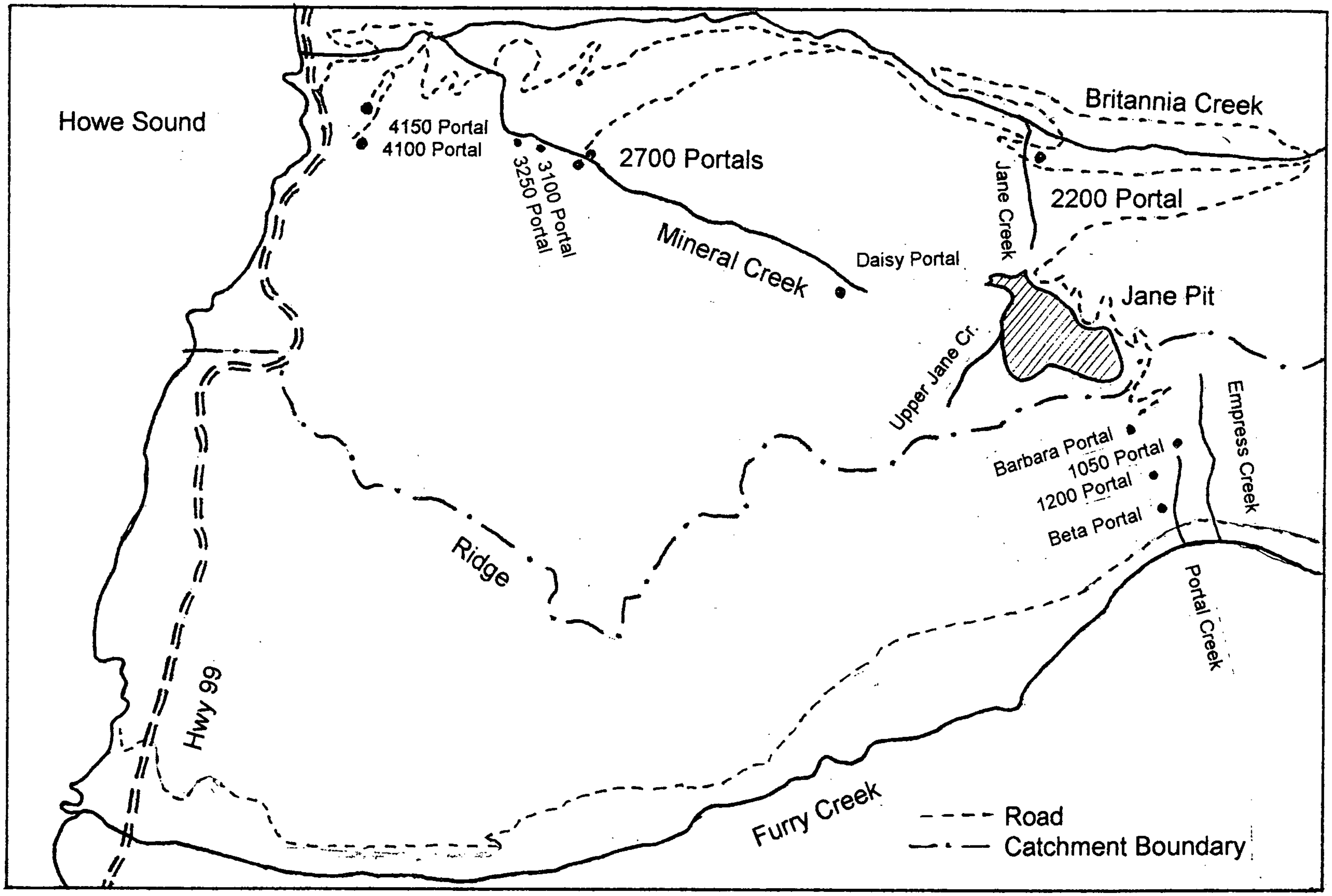


Figure 1.3. East-West Cross-section of the Britannia Mine

(Price, Schwab, and Hutt, 1995)

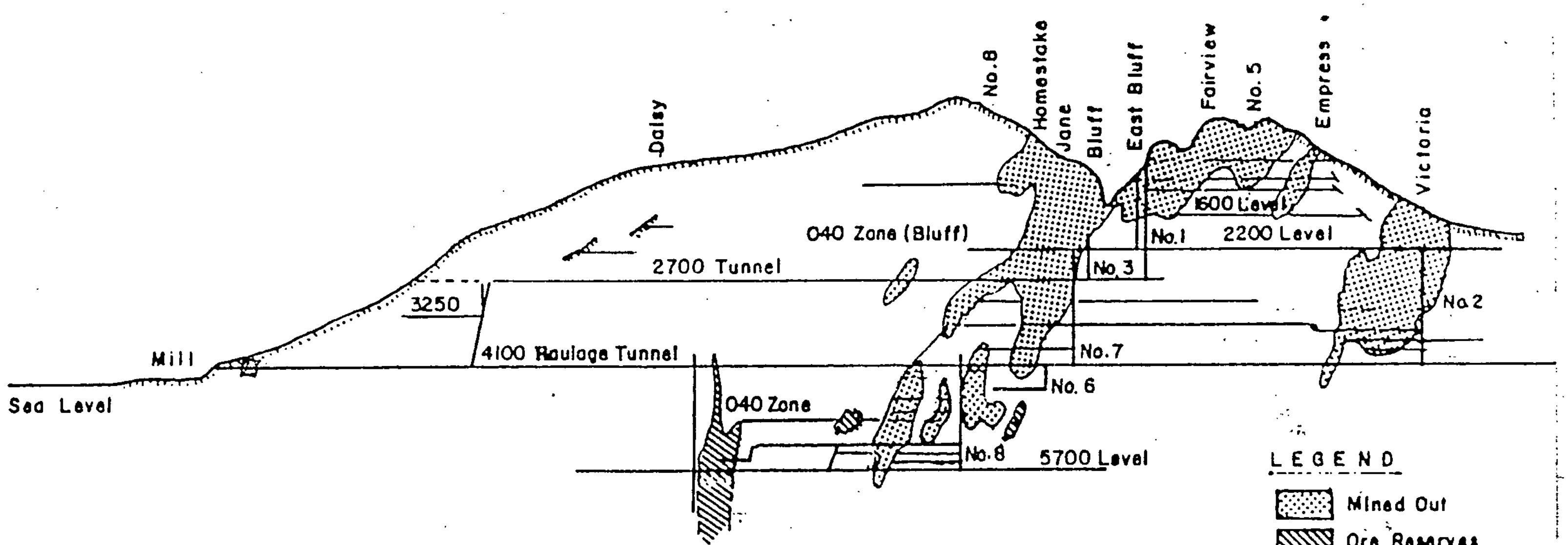


Figure 2.1. 4100 Level Concrete Plug Schematic Scale: 1: 20

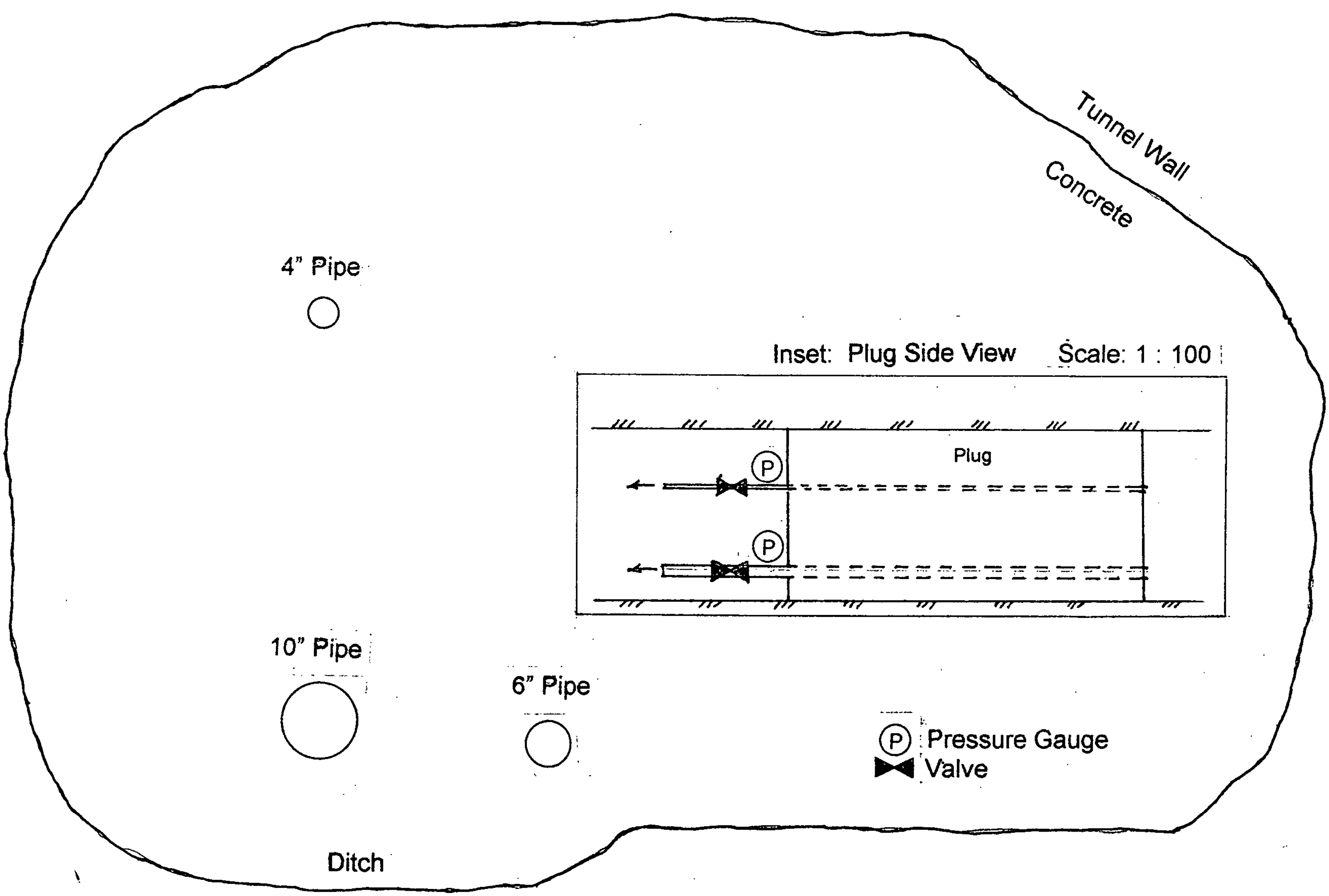


Figure 2.2. 4100 Level Portal ARD Flow Path to Howe Sound

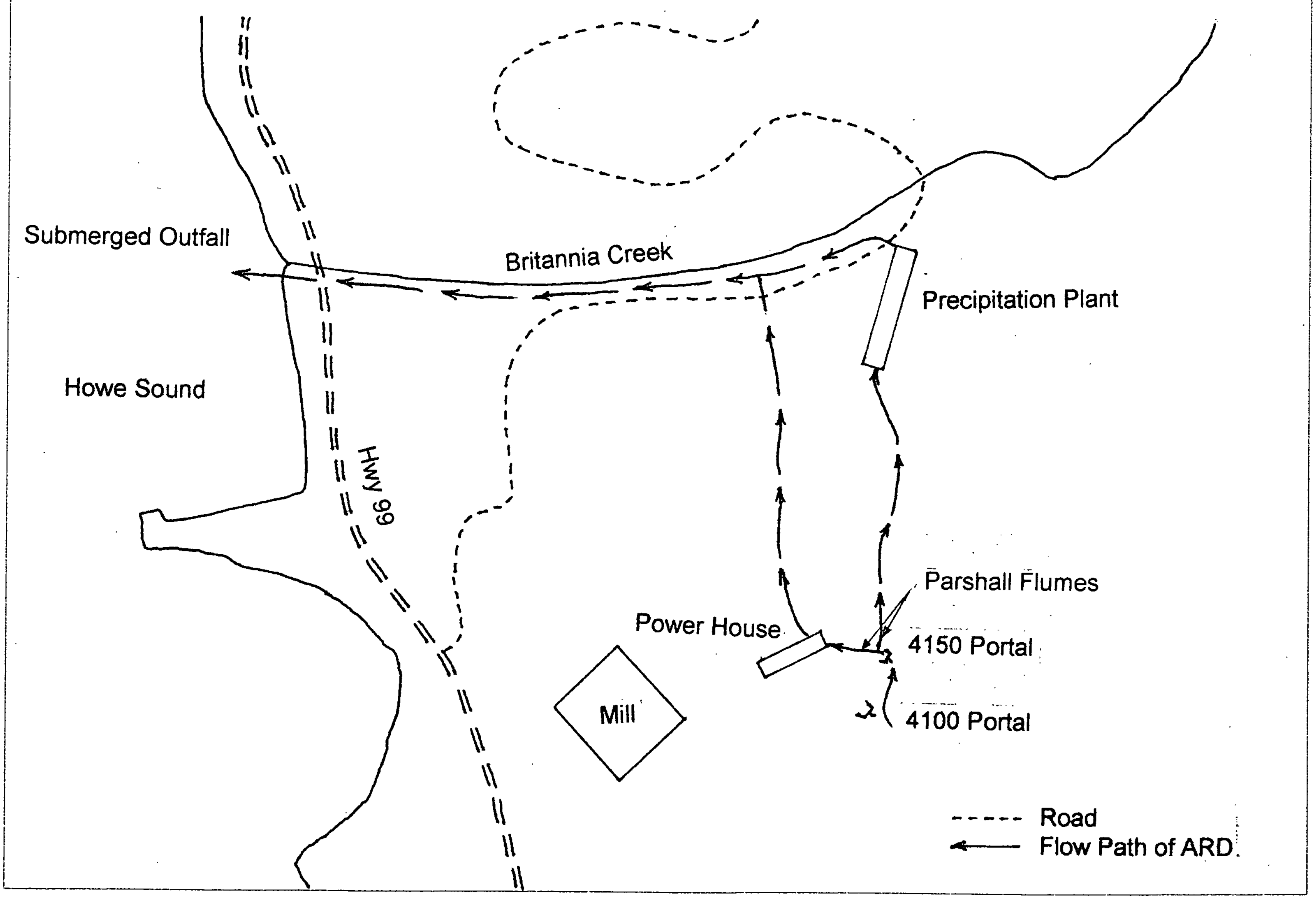
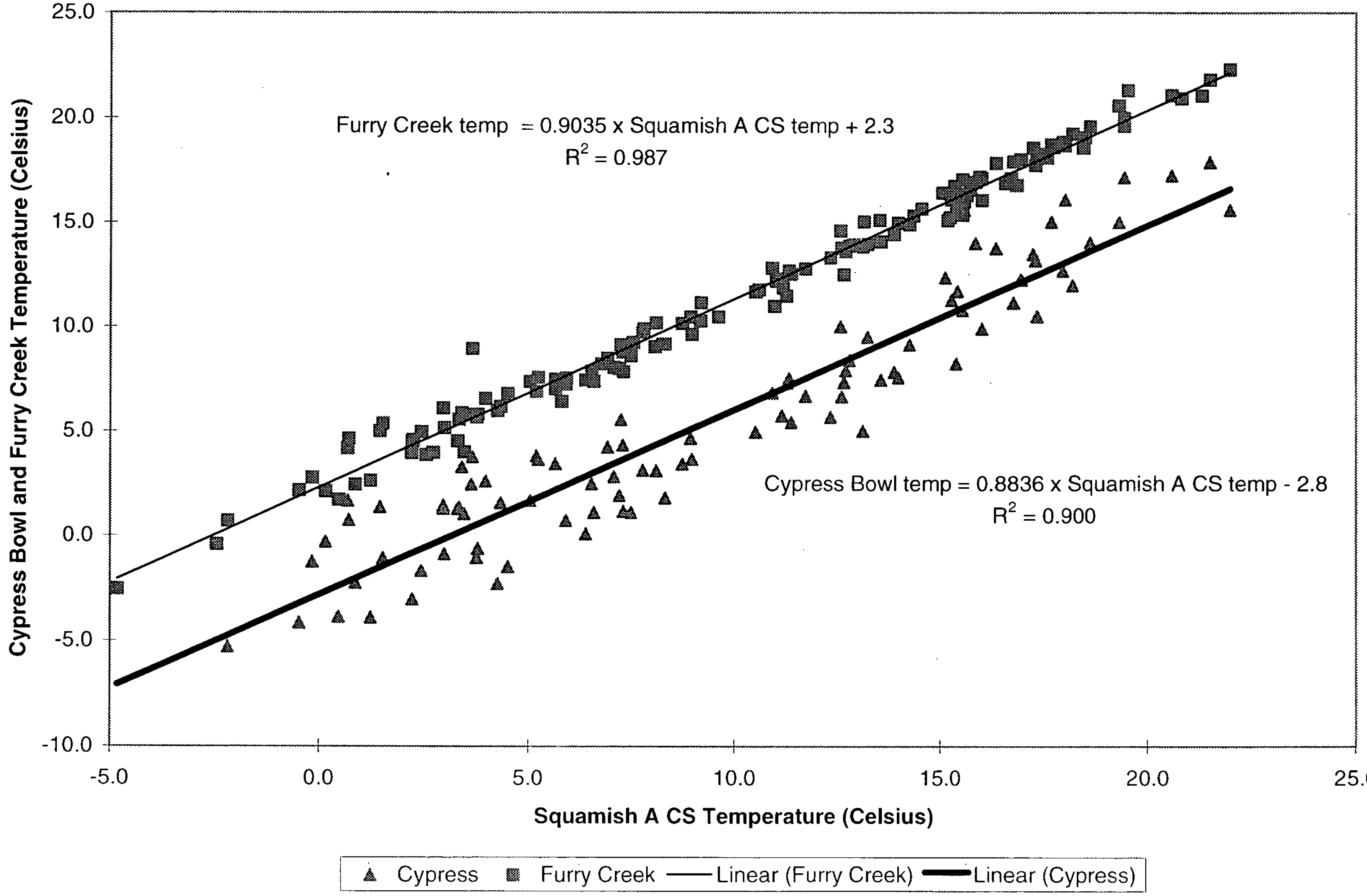


Figure 4.1. Regional Temperature Relationships



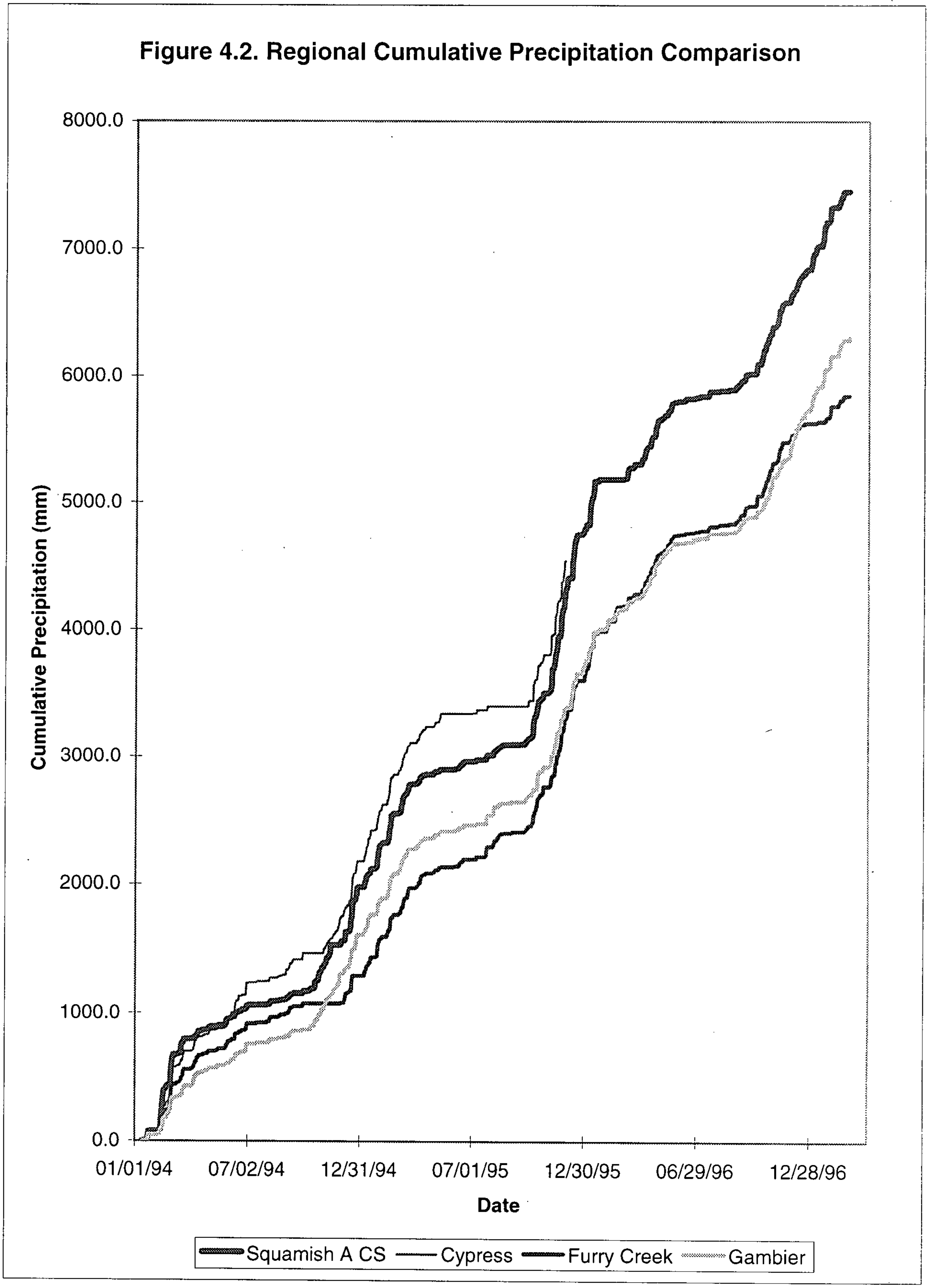


Figure 4.2. Regional Cumulative Precipitation Comparison
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
Cumulative Precipitation (mm)
01/01/94
07/02/94
12/31/94
07/01/95
12/30/95
06/29/96
12/28/96
Date
Squamish A CS
Cypress
Furry Creek
Gambier

Figure 4.3. Regional Precipitation Relationships

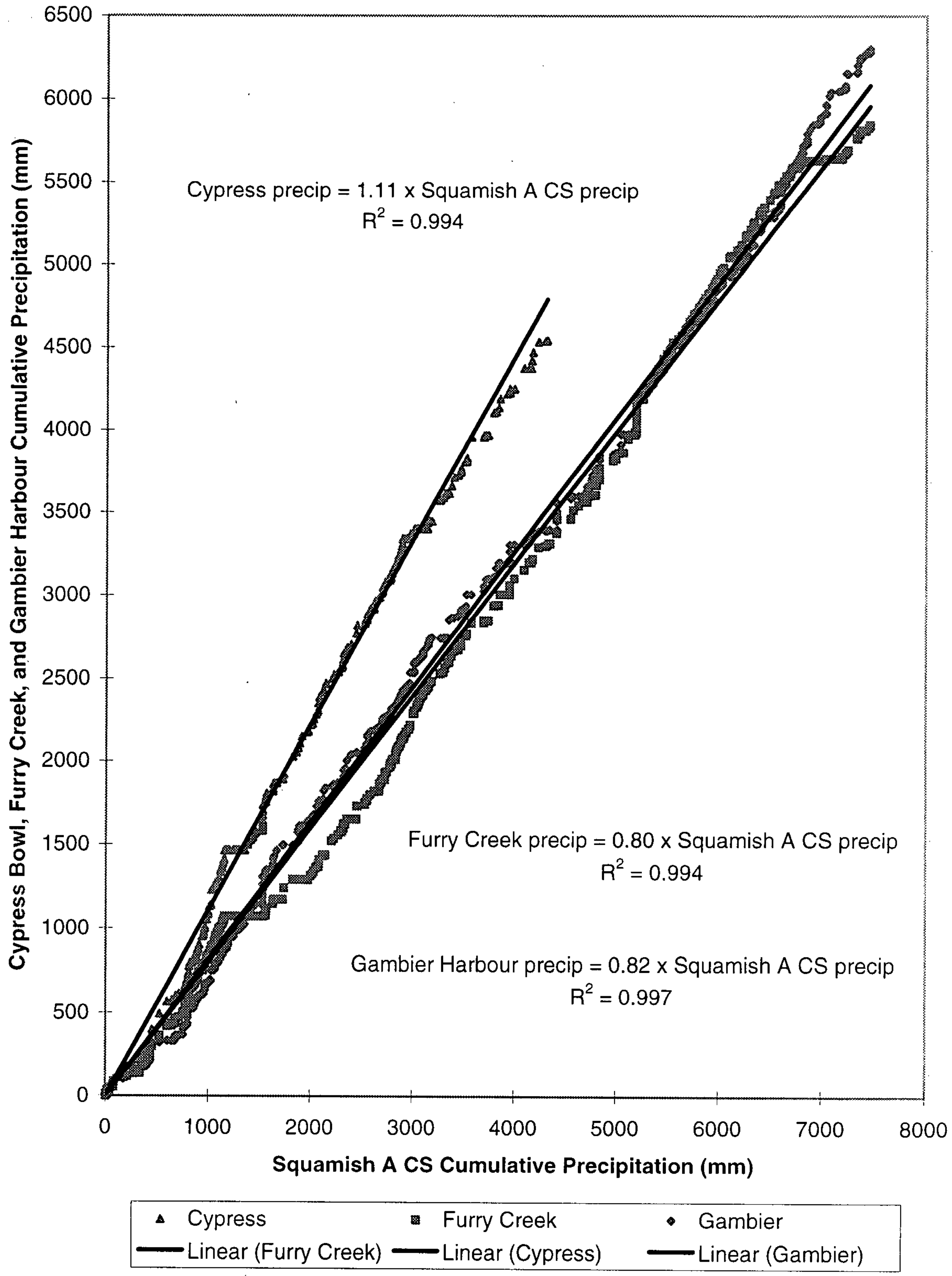


Figure 4.4. Local vs. Regional Temperature Comparison

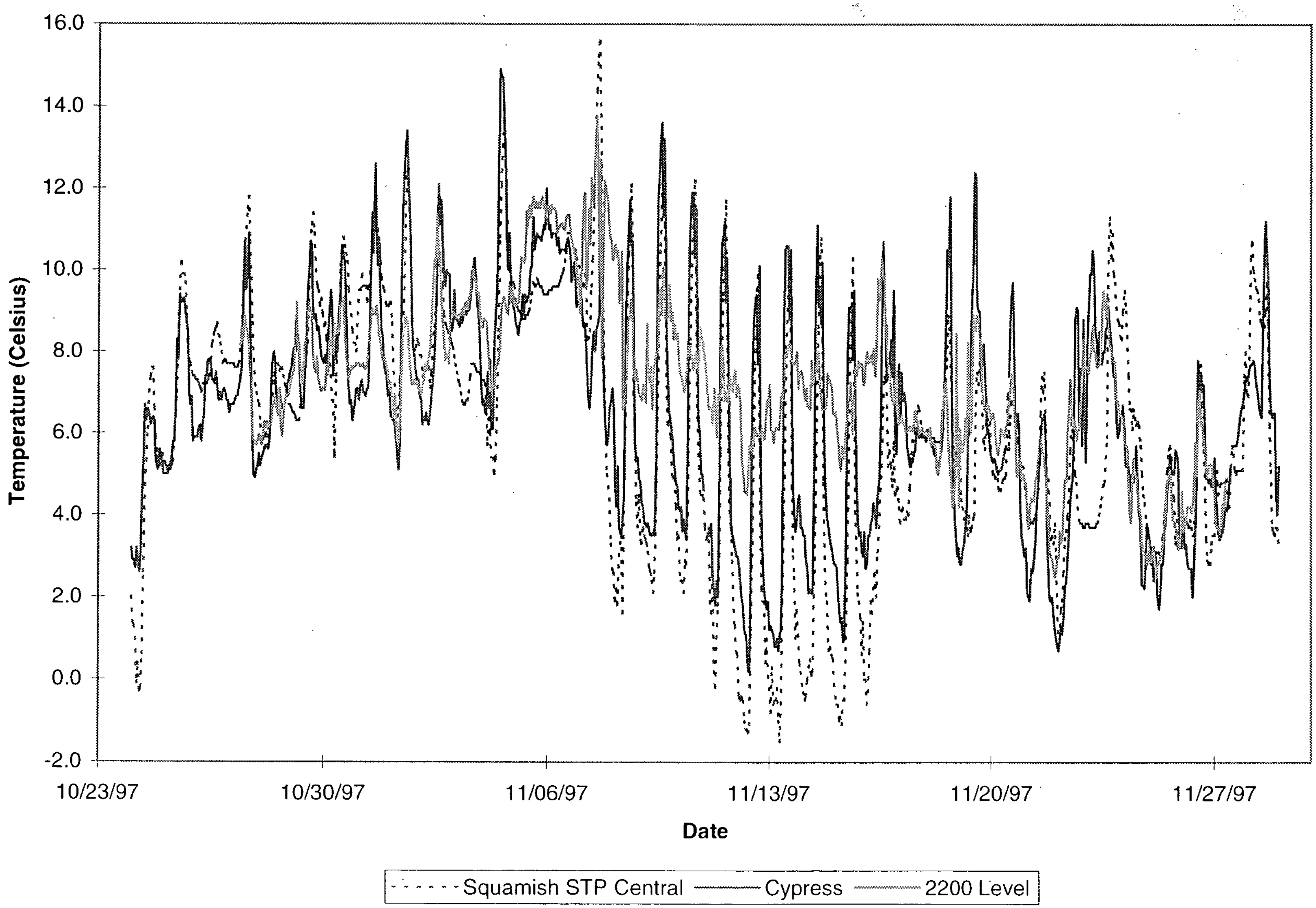


Figure 4.5. Local vs. Regional Cumulative Precipitation Comparison

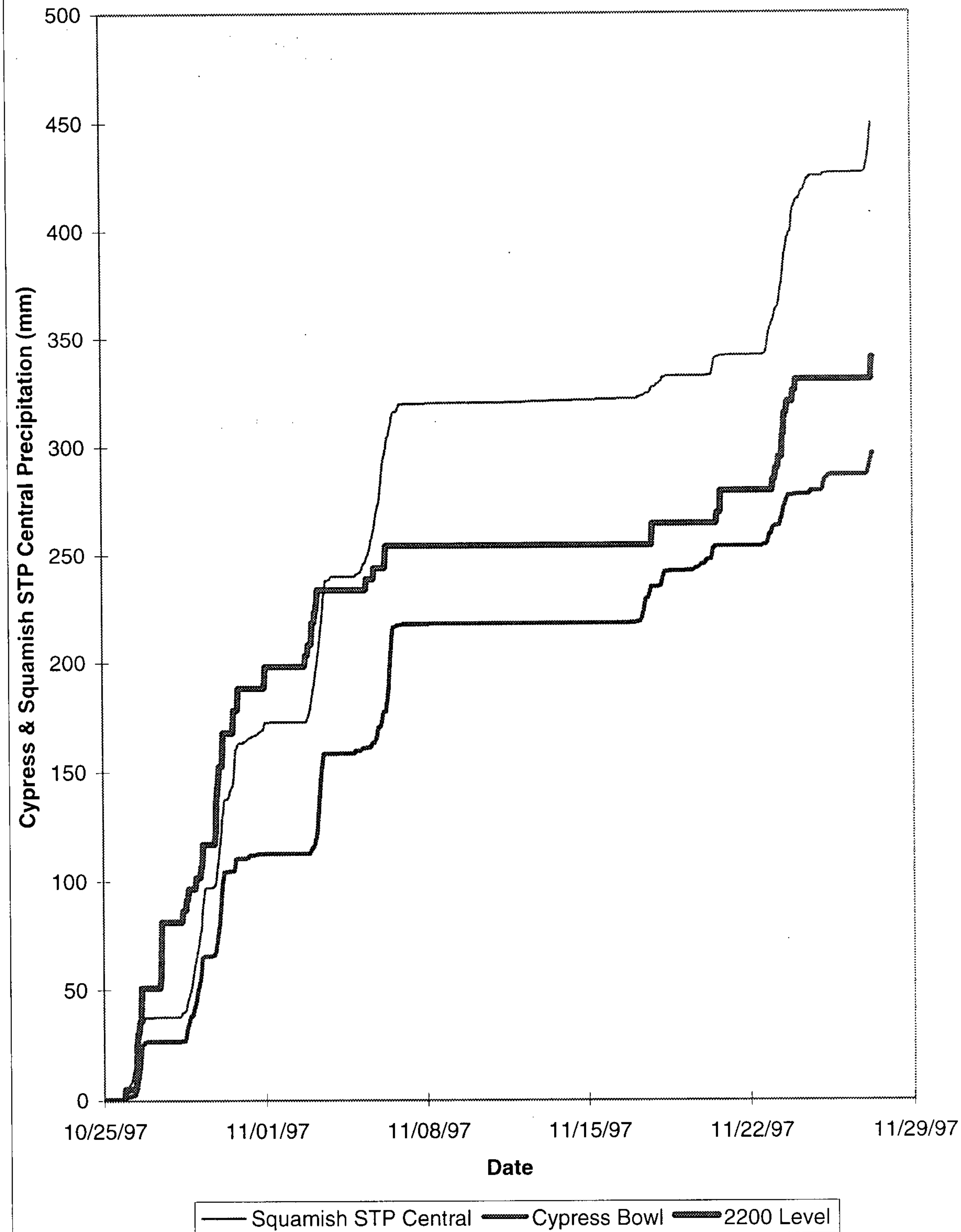


Figure 4.6. Annual Average and Maximum 2200 & 4100 Level Portal Flows vs. Return Period

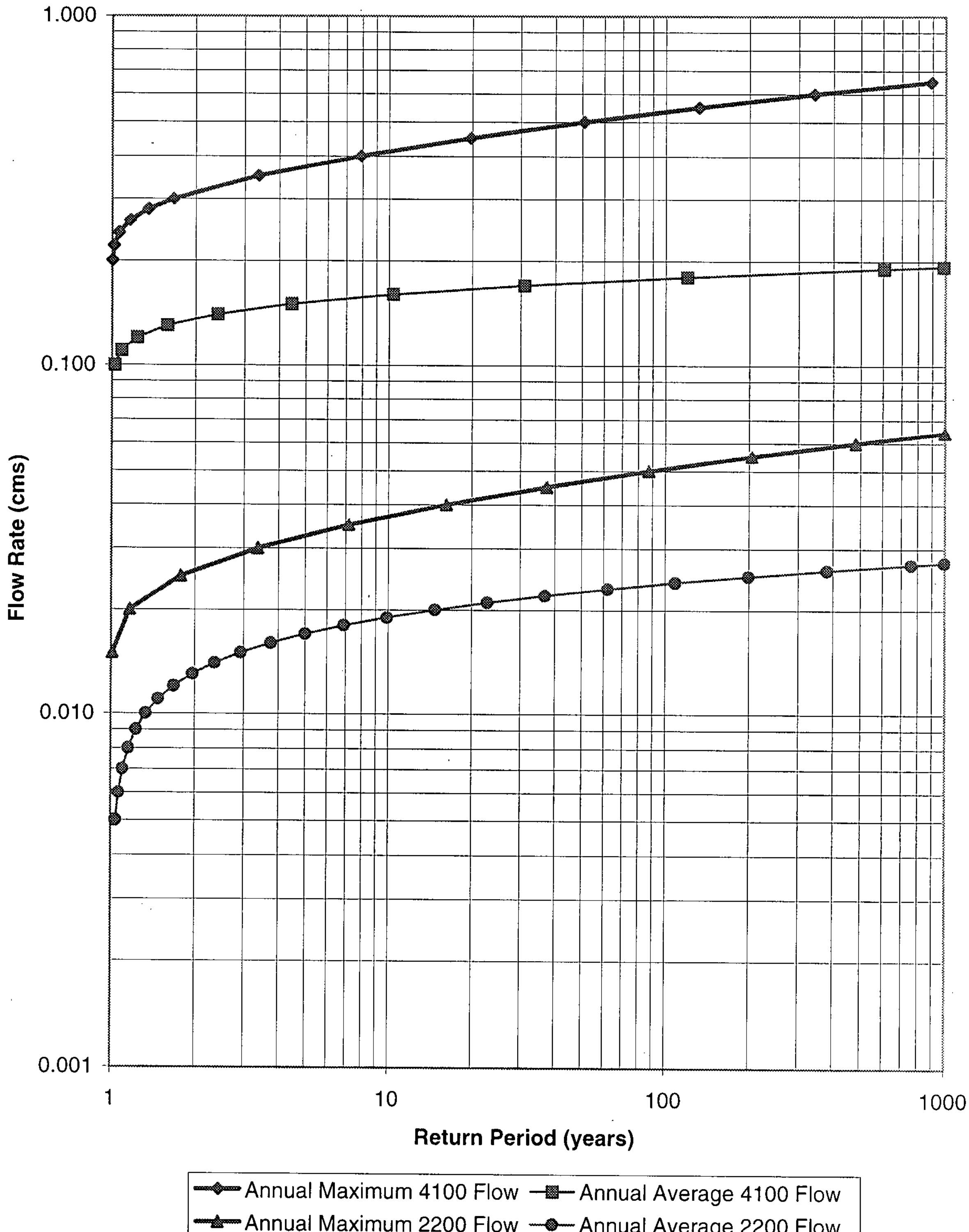


Figure 4.7. Total Annual Precipitation and 24hr Maximum Precipitation at the Furry Creek Station vs. Return Period

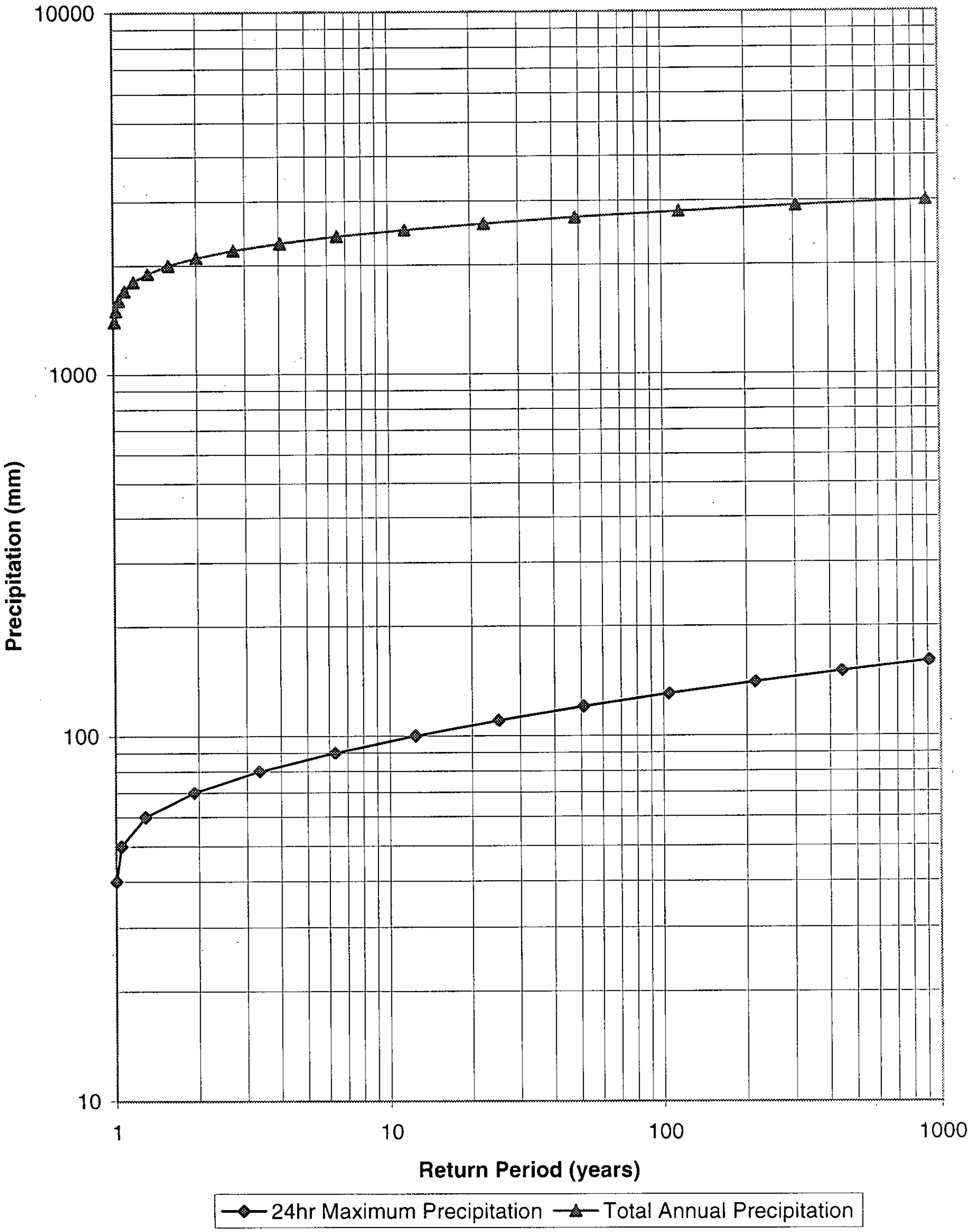


Figure 4.8. Flows & Precipitation vs. Time (November, 1997)

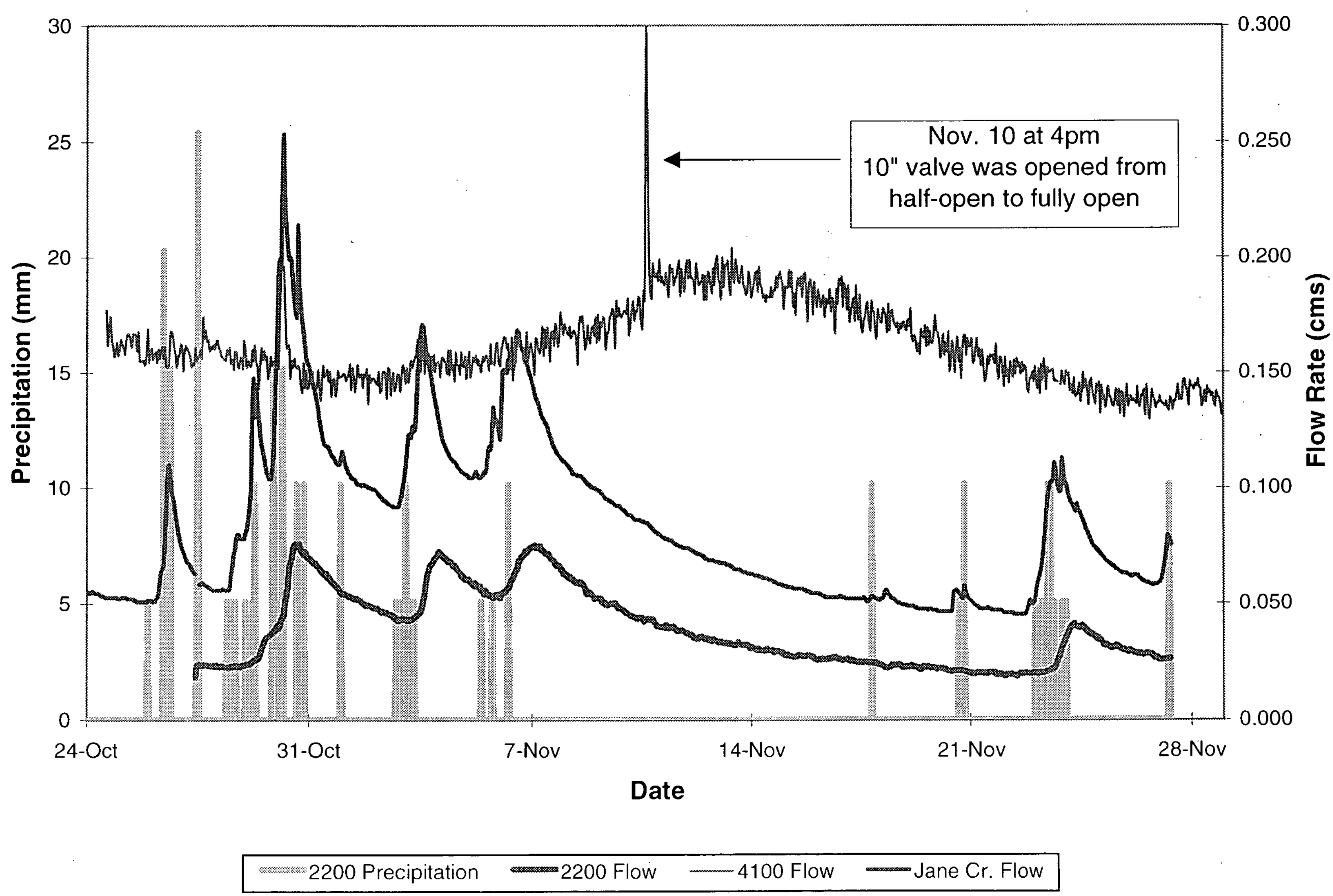


Figure 4.9. Flows and Precipitation vs. Time (1995 to 1997)

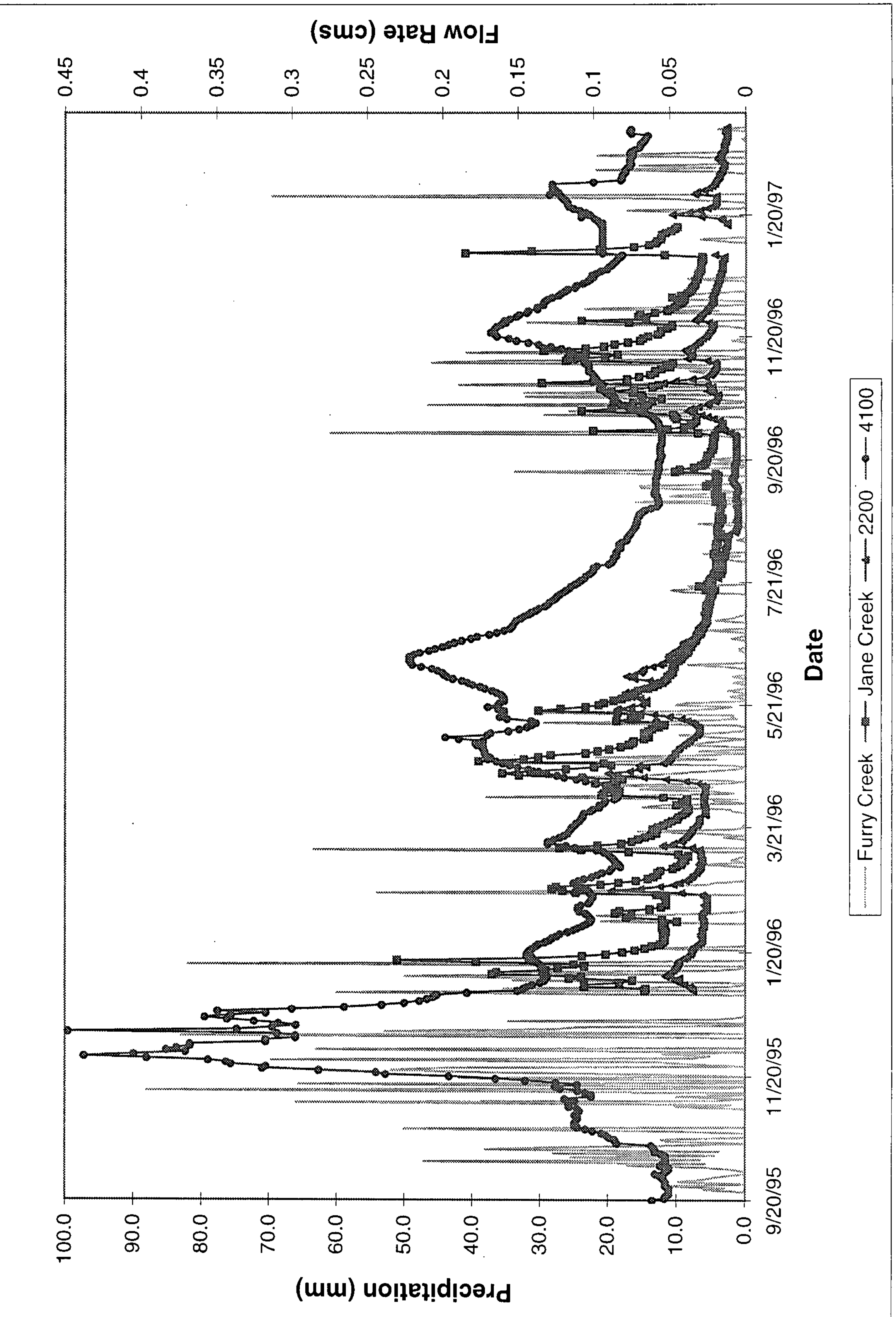


Figure 4.10. 4100 Level Portal Flow and Average Squamish A CS Precipitation vs. Time (1977 to 1993)

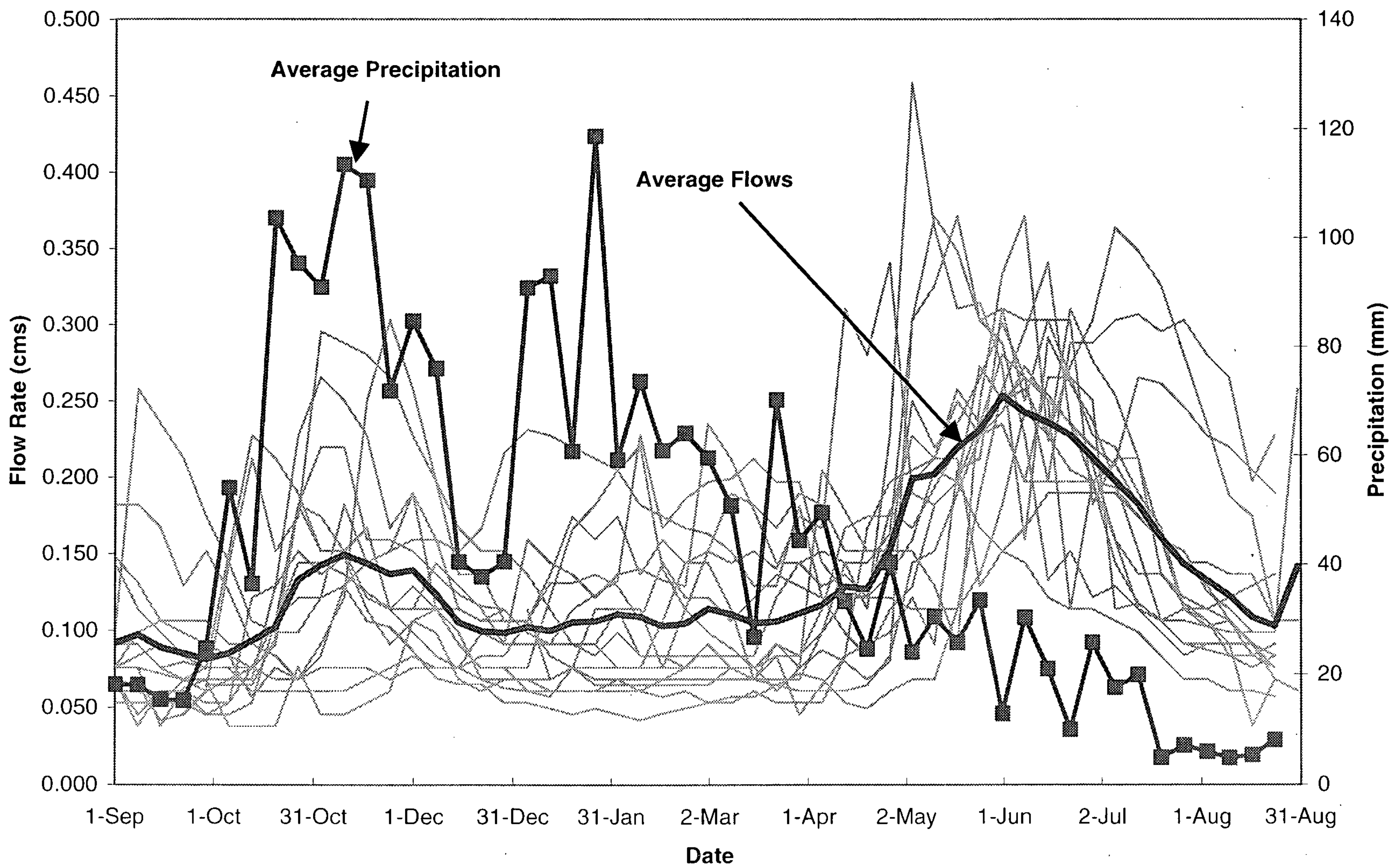


Figure 4.11. 2200 Level Portal Flow and Average Furry Creek Station Precipitation vs. Time (1931 to 1956)

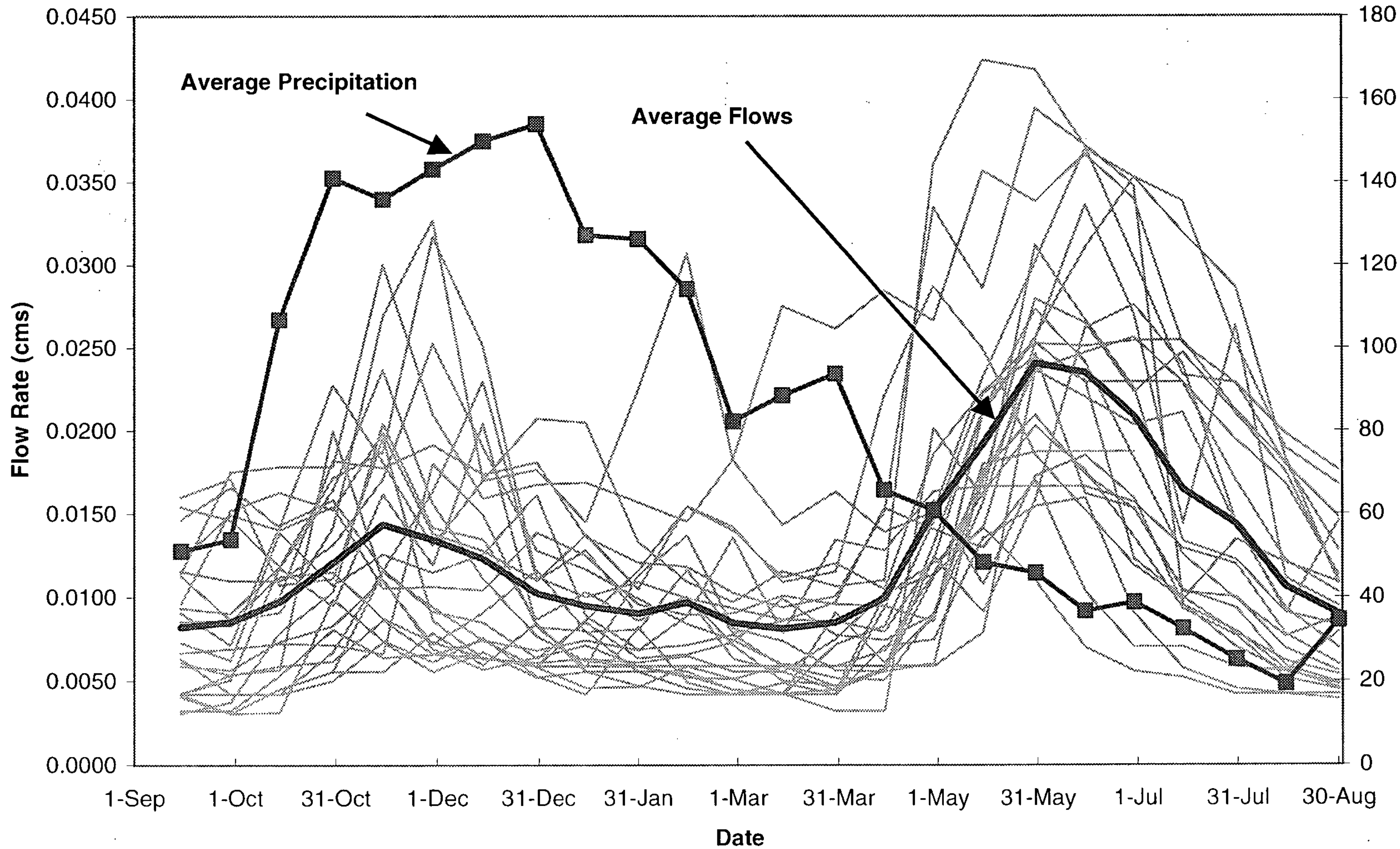


Figure 4.12. Annual Total Squamish A CS Precipitation, Annual Total 4100 Level Portal Flow Volume, and Effective Catchment Area vs. Time

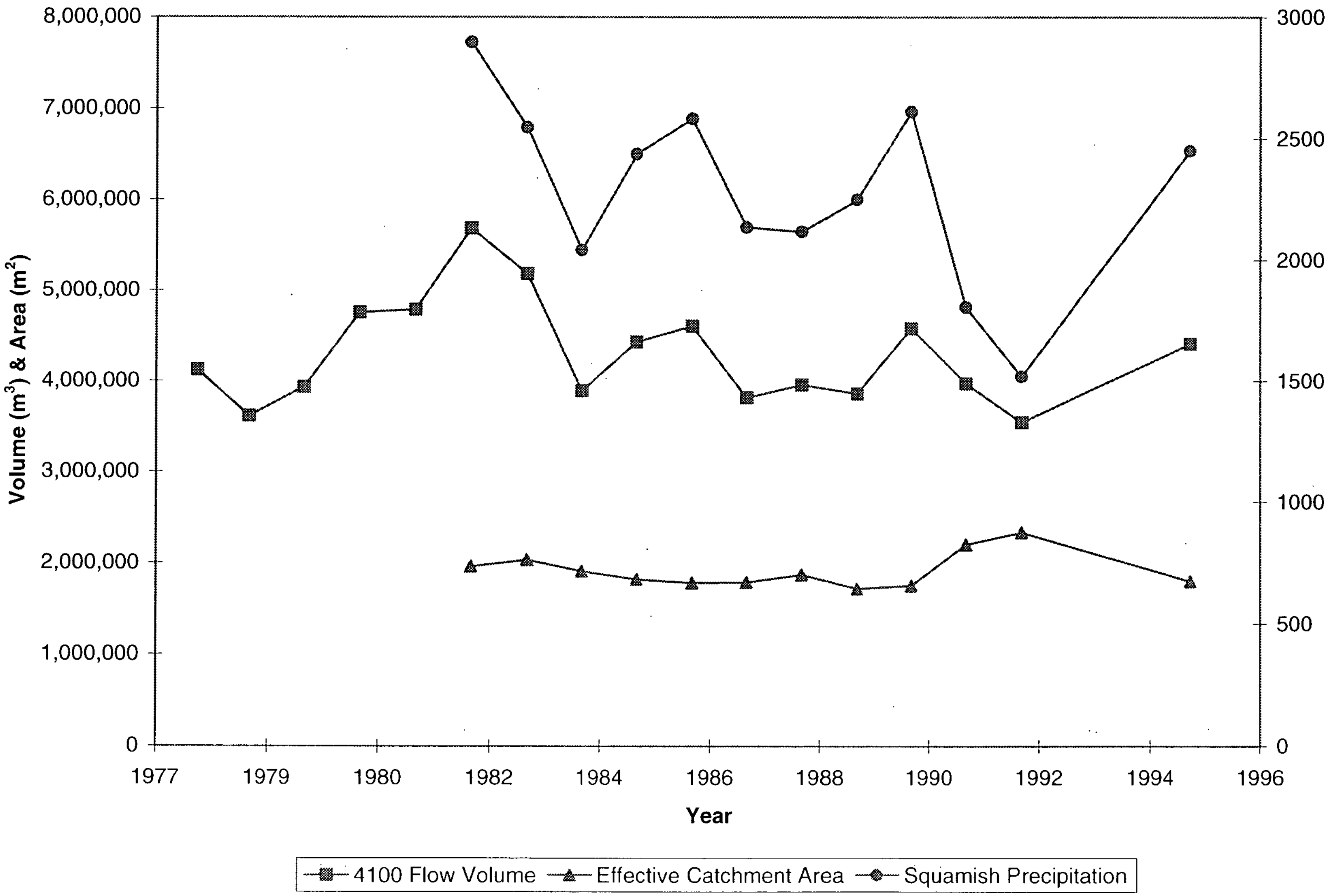


Figure 4.13. Annual Total Furry Creek Station Precipitation, Annual Total 2200 Level Portal Flow Volume, and Effective Catchment Area

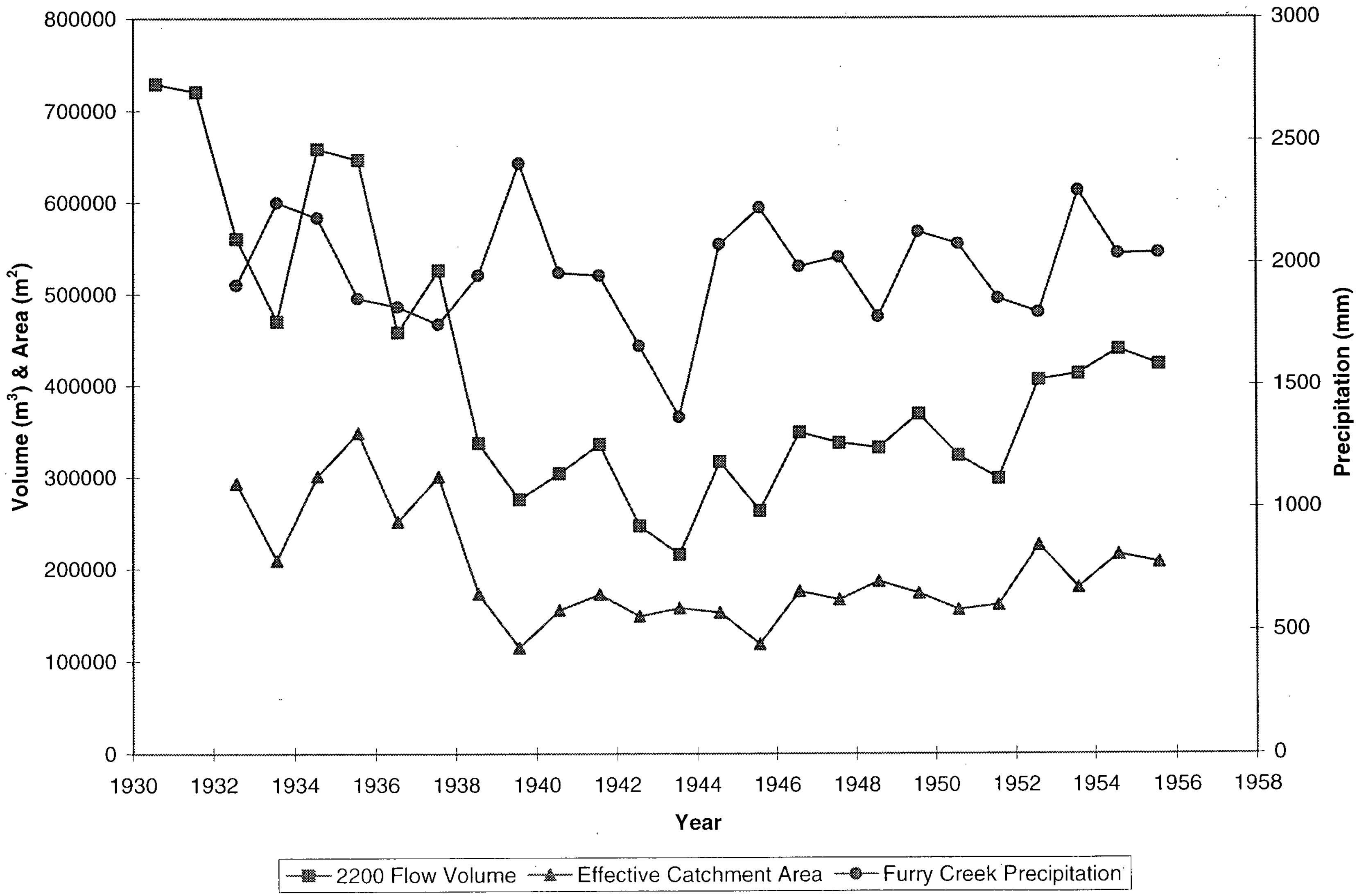


Figure 4.14. Pressure and Storage vs. Time

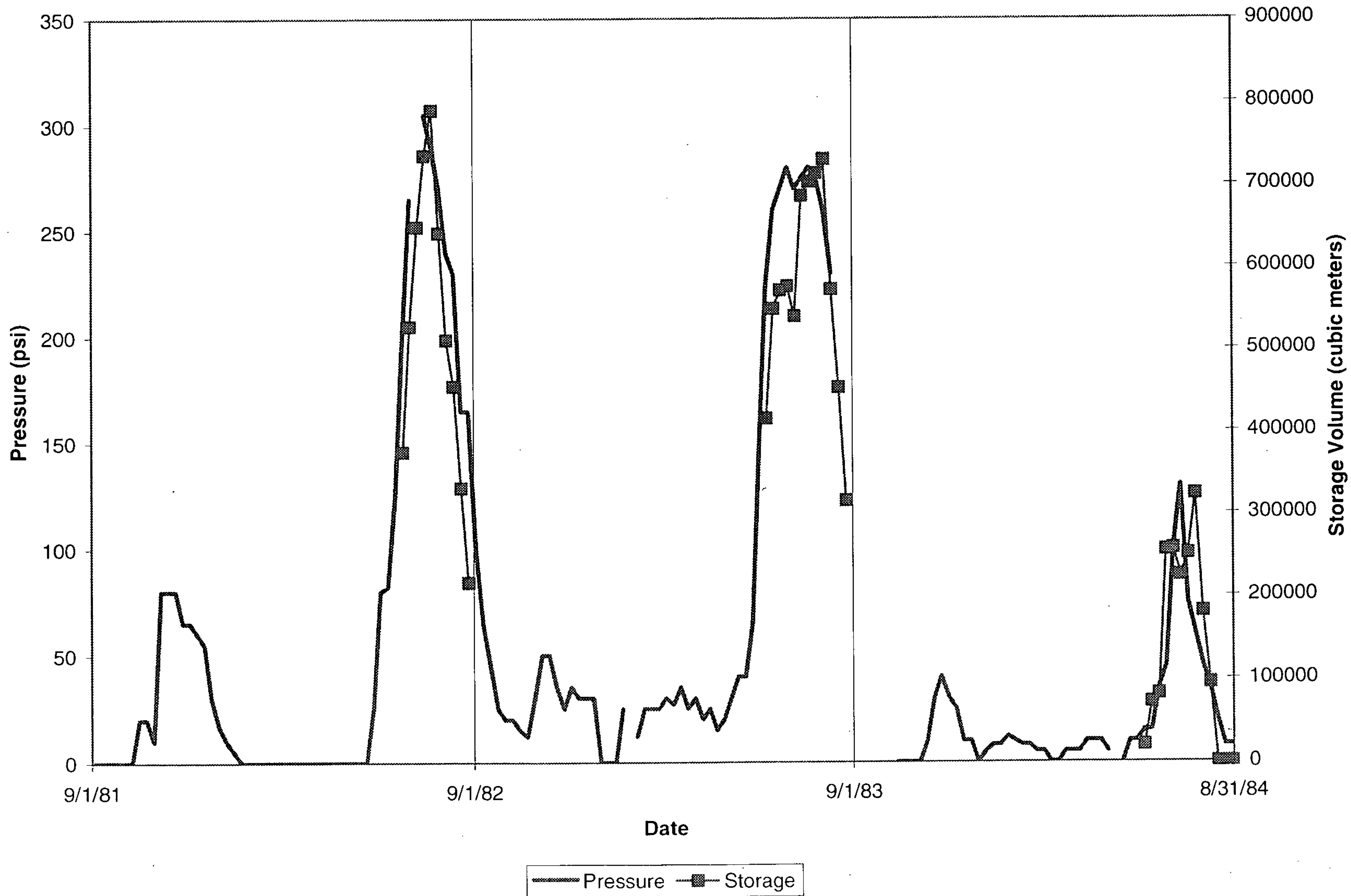


Figure 4.15. Storage vs. Pressure (1982, 1983, and 1984 Pressure Peaks and Shaft & Tunnel Volume)

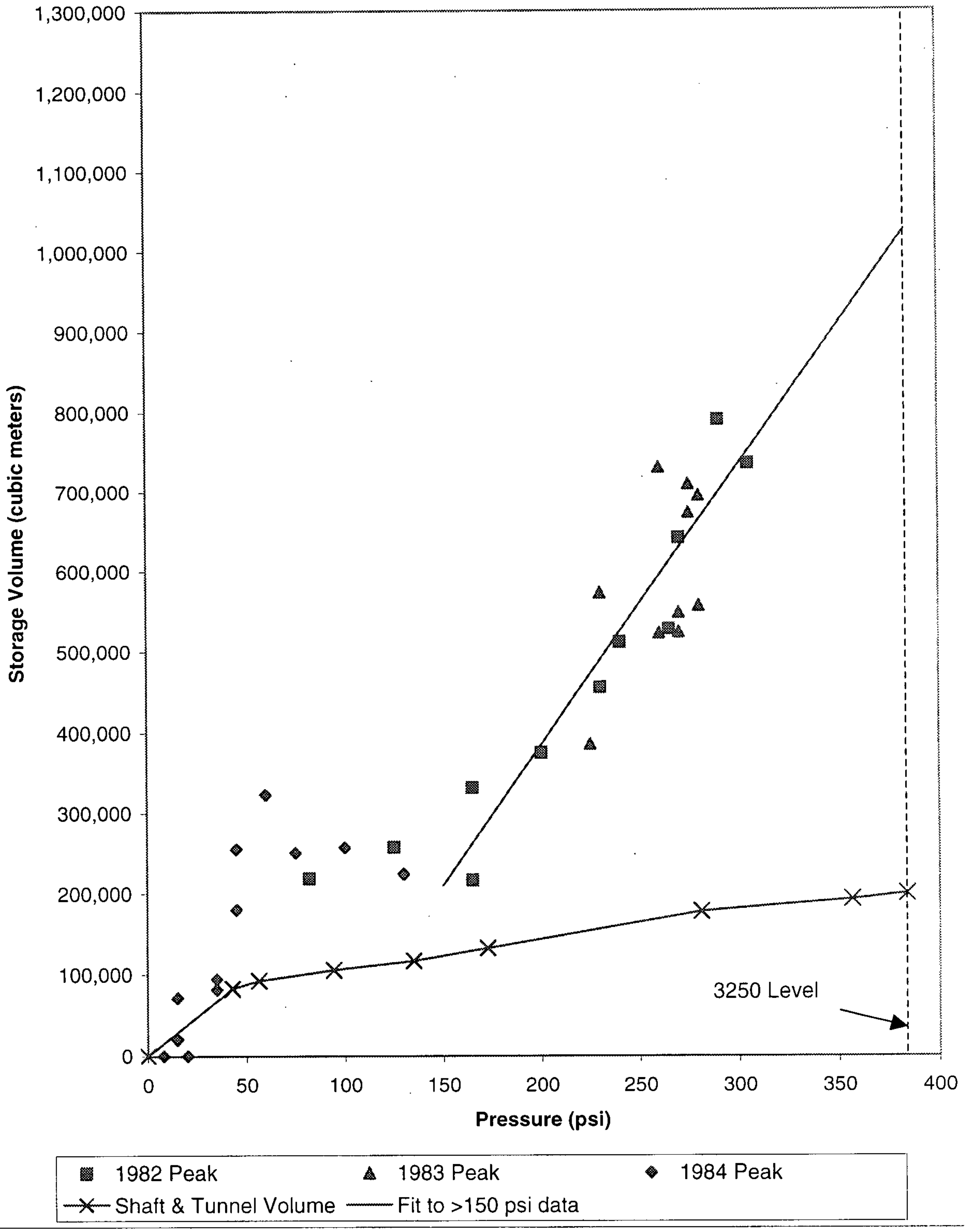


Figure 4.16. 2200 and 4100 Level Portal Flow - 10 Year Return Design Year

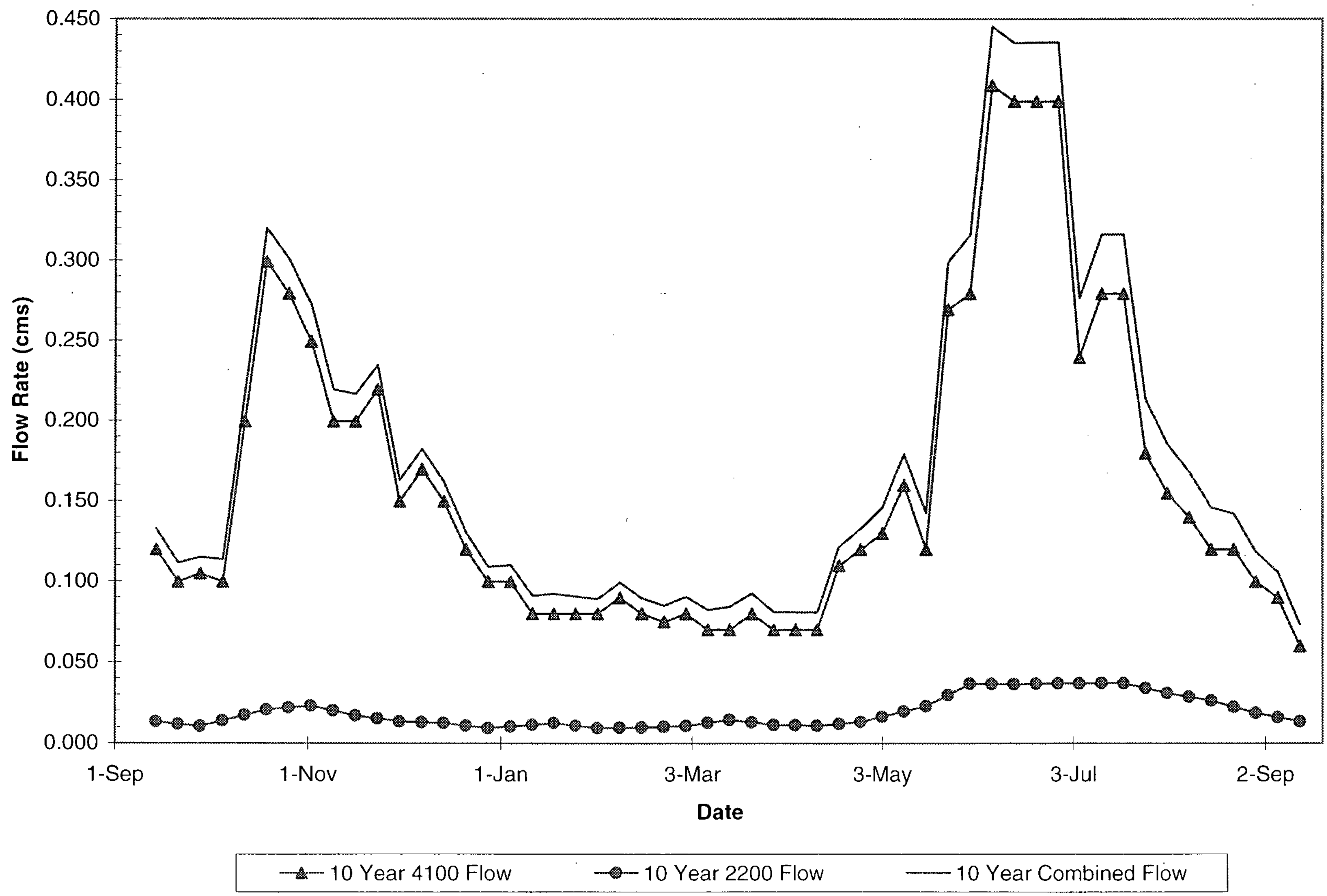


Figure 4.17. Required Storage vs. Treatment Plant Flow Rate

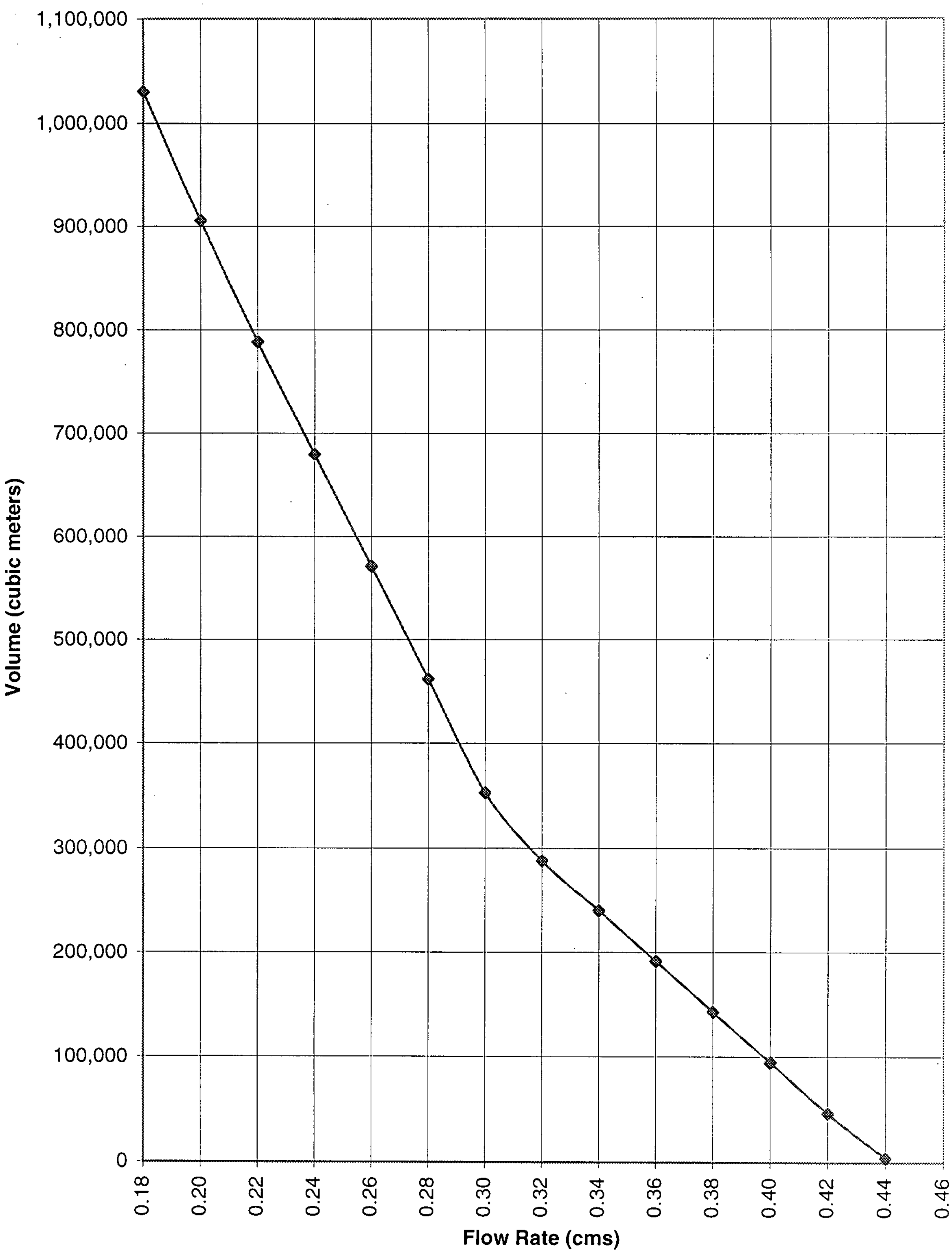


Figure 4.18. Comparison of Jane Creek Flow Routed Through 20 Reservoirs and 4100 Level Portal Flow

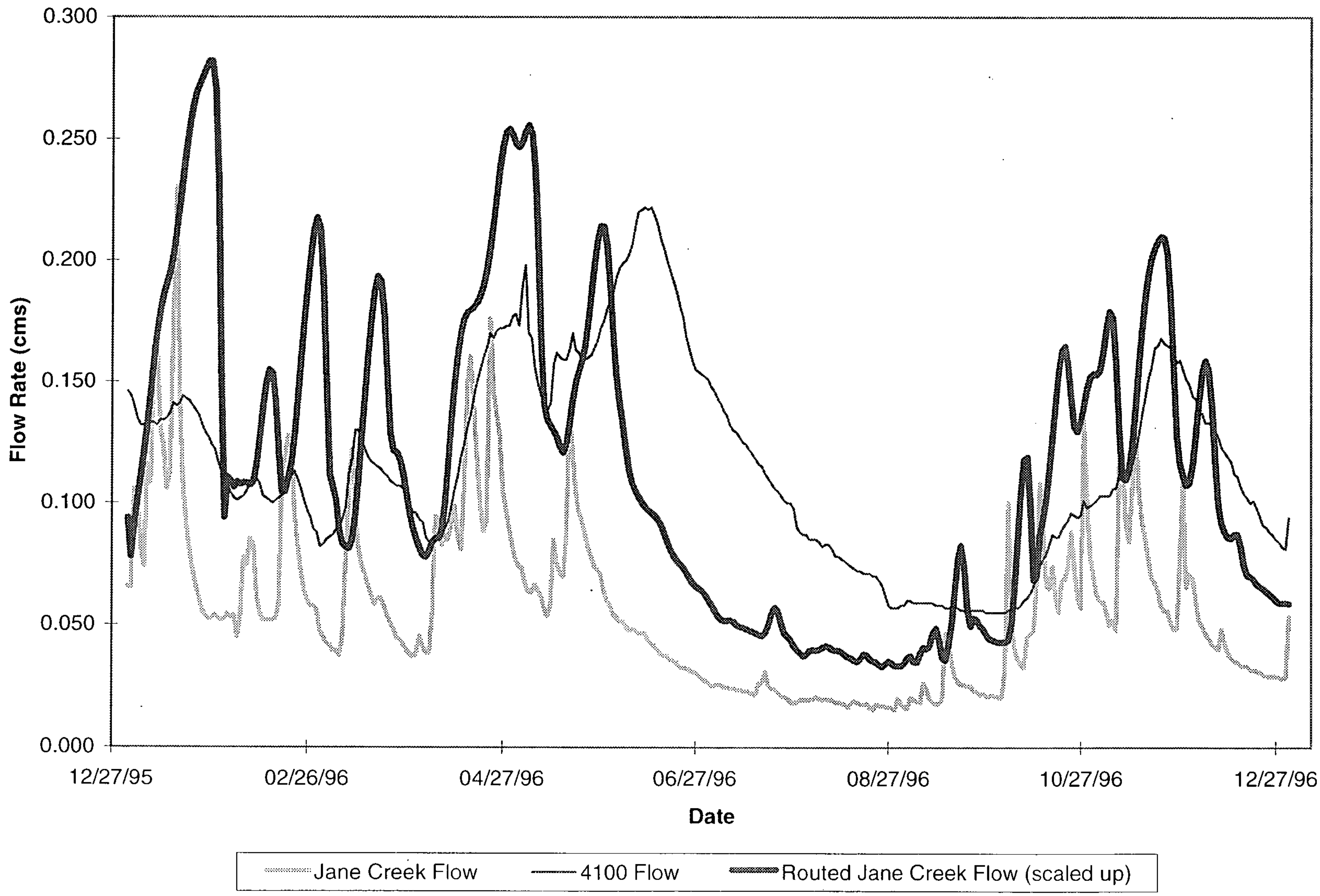
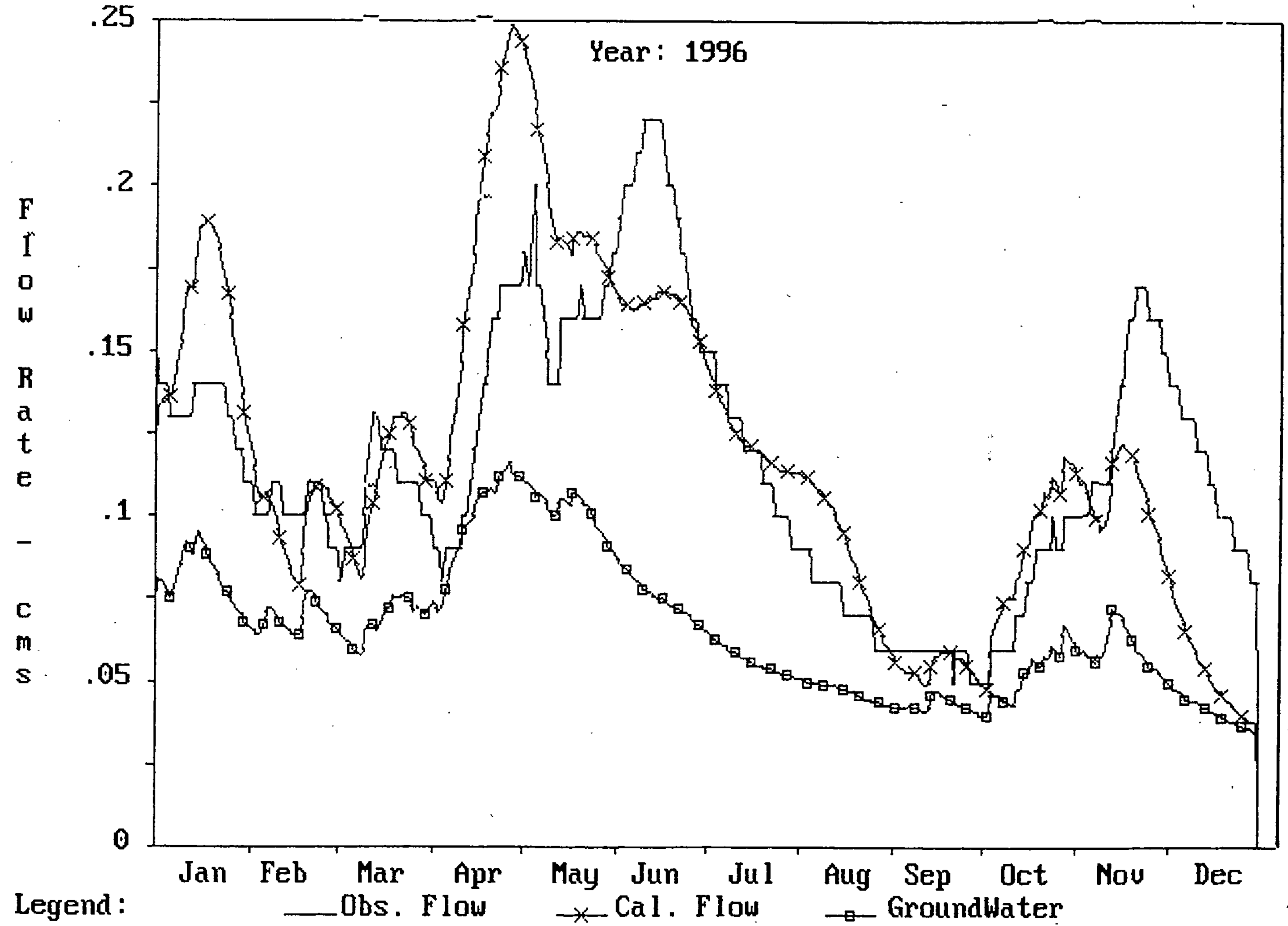


Figure 4.19. Output of the UBC Watershed Model - 4100 Level Portal Flow (actual and modeled with groundwater component shown)



Appendix A

Flow and Pressure Data

Table A-1. 2200 Level Portal Flow (1930-1956) (1/2)

Date mm/dd/yy	2200 Flow (cms)
01/14/30	0.021
01/30/30	0.020
02/14/30	0.018
02/28/30	0.025
03/15/30	0.023
03/31/30	0.024
04/15/30	0.037
04/30/30	0.044
05/15/30	0.045
05/31/30	0.045
06/15/30	0.048
06/30/30	0.032
07/15/30	0.024
07/31/30	0.026
08/15/30	0.017
08/31/30	0.014
09/14/30	0.013
09/29/30	0.012
10/14/30	0.012
10/30/30	0.015
11/14/30	0.020
11/29/30	0.018
12/14/30	0.019
12/30/30	0.018
01/14/31	0.017
01/30/31	0.028
02/14/31	0.030
02/28/31	0.021
03/15/31	0.028
03/31/31	0.030
04/15/31	0.033
04/30/31	0.036
05/15/31	0.039
05/31/31	0.037
06/15/31	0.034
06/30/31	0.023
07/15/31	0.034
07/31/31	0.016
08/15/31	0.011
08/31/31	0.011
09/15/31	0.011
09/30/31	0.018
10/15/31	0.018
10/31/31	0.018
11/15/31	0.030
11/30/31	0.021
12/15/31	0.016
12/31/31	0.017
01/15/32	0.017
01/31/32	0.016
02/15/32	0.015
02/29/32	0.018
03/15/32	0.028
03/31/32	0.026
04/15/32	0.028
04/30/32	0.027
05/15/32	0.036
05/31/32	0.034
06/15/32	0.037
06/30/32	0.034
07/15/32	0.025
07/31/32	0.023
08/15/32	0.020
08/31/32	0.018
09/14/32	0.015
09/29/32	0.015
10/14/32	0.012
10/30/32	0.017
11/14/32	0.019
11/29/32	0.032
12/14/32	0.025
12/30/32	0.011

Date mm/dd/yy	2200 Flow (cms)
01/14/33	0.010
01/30/33	0.011
02/14/33	0.010
02/28/33	0.009
03/15/33	0.009
03/31/33	0.009
04/15/33	0.008
04/30/33	0.012
05/15/33	0.021
05/31/33	0.026
06/15/33	0.031
06/30/33	0.035
07/15/33	0.032
07/31/33	0.029
08/15/33	0.018
08/31/33	0.011
09/14/33	0.010
09/29/33	0.015
10/14/33	0.016
10/30/33	0.015
11/14/33	0.020
11/29/33	0.014
12/14/33	0.013
12/30/33	0.011
01/14/34	0.014
01/30/34	0.011
02/14/34	0.015
02/28/34	0.014
03/15/34	0.011
03/31/34	0.012
04/15/34	0.022
04/30/34	0.029
05/15/34	0.025
05/31/34	0.019
06/15/34	0.015
06/30/34	0.012
07/15/34	0.010
07/31/34	0.013
08/15/34	0.012
08/31/34	0.011
09/14/34	0.009
09/29/34	0.009
10/14/34	0.009
10/30/34	0.014
11/14/34	0.027
11/29/34	0.033
12/14/34	0.017
12/30/34	0.018
01/14/35	0.015
01/30/35	0.022
02/14/35	0.031
02/28/35	0.018
03/15/35	0.014
03/31/35	0.016
04/15/35	0.014
04/30/35	0.015
05/15/35	0.023
05/31/35	0.030
06/15/35	0.037
06/30/35	0.035
07/15/35	0.034
07/31/35	0.025
08/15/35	0.019
08/31/35	0.017
09/15/35	0.015
09/30/35	0.017
10/15/35	0.014
10/31/35	0.023
11/15/35	0.018
11/30/35	0.013
12/15/35	0.017
12/31/35	0.021

Date mm/dd/yy	2200 Flow (cms)
01/15/36	0.020
01/31/36	0.013
02/15/36	0.011
02/29/36	0.010
03/15/36	0.012
03/31/36	0.011
04/15/36	0.011
04/30/36	0.036
05/15/36	0.042
05/31/36	0.042
06/15/36	0.037
06/30/36	0.030
07/15/36	0.023
07/31/36	0.023
08/15/36	0.018
08/31/36	0.015
09/14/36	0.012
09/29/36	0.015
10/14/36	0.014
10/30/36	0.015
11/14/36	0.011
11/29/36	0.011
12/14/36	0.010
12/30/36	0.014
01/14/37	0.013
01/30/37	0.010
02/14/37	0.009
02/28/37	0.009
03/15/37	0.010
03/31/37	0.010
04/15/37	0.009
04/30/37	0.009
05/15/37	0.021
05/31/37	0.026
06/15/37	0.034
06/30/37	0.027
07/15/37	0.014
07/31/37	0.026
08/15/37	0.011
08/31/37	0.009
09/14/37	0.008
09/29/37	0.008
10/14/37	0.010
10/30/37	0.018
11/14/37	0.018
11/29/37	0.019
12/14/37	0.017
12/30/37	0.018
01/14/38	0.014
01/30/38	0.012
02/14/38	0.012
02/28/38	0.010
03/15/38	0.009
03/31/38	0.010
04/15/38	0.015
04/30/38	0.033
05/15/38	0.029
05/31/38	0.039
06/15/38	0.037
06/30/38	0.035
07/15/38	0.010
07/31/38	0.007
08/15/38	0.006
08/31/38	0.005
09/14/38	0.004
09/29/38	0.005
10/14/38	0.012
10/30/38	0.009
11/14/38	0.016
11/29/38	0.012
12/14/38	0.020
12/30/38	0.008

Date mm/dd/yy	2200 Flow (cms)
01/14/39	0.008
01/30/39	0.006
02/14/39	0.006
02/28/39	0.004
03/15/39	0.004
03/31/39	0.007
04/15/39	0.008
04/30/39	0.015
05/15/39	0.022
05/31/39	0.024
06/15/39	0.023
06/30/39	0.012
07/15/39	0.010
07/31/39	0.008
08/15/39	0.006
08/31/39	0.005
09/15/39	0.004
09/30/39	0.004
10/15/39	0.004
10/31/39	0.007
11/15/39	0.012
11/30/39	0.016
12/15/39	0.023
12/31/39	0.011
01/15/40	0.013
01/31/40	0.009
02/15/40	0.010
02/29/40	0.006
03/15/40	0.006
03/31/40	0.008
04/15/40	0.010
04/30/40	0.011
05/15/40	0.014
05/31/40	0.011
06/15/40	0.007
06/30/40	0.006
07/15/40	0.005
07/31/40	0.004
08/15/40	0.004
08/31/40	0.004
09/14/40	0.004
09/29/40	0.005
10/14/40	0.006
10/30/40	0.020
11/14/40	0.011
11/29/40	0.007
12/14/40	0.009
12/30/40	0.012
01/14/41	0.008
01/30/41	0.008
02/14/41	0.012
02/28/41	0.008
03/15/41	0.009
03/31/41	0.010
04/15/41	0.015
04/30/41	0.014
05/15/41	0.013
05/31/41	0.017
06/15/41	0.010
06/30/41	0.007
07/15/41	0.007
07/31/41	0.006
08/15/41	0.006
08/31/41	0.008
09/14/41	0.016
09/29/41	0.017
10/14/41	0.011
10/30/41	0.011
11/14/41	0.020
11/29/41	0.009
12/14/41	0.006
12/30/41	0.006

Date mm/dd/yy	2200 Flow (cms)
01/14/42	0.006
01/30/42	0.006
02/14/42	0.006
02/28/42	0.006
03/15/42	0.006
03/31/42	0.004
04/15/42	0.010
04/30/42	0.012
05/15/42	0.014
05/31/42	0.025
06/15/42	0.016
06/30/42	0.015
07/15/42	0.010
07/31/42	0.010
08/15/42	0.007
08/31/42	0.006
09/14/42	0.004
09/29/42	0.003
10/14/42	0.005
10/30/42	0.006
11/14/42	0.006
11/29/42	0.008
12/14/42	0.006
12/30/42	0.008
01/14/43	0.006
01/30/43	0.005
02/14/43	0.004
02/28/43	0.004
03/15/43	0.004
03/31/43	0.004
04/15/43	0.009
04/30/43	0.016
05/15/43	0.011
05/31/43	0.017
06/15/43	0.018
06/30/43	0.016
07/15/43	0.010
07/31/43	0.008
08/15/43	0.006
08/31/43	0.005
09/15/43	0.004
09/30/43	0.003
10/15/43	0.003
10/31/43	0.010
11/15/43	0.007
11/30/43	0.006
12/15/43	0.008
12/31/43	0.005
01/15/44	0.004
01/31/44	0.008
02/15/44	0.005
02/29/44	0.004
03/15/44	0.005
03/31/44	0.004
04/15/44	0.007
04/30/44	0.007
05/15/44	0.014
05/31/44	0.015
06/15/44	0.016
06/30/44	0.009
07/15/44	0.006
07/31/44	0.005
08/15/44	0.004
08/31/44	0.004
09/14/44	0.003
09/29/44	0.004
10/14/44	0.008
10/30/44	0.010
11/14/44	0.020
11/29/44	0.014
12/14/44	0.013
12/30/44	0.009

Table A-2. 2200 Level Portal Flow (1930-1956) (2/2)

Date mm/dd/yy	2200 Flow (cms)
01/14/45	0.010
01/30/45	0.009
02/14/45	0.010
02/28/45	0.007
03/15/45	0.005
03/31/45	0.005
04/15/45	0.006
04/30/45	0.006
05/15/45	0.018
05/31/45	0.021
06/15/45	0.017
06/30/45	0.015
07/15/45	0.010
07/31/45	0.009
08/15/45	0.006
08/31/45	0.005
09/14/45	0.006
09/29/45	0.004
10/14/45	0.004
10/30/45	0.005
11/14/45	0.007
11/29/45	0.006
12/14/45	0.007
12/30/45	0.005
01/14/46	0.006
01/30/46	0.006
02/14/46	0.005
02/28/46	0.004
03/15/46	0.004
03/31/46	0.009
04/15/46	0.006
04/30/46	0.009
05/15/46	0.018
05/31/46	0.019
06/15/46	0.019
06/30/46	0.019
07/15/46	
07/31/46	
08/15/46	
08/31/46	
09/14/46	
09/29/46	
10/14/46	
10/30/46	0.006
11/14/46	0.012
11/29/46	0.009
12/14/46	0.007
12/30/46	0.007
01/14/47	0.007
01/30/47	0.007
02/14/47	0.009
02/28/47	0.014
03/15/47	0.008
03/31/47	0.013
04/15/47	0.013
04/30/47	0.016
05/15/47	0.017
05/31/47	0.017
06/15/47	0.017
06/30/47	0.016
07/15/47	0.013
07/31/47	0.012
08/15/47	0.008
08/31/47	0.006
09/15/47	0.006
09/30/47	0.006
10/15/47	0.007
10/31/47	0.008
11/15/47	0.011
11/30/47	0.007
12/15/47	0.006
12/31/47	0.006

Date mm/dd/yy	2200 Flow (cms)
01/15/48	0.007
01/31/48	0.006
02/15/48	0.005
02/29/48	0.004
03/15/48	0.004
03/31/48	0.003
04/15/48	0.003
04/30/48	0.020
05/15/48	0.016
05/31/48	0.031
06/15/48	0.027
06/30/48	0.023
07/15/48	0.013
07/31/48	0.012
08/15/48	0.009
08/31/48	0.015
09/14/48	0.011
09/29/48	0.009
10/14/48	0.011
10/30/48	0.012
11/14/48	0.009
11/29/48	0.007
12/14/48	0.006
12/30/48	0.006
01/14/49	0.006
01/30/49	0.006
02/14/49	0.005
02/28/49	0.005
03/15/49	0.006
03/31/49	0.005
04/15/49	0.006
04/30/49	0.013
05/15/49	0.021
05/31/49	0.027
06/15/49	0.024
06/30/49	0.018
07/15/49	0.013
07/31/49	0.010
08/15/49	0.008
08/31/49	0.009
09/14/49	0.007
09/29/49	0.007
10/14/49	0.007
10/30/49	0.007
11/14/49	0.007
11/29/49	0.018
12/14/49	0.015
12/30/49	0.008
01/14/50	0.006
01/30/50	0.011
02/14/50	0.014
02/28/50	0.008
03/15/50	0.007
03/31/50	0.006
04/15/50	0.006
04/30/50	0.012
05/15/50	0.009
05/31/50	0.016
06/15/50	0.026
06/30/50	0.028
07/15/50	0.024
07/31/50	0.014
08/15/50	0.009
08/31/50	0.008
09/14/50	0.007
09/29/50	0.006
10/14/50	0.014
10/30/50	0.011
11/14/50	0.013
11/29/50	0.011
12/14/50	0.013
12/30/50	0.016

Date mm/dd/yy	2200 Flow (cms)
01/14/51	0.009
01/30/51	0.007
02/14/51	0.007
02/28/51	0.008
03/15/51	0.006
03/31/51	0.006
04/15/51	0.007
04/30/51	0.011
05/15/51	0.016
05/31/51	0.020
06/15/51	0.018
06/30/51	0.014
07/15/51	0.009
07/31/51	0.008
08/15/51	0.005
08/31/51	0.004
09/15/51	0.003
09/30/51	0.003
10/15/51	0.005
10/31/51	0.008
11/15/51	0.006
11/30/51	0.007
12/15/51	0.007
12/31/51	0.006
01/15/52	0.005
01/31/52	0.005
02/15/52	0.006
02/29/52	0.005
03/15/52	0.004
03/31/52	0.004
04/15/52	0.006
04/30/52	0.011
05/15/52	0.017
05/31/52	0.024
06/15/52	0.022
06/30/52	0.020
07/15/52	0.021
07/31/52	0.014
08/15/52	0.009
08/31/52	0.007
09/14/52	0.006
09/29/52	0.005
10/14/52	0.006
10/30/52	0.006
11/14/52	0.009
11/29/52	0.007
12/14/52	0.006
12/30/52	0.006
01/14/53	0.009
01/30/53	0.012
02/14/53	0.015
02/28/53	0.014
03/15/53	0.011
03/31/53	0.012
04/15/53	0.010
04/30/53	0.019
05/15/53	0.022
05/31/53	0.025
06/15/53	0.023
06/30/53	0.023
07/15/53	0.023
07/31/53	0.017
08/15/53	0.012
08/31/53	0.010
09/14/53	0.009
09/29/53	0.007
10/14/53	0.014
10/30/53	0.016
11/14/53	0.012
11/29/53	0.009
12/14/53	0.009
12/30/53	0.006

Date mm/dd/yy	2200 Flow (cms)
01/14/54	0.009
01/30/54	0.006
02/14/54	0.007
02/28/54	0.007
03/15/54	0.010
03/31/54	0.008
04/15/54	0.007
04/30/54	0.009
05/15/54	0.016
05/31/54	0.025
06/15/54	0.025
06/30/54	0.025
07/15/54	0.025
07/31/54	0.021
08/15/54	0.018
08/31/54	0.013
09/14/54	0.012
09/29/54	0.011
10/14/54	0.011
10/30/54	0.013
11/14/54	0.017
11/29/54	0.025
12/14/54	0.019
12/30/54	0.013
01/14/55	0.012
01/30/55	0.010
02/14/55	0.008
02/28/55	0.007
03/15/55	0.006
03/31/55	0.006
04/15/55	0.006
04/30/55	0.006
05/15/55	0.008
05/31/55	0.024
06/15/55	0.025
06/30/55	0.026
07/15/55	0.023
07/31/55	0.019
08/15/55	0.017
08/31/55	0.011
09/15/55	0.009
09/30/55	0.009
10/15/55	0.012
10/31/55	0.016
11/15/55	0.024
11/30/55	0.016
12/15/55	0.011
12/31/55	0.008
01/15/56	0.006
01/31/56	0.006
02/15/56	0.006
02/29/56	0.006
03/15/56	0.006
03/31/56	0.005
04/15/56	0.005
04/30/56	0.009
05/15/56	0.017
05/31/56	0.028
06/15/56	0.027
06/30/56	0.022
07/15/56	0.025
07/31/56	0.021
08/15/56	0.018
08/31/56	0.011
09/14/56	0.007
09/29/56	0.007
10/14/56	0.009
10/30/56	0.013
11/14/56	0.015
11/29/56	0.011
12/14/56	0.009
12/30/56	0.008

Table A-3. 2200 Level Portal Flow (1995-1998) (1/2)

Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)
08/17/95	0.008	02/20/96	0.069	04/26/96	0.048	07/01/96	0.026	09/05/96	0.005
08/29/95	0.004	02/21/96	0.056	04/27/96	0.046	07/02/96	0.026	09/06/96	0.006
09/06/95	0.003	02/22/96	0.047	04/28/96	0.046	07/03/96	0.026	09/07/96	0.007
09/12/95	0.002	02/23/96	0.043	04/29/96	0.044	07/04/96	0.026	09/08/96	0.008
09/19/95	0.001	02/24/96	0.039	04/30/96	0.043	07/05/96	0.027	09/09/96	0.008
09/26/95	0.000	02/25/96	0.037	05/01/96	0.041	07/06/96	0.027	09/10/96	0.009
10/04/95	0.000	02/26/96	0.035	05/02/96	0.039	07/07/96	0.026	09/11/96	0.009
10/11/95	0.034	02/27/96	0.034	05/03/96	0.037	07/08/96	0.026	09/12/96	0.008
10/17/95	0.065	02/28/96	0.032	05/04/96	0.036	07/09/96	0.026	09/13/96	0.007
10/24/95	0.021	02/29/96	0.031	05/05/96	0.034	07/10/96	0.026	09/14/96	0.007
10/31/95	0.021	03/01/96	0.030	05/06/96	0.032	07/11/96	0.026	09/15/96	0.007
11/07/95	0.016	03/02/96	0.029	05/07/96	0.031	07/12/96	0.025	09/16/96	0.007
11/15/95	0.085	03/03/96	0.030	05/08/96	0.030	07/13/96	0.024	09/17/96	0.007
11/28/95	0.076	03/04/96	0.029	05/09/96	0.030	07/14/96	0.024	09/18/96	0.007
12/12/95	0.103	03/05/96	0.028	05/10/96	0.031	07/15/96	0.023	09/19/96	0.006
12/19/95	0.060	03/06/96	0.029	05/11/96	0.033	07/16/96	0.022	09/20/96	0.006
01/01/96	0.034	03/07/96	0.029	05/12/96	0.035	07/17/96	0.020	09/21/96	0.006
01/02/96	0.035	03/08/96	0.029	05/13/96	0.038	07/18/96	0.022	09/22/96	0.006
01/03/96	0.036	03/09/96	0.030	05/14/96	0.042	07/19/96	0.024	09/23/96	0.006
01/04/96	0.040	03/10/96	0.030	05/15/96	0.050	07/20/96	0.025	09/24/96	0.006
01/05/96	0.043	03/11/96	0.035	05/16/96	0.060	07/21/96	0.024	09/25/96	0.006
01/06/96	0.046	03/12/96	0.054	05/17/96	0.069	07/22/96	0.022	09/26/96	0.006
01/07/96	0.043	03/13/96	0.047	05/18/96	0.075	07/23/96	0.018	09/27/96	0.006
01/08/96	0.052	03/14/96	0.042	05/19/96	0.084	07/24/96	0.018	09/28/96	0.006
01/09/96	0.051	03/15/96	0.041	05/20/96	0.075	07/25/96	0.016	09/29/96	0.006
01/10/96	0.049	03/16/96	0.039	05/21/96	0.068	07/26/96	0.016	09/30/96	0.006
01/11/96	0.047	03/17/96	0.038	05/22/96	0.065	07/27/96	0.015	10/01/96	0.006
01/12/96	0.046	03/18/96	0.037	05/23/96	0.065	07/28/96	0.015	10/02/96	0.007
01/13/96	0.045	03/19/96	0.036	05/24/96	0.069	07/29/96	0.015	10/03/96	0.010
01/14/96	0.044	03/20/96	0.035	05/25/96	0.075	07/30/96	0.015	10/04/96	0.014
01/15/96	0.044	03/21/96	0.034	05/26/96	0.079	07/31/96	0.016	10/05/96	0.019
01/16/96	0.043	03/22/96	0.032	05/27/96	0.079	08/01/96	0.015	10/06/96	0.018
01/17/96	0.040	03/23/96	0.031	05/28/96	0.073	08/02/96	0.016	10/07/96	0.016
01/18/96	0.038	03/24/96	0.030	05/29/96	0.069	08/03/96	0.014	10/08/96	0.015
01/19/96	0.036	03/25/96	0.030	05/30/96	0.064	08/04/96	0.014	10/09/96	0.017
01/20/96	0.035	03/26/96	0.030	05/31/96	0.061	08/05/96	0.014	10/10/96	0.021
01/21/96	0.035	03/27/96	0.026	06/01/96	0.060	08/06/96	0.013	10/11/96	0.025
01/22/96	0.034	03/28/96	0.026	06/02/96	0.063	08/07/96	0.014	10/12/96	0.029
01/23/96	0.033	03/29/96	0.026	06/03/96	0.073	08/08/96	0.012	10/13/96	0.034
01/24/96	0.031	03/30/96	0.026	06/04/96	0.078	08/09/96	0.012	10/14/96	0.038
01/25/96	0.029	03/31/96	0.027	06/05/96	0.073	08/10/96	0.012	10/15/96	0.036
01/26/96	0.028	04/01/96	0.027	06/06/96	0.069	08/11/96	0.013	10/16/96	0.031
01/27/96	0.028	04/02/96	0.027	06/07/96	0.068	08/12/96	0.012	10/17/96	0.025
01/28/96	0.029	04/03/96	0.027	06/08/96	0.067	08/13/96	0.012	10/18/96	0.024
01/29/96	0.029	04/04/96	0.027	06/09/96	0.061	08/14/96	0.011	10/19/96	0.020
01/30/96	0.028	04/05/96	0.027	06/10/96	0.056	08/15/96	0.007	10/20/96	0.019
01/31/96	0.028	04/06/96	0.027	06/11/96	0.054	08/16/96	0.006	10/21/96	0.018
02/01/96	0.028	04/07/96	0.027	06/12/96	0.051	08/17/96	0.006	10/22/96	0.018
02/02/96	0.027	04/08/96	0.026	06/13/96	0.050	08/18/96	0.005	10/23/96	0.021
02/03/96	0.027	04/09/96	0.026	06/14/96	0.051	08/19/96	0.005	10/24/96	0.025
02/04/96	0.027	04/10/96	0.026	06/15/96	0.050	08/20/96	0.006	10/25/96	0.023
02/05/96	0.028	04/11/96	0.028	06/16/96	0.048	08/21/96	0.006	10/26/96	0.022
02/06/96	0.028	04/12/96	0.031	06/17/96	0.046	08/22/96	0.005	10/27/96	0.025
02/07/96	0.028	04/13/96	0.039	06/18/96	0.044	08/23/96	0.005	10/28/96	0.054
02/08/96	0.028	04/14/96	0.052	06/19/96	0.042	08/24/96	0.005	10/29/96	0.046
02/09/96	0.027	04/15/96	0.067	06/20/96	0.041	08/25/96	0.005	10/30/96	0.035
02/10/96	0.025	04/16/96	0.084	06/21/96	0.041	08/26/96	0.005	10/31/96	0.026
02/11/96	0.026	04/17/96	0.090	06/22/96	0.038	08/27/96	0.006	11/01/96	0.023
02/12/96	0.027	04/18/96	0.076	06/23/96	0.034	08/28/96	0.006	11/02/96	0.022
02/13/96	0.025	04/19/96	0.070	06/24/96	0.032	08/29/96	0.005	11/03/96	0.021
02/14/96	0.025	04/20/96	0.065	06/25/96	0.030	08/30/96	0.006	11/04/96	0.020
02/15/96	0.025	04/21/96	0.070	06/26/96	0.029	08/31/96	0.006	11/05/96	0.019
02/16/96	0.027	04/22/96	0.054	06/27/96	0.029	09/01/96	0.006	11/06/96	0.019
02/17/96	0.028	04/23/96	0.051	06/28/96	0.028	09/02/96	0.006	11/07/96	0.020
02/18/96	0.042	04/24/96	0.050	06/29/96	0.028	09/03/96	0.006	11/08/96	0.025
02/19/96	0.088	04/25/96	0.049	06/30/96	0.027	09/04/96	0.006	11/09/96	0.038

Table A-4. 2200 Level Portal Flow (1995-1998) (2/2)

Date mm/dd/yy	Flow (cms)
11/10/96	0.036
11/11/96	0.035
11/12/96	0.038
11/13/96	0.040
11/14/96	0.038
11/15/96	0.035
11/16/96	0.033
11/17/96	0.031
11/18/96	0.030
11/19/96	0.028
11/20/96	0.026
11/21/96	0.025
11/22/96	0.024
11/23/96	0.023
11/24/96	0.022
11/25/96	0.022
11/26/96	0.021
11/27/96	0.024
11/28/96	0.033
11/29/96	0.032
11/30/96	0.030
12/01/96	0.029
12/02/96	0.028
12/03/96	0.026
12/04/96	0.025
12/05/96	0.024
12/06/96	0.023
12/07/96	0.022
12/08/96	0.021
12/09/96	0.021
12/10/96	0.022
12/11/96	0.021
12/12/96	0.021
12/13/96	0.020
12/14/96	0.020
12/15/96	0.019
12/16/96	0.019
12/17/96	0.018
12/18/96	0.018
12/19/96	0.017
12/20/96	0.017
12/21/96	0.017
12/22/96	0.016
12/23/96	0.016
12/24/96	0.015
12/25/96	0.015
12/26/96	0.015
12/27/96	0.015
12/28/96	0.015
12/29/96	0.014
12/30/96	0.014
12/31/96	0.020
01/15/97	0.012
01/16/97	0.012
01/17/97	0.015
01/18/97	0.016
01/19/97	0.029
01/20/97	0.048
01/21/97	0.037
01/22/97	0.030
01/23/97	0.025
01/24/97	0.022
01/25/97	0.020
01/26/97	0.019
01/27/97	0.019
01/28/97	0.019

Date mm/dd/yy	Flow (cms)
01/29/97	0.019
01/30/97	0.033
01/31/97	0.032
02/01/97	0.027
02/02/97	0.024
02/03/97	0.022
02/04/97	0.020
02/05/97	0.020
02/06/97	0.019
02/07/97	0.018
02/08/97	0.017
02/09/97	0.017
02/10/97	0.016
02/11/97	0.015
02/12/97	0.015
02/13/97	0.014
02/14/97	0.015
02/15/97	0.016
02/16/97	0.018
02/17/97	0.018
02/18/97	0.016
02/19/97	0.016
02/20/97	0.015
02/21/97	0.014
02/22/97	0.014
02/23/97	0.014
02/24/97	0.014
02/25/97	0.013
02/26/97	0.013
02/27/97	0.012
02/28/97	0.012
03/01/97	0.013
03/02/97	0.013
03/03/97	0.013
03/04/97	0.012
03/05/97	0.013
03/06/97	0.013
03/07/97	0.014
03/08/97	0.014
03/09/97	0.014
03/10/97	0.015
03/11/97	0.015
03/12/97	0.015
03/13/97	0.016
03/14/97	0.016
03/15/97	0.016
03/16/97	0.017
03/17/97	0.017
03/18/97	0.022
03/19/97	0.059
03/20/97	0.070
03/21/97	0.047
03/22/97	0.036
03/23/97	0.030
03/24/97	0.027
03/25/97	0.026
03/26/97	0.025
03/27/97	0.024
03/28/97	0.023
03/29/97	0.022
03/30/97	0.022
03/31/97	0.020
04/01/97	0.020
04/02/97	0.020
04/03/97	0.018
04/04/97	0.017

Date mm/dd/yy	Flow (cms)
04/05/97	0.017
04/06/97	0.017
04/07/97	0.017
04/08/97	0.018
04/09/97	0.018
04/10/97	0.018
04/11/97	0.019
04/12/97	0.022
04/13/97	0.025
04/14/97	0.021
04/15/97	0.024
04/16/97	0.092
04/17/97	0.087
04/18/97	0.058
04/19/97	0.047
04/20/97	0.057
04/21/97	0.058
04/22/97	0.054
04/23/97	0.054
04/24/97	0.056
04/25/97	0.057
04/26/97	0.070
04/27/97	0.103
04/28/97	0.081
04/29/97	0.069
04/30/97	0.064
05/01/97	0.057
05/02/97	0.054
05/03/97	0.055
05/04/97	0.058
05/05/97	0.072
05/06/97	0.090
05/07/97	0.077
05/08/97	0.075
05/09/97	0.078
05/10/97	0.089
05/11/97	0.099
05/12/97	0.125
05/13/97	0.145
05/14/97	0.167
05/15/97	0.180
05/16/97	0.175
05/17/97	0.160
05/18/97	0.137
05/19/97	0.123
05/20/97	0.112
05/21/97	0.103
05/22/97	0.096
07/09/97	0.069
09/10/97	0.004
10/23/97	0.027
10/24/97	0.027
10/28/97	0.023
10/29/97	0.030
10/30/97	0.062
10/31/97	0.063
11/01/97	0.052
11/02/97	0.046
11/03/97	0.052
11/04/97	0.067
11/05/97	0.056
11/06/97	0.064
11/07/97	0.071
11/08/97	0.059
11/09/97	0.050
11/10/97	0.044

Date mm/dd/yy	Flow (cms)
11/11/97	0.039
11/12/97	0.035
11/13/97	0.033
11/14/97	0.030
11/15/97	0.028
11/16/97	0.026
11/17/97	0.025
11/18/97	0.023
11/19/97	0.023
11/20/97	0.021
11/21/97	0.020
11/22/97	0.020
11/23/97	0.023
11/24/97	0.038
11/25/97	0.032
11/26/97	0.028
11/27/97	0.026
11/28/97	0.035
11/29/97	0.045
11/30/97	0.050
12/01/97	0.041
12/02/97	0.037
12/03/97	0.033
12/04/97	0.030
12/05/97	0.028
12/06/97	0.026
12/07/97	0.024
12/08/97	0.023
12/09/97	0.021
12/10/97	0.021
12/11/97	0.020
12/12/97	0.019
12/13/97	0.018
12/14/97	0.018
12/15/97	0.017
12/16/97	0.017
12/17/97	0.017
12/18/97	0.016
12/19/97	0.015
12/20/97	0.016
12/21/97	0.015
12/22/97	0.015
12/23/97	0.015
12/24/97	0.014
12/25/97	0.014
12/26/97	0.014
12/27/97	0.014
12/28/97	0.014
12/29/97	0.016
12/30/97	0.016
12/31/97	0.016
01/01/98	0.018
01/02/98	0.021
01/03/98	0.021
01/04/98	0.020
01/05/98	0.019
01/06/98	0.018
01/07/98	0.017
01/08/98	0.015
01/09/98	0.016
01/10/98	0.015
01/11/98	0.014
01/12/98	0.014
01/13/98	0.015
01/14/98	0.016
01/15/98	0.017

Date mm/dd/yy	Flow (cms)
01/16/98	0.016
01/17/98	0.016
01/18/98	0.017
01/19/98	0.018
01/20/98	0.017
01/21/98	0.015
01/22/98	0.015
01/23/98	0.017
02/11/98	0.022
04/22/98	0.015
05/12/98	0.077

Table A-5. 4100 Level Portal Flow (1977-1993) (1/3)

Date mm/dd/yy	4100 Flow (cms)
10/01/77	0.064
10/08/77	0.064
10/15/77	0.064
10/22/77	0.095
11/01/77	0.182
11/08/77	0.152
11/15/77	0.152
11/22/77	0.121
12/01/77	0.114
12/07/77	0.114
12/13/77	0.144
12/19/77	0.129
12/25/77	0.114
01/01/78	0.091
01/08/78	0.091
01/15/78	0.091
01/22/78	0.091
02/01/78	0.083
02/08/78	0.098
02/15/78	0.083
02/22/78	0.083
03/01/78	0.083
03/07/78	0.083
03/13/78	0.083
03/19/78	0.083
03/25/78	0.121
04/01/78	0.144
04/08/78	0.129
04/15/78	0.136
04/22/78	0.121
05/01/78	0.178
05/08/78	0.167
05/15/78	0.193
05/22/78	0.220
06/01/78	0.227
06/07/78	0.234
06/13/78	0.197
06/19/78	0.265
06/25/78	0.265
07/01/78	0.250
07/08/78	0.114
07/15/78	0.117
07/22/78	0.106
08/01/78	0.106
08/08/78	0.102
08/15/78	0.098
08/22/78	0.098
09/01/78	0.098
09/08/78	0.258
09/15/78	0.235
09/22/78	0.212
10/01/78	0.174
10/08/78	0.144
10/15/78	0.106
10/22/78	0.098
11/01/78	0.098
11/08/78	0.121
11/15/78	0.129
11/22/78	0.106
12/01/78	0.102
12/07/78	0.087
12/13/78	0.069
12/19/78	0.065
12/25/78	0.065
01/01/79	0.053
01/08/79	0.053

Date mm/dd/yy	4100 Flow (cms)
01/15/79	0.049
01/22/79	0.045
02/01/79	0.049
02/08/79	0.045
02/15/79	0.042
02/22/79	0.046
03/01/79	0.049
03/07/79	0.053
03/13/79	0.057
03/19/79	0.057
03/25/79	0.064
04/01/79	0.061
04/08/79	0.061
04/15/79	0.061
04/22/79	0.064
05/01/79	0.083
05/08/79	0.144
05/15/79	0.152
05/22/79	0.189
06/01/79	0.227
06/07/79	0.235
06/13/79	0.197
06/19/79	0.197
06/25/79	0.197
07/01/79	0.197
07/08/79	0.193
07/15/79	0.174
07/22/79	0.159
08/01/79	0.144
08/07/79	0.129
08/13/79	0.106
08/19/79	0.083
08/25/79	0.076
09/01/79	0.076
09/08/79	0.098
09/15/79	0.106
09/22/79	0.106
10/01/79	0.106
10/08/79	0.091
10/15/79	0.091
10/22/79	0.083
11/01/79	
11/08/79	
11/15/79	
11/22/79	
12/01/79	
12/08/79	
12/15/79	
12/22/79	
01/01/80	
01/08/80	
01/15/80	0.114
01/22/80	0.068
02/01/80	0.076
02/07/80	0.076
02/13/80	0.076
02/19/80	0.076
02/25/80	0.106
03/01/80	0.144
03/08/80	0.144
03/15/80	0.114
03/22/80	0.068
04/01/80	0.083
04/08/80	0.045
04/15/80	0.064
04/22/80	0.083

Date mm/dd/yy	4100 Flow (cms)
05/02/80	0.167
05/09/80	0.197
05/16/80	0.204
05/23/80	0.212
05/30/80	0.212
06/06/80	0.129
06/13/80	0.152
06/20/80	0.167
06/27/80	0.189
07/04/80	0.189
07/11/80	0.189
07/18/80	0.189
07/25/80	0.174
08/01/80	0.159
08/08/80	0.152
08/15/80	0.125
08/22/80	0.114
08/29/80	0.098
09/05/80	0.095
09/12/80	0.091
09/19/80	0.076
09/26/80	0.068
10/03/80	0.076
10/10/80	0.076
10/17/80	0.076
10/24/80	0.068
10/31/80	0.068
11/07/80	0.083
11/14/80	0.129
11/21/80	0.144
11/28/80	0.152
12/05/80	0.159
12/12/80	0.159
12/19/80	0.152
12/26/80	0.167
01/02/81	0.216
01/09/81	0.231
01/16/81	0.227
01/23/81	0.220
01/30/81	0.212
02/06/81	0.205
02/13/81	0.182
02/20/81	0.174
02/27/81	0.167
03/06/81	0.163
03/13/81	0.152
03/20/81	0.129
03/27/81	0.129
04/03/81	0.181
04/10/81	0.121
04/17/81	0.098
04/24/81	0.083
05/01/81	0.114
05/08/81	0.129
05/15/81	0.182
05/22/81	0.197
05/29/81	0.235
06/05/81	0.280
06/12/81	0.265
06/19/81	0.250
06/26/81	0.235
07/03/81	0.220
07/10/81	0.208
07/17/81	0.182
07/24/81	0.159
07/31/81	0.114

Date mm/dd/yy	4100 Flow (cms)
08/07/81	0.106
08/14/81	0.083
08/21/81	0.083
08/28/81	0.076
09/04/81	0.068
09/11/81	0.064
09/18/81	0.042
09/25/81	0.045
10/02/81	0.061
10/09/81	0.144
10/16/81	0.212
10/23/81	0.152
10/30/81	0.174
11/06/81	0.295
11/13/81	0.288
11/20/81	0.280
11/27/81	0.265
12/04/81	0.227
12/11/81	0.197
12/18/81	0.167
12/25/81	0.152
01/01/82	0.152
01/08/82	0.136
01/15/82	0.114
01/22/82	0.091
01/29/82	0.091
02/05/82	0.076
02/12/82	0.076
02/19/82	0.076
02/26/82	0.076
03/05/82	0.076
03/12/82	0.076
03/19/82	0.068
03/26/82	0.064
04/02/82	0.072
04/09/82	0.068
04/16/82	0.053
04/23/82	0.049
04/30/82	0.061
05/07/82	0.068
05/14/82	0.068
05/21/82	0.114
05/28/82	0.189
06/04/82	0.258
06/11/82	0.295
06/18/82	0.341
06/25/82	0.235
07/02/82	0.197
07/09/82	0.208
07/16/82	0.265
07/23/82	0.261
07/30/82	0.246
08/06/82	0.227
08/13/82	0.220
08/20/82	0.205
08/27/82	0.189
09/03/82	0.148
09/10/82	0.131
09/17/82	0.106
09/24/82	0.098
10/01/82	0.091
10/08/82	0.083
10/15/82	0.076
10/22/82	0.091
10/29/82	0.182
11/05/82	0.220

Date mm/dd/yy	4100 Flow (cms)
11/12/82	0.220
11/19/82	0.159
11/26/82	0.159
12/03/82	0.152
12/10/82	0.136
12/17/82	0.123
12/24/82	0.116
12/31/82	0.114
01/07/83	0.098
01/14/83	0.091
01/21/83	0.113
01/28/83	0.123
02/04/83	0.133
02/11/83	0.227
02/18/83	0.167
02/25/83	0.186
03/04/83	0.197
03/11/83	0.199
03/18/83	0.212
03/25/83	0.197
04/01/83	0.197
04/08/83	0.144
04/15/83	0.125
04/22/83	0.121
04/29/83	0.136
05/06/83	0.159
05/13/83	0.205
05/20/83	0.197
05/27/83	0.273
06/03/83	0.250
06/10/83	0.265
06/17/83	0.197
06/24/83	0.288
07/01/83	0.288
07/08/83	0.303
07/15/83	0.307
07/22/83	0.295
07/29/83	0.303
08/05/83	0.280
08/12/83	0.265
08/19/83	0.197
08/26/83	0.227
09/02/83	0.182
09/09/83	0.182
09/16/83	0.167
09/23/83	0.129
09/30/83	0.152
10/07/83	0.125
10/14/83	0.091
10/21/83	0.083
10/28/83	0.068
11/04/83	0.091
11/11/83	0.121
11/18/83	0.250
11/25/83	0.303
12/02/83	0.258
12/09/83	0.197
12/16/83	0.136
12/23/83	0.136
12/30/83	0.106
01/06/84	0.106
01/13/84	0.131
01/20/84	0.131
01/27/84	0.136
02/03/84	0.129
02/10/84	0.106

Table A-6. 4100 Level Portal Flow (1977-1993) (2/3)

Date mm/dd/yy	4100 Flow (cms)
02/17/84	0.144
02/24/84	0.121
03/02/84	0.121
03/09/84	0.106
03/16/84	0.121
03/23/84	0.136
03/30/84	0.129
04/06/84	0.121
04/13/84	0.121
04/20/84	0.121
04/27/84	0.121
05/04/84	0.114
05/11/84	0.114
05/18/84	0.114
05/25/84	0.136
06/01/84	0.182
06/08/84	0.242
06/15/84	0.227
06/22/84	0.273
06/29/84	0.303
07/06/84	0.364
07/13/84	0.349
07/20/84	0.326
07/27/84	0.280
08/03/84	0.235
08/10/84	0.188
08/17/84	0.174
08/24/84	0.106
08/31/84	0.106
09/07/84	0.091
09/14/84	0.091
09/21/84	0.076
09/28/84	0.080
10/05/84	0.076
10/12/84	0.152
10/19/84	0.227
10/26/84	0.212
11/02/84	0.189
11/09/84	0.152
11/16/84	0.152
11/23/84	0.167
11/30/84	0.114
12/07/84	0.129
12/14/84	0.114
12/21/84	0.091
12/28/84	0.076
01/04/85	0.076
01/11/85	0.061
01/18/85	0.061
01/25/85	0.061
02/01/85	0.061
02/08/85	0.068
02/15/85	0.061
02/22/85	0.057
03/01/85	0.061
03/08/85	0.053
03/15/85	0.053
03/22/85	0.061
03/29/85	0.053
04/05/85	0.053
04/12/85	0.053
04/19/85	0.083
04/26/85	0.091
05/03/85	0.098
05/10/85	0.121
05/17/85	0.091

Date mm/dd/yy	4100 Flow (cms)
05/24/85	0.205
05/31/85	0.212
06/07/85	0.311
06/14/85	0.303
06/21/85	0.303
06/28/85	0.303
07/05/85	0.182
07/12/85	0.212
07/19/85	0.212
07/26/85	0.136
08/02/85	0.117
08/09/85	0.106
08/16/85	0.091
08/23/85	0.091
08/30/85	0.076
09/06/85	0.068
09/13/85	0.045
09/20/85	0.061
09/27/85	0.061
10/04/85	0.045
10/11/85	0.045
10/18/85	0.053
10/25/85	0.106
11/01/85	0.144
11/08/85	0.144
11/15/85	0.136
11/22/85	
11/29/85	0.114
12/06/85	0.098
12/13/85	0.083
12/20/85	
12/27/85	0.068
01/03/86	0.068
01/10/86	0.068
01/17/86	0.068
01/24/86	0.076
01/31/86	0.114
02/07/86	0.114
02/14/86	0.114
02/21/86	0.076
02/28/86	0.114
03/07/86	0.152
03/14/86	0.189
03/21/86	0.182
03/28/86	0.167
04/04/86	0.189
04/11/86	0.182
04/18/86	0.152
04/25/86	0.152
05/02/86	0.152
05/09/86	0.152
05/16/86	0.129
05/23/86	0.091
05/30/86	0.250
06/06/86	0.333
06/13/86	0.371
06/20/86	0.223
06/27/86	0.311
07/04/86	0.277
07/11/86	0.254
07/18/86	0.212
07/25/86	0.159
08/01/86	0.144
08/08/86	0.144
08/15/86	0.136
08/22/86	0.136

Date mm/dd/yy	4100 Flow (cms)
08/29/86	0.106
09/05/86	0.076
09/12/86	0.083
09/19/86	0.091
09/26/86	0.083
10/03/86	0.076
10/10/86	0.076
10/17/86	0.061
10/24/86	0.061
10/31/86	0.061
11/07/86	0.061
11/14/86	0.061
11/21/86	0.068
11/28/86	0.076
12/05/86	0.083
12/12/86	0.076
12/19/86	0.076
12/26/86	0.098
01/02/87	0.091
01/09/87	0.159
01/16/87	0.144
01/23/87	0.136
01/30/87	0.121
02/06/87	0.136
02/13/87	0.140
02/20/87	0.133
02/27/87	0.129
03/06/87	0.235
03/13/87	0.212
03/20/87	
03/27/87	0.144
04/03/87	0.144
04/10/87	0.152
04/17/87	0.144
04/24/87	0.114
05/01/87	0.227
05/08/87	0.458
05/15/87	0.364
05/22/87	0.311
05/29/87	0.314
06/05/87	0.273
06/12/87	0.159
06/19/87	0.292
06/26/87	0.261
07/03/87	0.237
07/10/87	0.197
07/17/87	0.152
07/24/87	0.106
07/31/87	0.114
08/07/87	0.102
08/14/87	0.106
08/21/87	0.091
08/28/87	0.083
09/04/87	0.076
09/11/87	0.076
09/18/87	0.072
09/25/87	0.068
10/02/87	0.068
10/09/87	0.038
10/16/87	0.038
10/23/87	0.038
10/30/87	0.076
11/06/87	0.045
11/13/87	0.045
11/20/87	0.053
11/27/87	0.061

Date mm/dd/yy	4100 Flow (cms)
12/04/87	0.106
12/11/87	0.098
12/18/87	0.068
12/25/87	0.061
01/01/88	0.068
01/08/88	0.068
01/15/88	0.061
01/22/88	0.061
01/29/88	0.061
02/05/88	0.061
02/12/88	0.061
02/19/88	0.068
02/26/88	0.068
03/04/88	0.068
03/11/88	0.068
03/18/88	0.068
03/25/88	0.068
04/01/88	0.068
04/08/88	0.098
04/15/88	0.144
04/22/88	0.144
04/29/88	0.163
05/06/88	0.303
05/13/88	0.326
05/20/88	0.371
05/27/88	0.303
06/03/88	0.311
06/10/88	0.250
06/17/88	0.303
06/24/88	0.265
07/01/88	0.227
07/08/88	0.220
07/15/88	0.189
07/22/88	0.167
07/29/88	0.114
08/05/88	0.114
08/12/88	0.106
08/19/88	0.083
08/26/88	0.091
09/02/88	0.076
09/09/88	0.076
09/16/88	0.038
09/23/88	0.063
09/30/88	0.068
10/07/88	0.068
10/14/88	0.076
10/21/88	0.106
10/28/88	0.182
11/04/88	0.174
11/11/88	0.152
11/18/88	0.121
11/25/88	0.114
12/02/88	0.114
12/09/88	0.114
12/16/88	0.114
12/23/88	0.106
12/30/88	0.106
01/06/89	0.106
01/13/89	0.083
01/20/89	0.076
01/27/89	0.068
02/03/89	0.068
02/10/89	0.068
02/17/89	0.068
02/24/89	0.076
03/03/89	0.076

Date mm/dd/yy	4100 Flow (cms)
03/10/89	0.076
03/17/89	0.068
03/24/89	0.091
03/31/89	0.076
04/07/89	0.205
04/14/89	
04/21/89	0.152
04/28/89	0.152
05/05/89	0.250
05/12/89	0.220
05/19/89	0.235
05/26/89	0.265
06/02/89	0.301
06/09/89	0.265
06/16/89	0.254
06/23/89	0.235
06/30/89	0.208
07/07/89	0.159
07/14/89	0.114
07/21/89	0.098
07/28/89	0.083
08/04/89	0.091
08/11/89	0.091
08/18/89	0.091
08/25/89	0.068
09/01/89	0.068
09/08/89	0.038
09/15/89	0.061
09/22/89	0.061
09/29/89	0.053
10/06/89	0.053
10/13/89	0.076
10/20/89	0.106
10/27/89	0.121
11/03/89	0.121
11/10/89	0.182
11/17/89	0.144
11/24/89	0.152
12/01/89	0.189
12/08/89	0.159
12/15/89	0.114
12/22/89	0.106
12/29/89	0.114
01/05/90	0.098
01/12/90	0.091
01/19/90	0.091
01/26/90	0.091
02/02/90	0.114
02/09/90	0.083
02/16/90	0.083
02/23/90	0.076
03/02/90	0.091
03/09/90	0.076
03/16/90	0.076
03/23/90	0.091
03/30/90	0.083
04/06/90	0.114
04/13/90	0.167
04/20/90	0.174
04/27/90	0.174
05/04/90	0.227
05/11/90	0.212
05/18/90	0.250
05/25/90	0.227
06/01/90	0.242
06/08/90	0.273

Table A-7. 4100 Level Portal Flow (1977-1993) (3/3)

Date mm/dd/yy	4100 Flow (cms)
06/15/90	0.250
06/22/90	0.114
06/29/90	0.197
07/06/90	0.144
07/13/90	0.117
07/20/90	0.106
07/27/90	0.091
08/03/90	0.091
08/10/90	0.091
08/17/90	0.038
08/24/90	0.068
08/31/90	0.061
09/07/90	0.061
09/14/90	0.061
09/21/90	0.053
09/28/90	0.068
10/05/90	0.061
10/12/90	0.068
10/19/90	0.068
10/26/90	0.129
11/02/90	0.227
11/09/90	0.265
11/16/90	0.250
11/23/90	0.227
11/30/90	0.167
12/07/90	0.189
12/14/90	0.114
12/21/90	0.091
12/28/90	0.076
01/04/91	0.076
01/11/91	0.076
01/18/91	0.121
01/25/91	0.166
02/01/91	0.182
02/08/91	0.205
02/15/91	0.220
02/22/91	0.140
03/01/91	0.114
03/08/91	0.098
03/15/91	0.089
03/22/91	0.076
03/29/91	0.083
04/05/91	0.083
04/12/91	0.098
04/19/91	0.121
04/26/91	0.129
05/03/91	0.159
05/10/91	0.197
05/17/91	0.212
05/24/91	0.258
05/31/91	0.235
06/07/91	0.250
06/14/91	0.258
06/21/91	0.227
06/28/91	0.205
07/05/91	0.197
07/12/91	0.159
07/19/91	0.136
07/26/91	0.136
08/02/91	0.121
08/09/91	0.114
08/16/91	
08/23/91	
08/30/91	
09/06/91	0.144
09/13/91	0.114

Date mm/dd/yy	4100 Flow (cms)
09/20/91	
09/27/91	0.083
10/04/91	0.083
10/11/91	0.083
10/18/91	0.057
10/25/91	0.076
11/01/91	0.068
11/08/91	0.076
11/15/91	0.076
11/22/91	0.076
11/29/91	0.068
12/06/91	0.076
12/13/91	0.076
12/20/91	0.076
12/27/91	0.083
01/03/92	0.083
01/10/92	0.106
01/17/92	0.136
01/24/92	0.174
01/31/92	0.159
02/07/92	0.174
02/14/92	0.136
02/21/92	0.159
02/28/92	0.144
03/06/92	0.152
03/13/92	0.144
03/20/92	0.152
03/27/92	0.140
04/03/92	0.174
04/10/92	0.167
04/17/92	0.311
04/24/92	0.280
05/01/92	0.341
05/08/92	0.189
05/15/92	0.182
05/22/92	0.197
05/29/92	0.167
06/05/92	0.152
06/12/92	0.144
06/19/92	0.121
06/26/92	0.114
07/03/92	0.114
07/10/92	0.106
07/17/92	0.098
07/24/92	0.083
07/31/92	0.068
08/07/92	0.068
08/14/92	0.061
08/21/92	0.061
08/28/92	0.057
09/04/92	0.053
09/11/92	0.053
09/18/92	0.053
09/25/92	0.053
10/02/92	0.045
10/09/92	0.053
10/16/92	0.121
10/23/92	0.129
10/30/92	0.152
11/06/92	0.136
11/13/92	0.148
11/20/92	0.114
11/27/92	0.091
12/04/92	0.106
12/11/92	0.114
12/18/92	0.098

Date mm/dd/yy	4100 Flow (cms)
12/25/92	0.068
01/01/93	0.063
01/08/93	0.061
01/15/93	0.057
01/22/93	0.076
01/29/93	0.064
02/05/93	0.064
02/12/93	0.064
02/19/93	0.064
02/26/93	0.064
03/05/93	0.064
03/12/93	0.076
03/19/93	0.076
03/26/93	0.061
04/02/93	0.076
04/09/93	0.087
04/16/93	0.080
04/23/93	0.068
04/30/93	0.080
05/07/93	0.303
05/14/93	0.371
05/21/93	0.349
05/28/93	0.303
06/04/93	0.288
06/11/93	0.227
06/18/93	0.133
06/25/93	0.152
07/02/93	0.121
07/09/93	0.129
07/16/93	0.114
07/23/93	0.106
07/30/93	0.091
08/06/93	0.087
08/13/93	0.083
08/20/93	0.076
08/27/93	0.083
09/03/93	0.076
09/10/93	0.061
09/17/93	0.057
09/24/93	0.053
10/01/93	0.053
10/08/93	0.053
10/15/93	0.053
10/22/93	0.061
10/29/93	0.068
11/05/93	0.061
11/12/93	0.053
11/19/93	0.061
11/26/93	0.076
12/03/93	0.076
12/10/93	0.061
12/17/93	0.061

Table A-8. 4100 Level Portal Flow (1995-1998) (1/2)

Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)
08/09/95	0.081	12/06/95	0.367	02/17/96	0.101	04/23/96	0.164	06/28/96	0.155
08/17/95	0.081	12/07/95	0.317	02/18/96	0.102	04/24/96	0.170	06/29/96	0.154
08/29/95	0.073	12/08/95	0.317	02/19/96	0.103	04/25/96	0.168	06/30/96	0.153
09/06/95	0.073	12/09/95	0.297	02/20/96	0.105	04/26/96	0.171	07/01/96	0.152
09/12/95	0.081	12/10/95	0.297	02/21/96	0.108	04/27/96	0.172	07/02/96	0.151
09/19/95	0.058	12/11/95	0.310	02/22/96	0.111	04/28/96	0.172	07/03/96	0.148
09/20/95	0.061	12/12/95	0.448	02/23/96	0.113	04/29/96	0.173	07/04/96	0.146
09/21/95	0.053	12/13/95	0.336	02/24/96	0.110	04/30/96	0.173	07/05/96	0.143
09/22/95	0.052	12/14/95	0.313	02/25/96	0.106	05/01/96	0.177	07/06/96	0.141
09/23/95	0.050	12/15/95	0.297	02/26/96	0.101	05/02/96	0.178	07/07/96	0.138
09/26/95	0.050	12/16/95	0.309	02/27/96	0.097	05/03/96	0.173	07/08/96	0.136
09/27/95	0.052	12/17/95	0.325	02/28/96	0.094	05/04/96	0.189	07/09/96	0.132
09/29/95	0.052	12/18/95	0.343	02/29/96	0.089	05/05/96	0.198	07/10/96	0.130
10/03/95	0.059	12/19/95	0.358	03/01/96	0.088	05/06/96	0.170	07/11/96	0.129
10/04/95	0.052	12/20/95	0.340	03/02/96	0.082	05/07/96	0.168	07/12/96	0.127
10/05/95	0.050	12/21/95	0.317	03/03/96	0.083	05/08/96	0.156	07/13/96	0.125
10/06/95	0.050	12/22/95	0.349	03/04/96	0.085	05/09/96	0.149	07/14/96	0.124
10/07/95	0.055	12/23/95	0.300	03/05/96	0.086	05/10/96	0.144	07/15/96	0.122
10/09/95	0.052	12/30/95	0.203	03/06/96	0.087	05/11/96	0.141	07/16/96	0.120
10/11/95	0.052	12/31/95	0.183	03/07/96	0.089	05/12/96	0.138	07/17/96	0.118
10/12/95	0.052	01/02/96	0.146	03/08/96	0.090	05/13/96	0.141	07/18/96	0.116
10/14/95	0.059	01/03/96	0.144	03/09/96	0.093	05/14/96	0.157	07/19/96	0.115
10/17/95	0.061	01/04/96	0.140	03/10/96	0.098	05/15/96	0.162	07/20/96	0.112
10/18/95	0.084	01/05/96	0.135	03/11/96	0.112	05/16/96	0.160	07/21/96	0.110
10/20/95	0.086	01/06/96	0.132	03/12/96	0.118	05/17/96	0.159	07/22/96	0.108
10/21/95	0.089	01/07/96	0.132	03/13/96	0.130	05/18/96	0.159	07/23/96	0.106
10/23/95	0.094	01/08/96	0.130	03/14/96	0.130	05/19/96	0.163	07/24/96	0.105
10/24/95	0.105	01/09/96	0.133	03/15/96	0.126	05/20/96	0.170	07/25/96	0.103
10/25/95	0.105	01/10/96	0.133	03/16/96	0.122	05/21/96	0.163	07/26/96	0.101
10/26/95	0.110	01/11/96	0.132	03/17/96	0.119	05/22/96	0.162	07/27/96	0.100
10/27/95	0.112	01/12/96	0.134	03/18/96	0.117	05/23/96	0.159	07/28/96	0.100
10/31/95	0.110	01/13/96	0.134	03/19/96	0.116	05/24/96	0.159	07/29/96	0.098
11/01/95	0.112	01/14/96	0.135	03/20/96	0.115	05/25/96	0.160	07/30/96	0.090
11/02/95	0.110	01/15/96	0.137	03/21/96	0.114	05/26/96	0.161	07/31/96	0.088
11/03/95	0.109	01/16/96	0.141	03/22/96	0.112	05/27/96	0.164	08/01/96	0.087
11/04/95	0.110	01/17/96	0.140	03/23/96	0.111	05/28/96	0.167	08/02/96	0.087
11/05/95	0.116	01/18/96	0.141	03/24/96	0.109	05/29/96	0.172	08/03/96	0.085
11/06/95	0.116	01/19/96	0.144	03/25/96	0.108	05/30/96	0.175	08/04/96	0.085
11/07/95	0.116	01/20/96	0.143	03/26/96	0.107	05/31/96	0.180	08/05/96	0.085
11/08/95	0.112	01/21/96	0.142	03/27/96	0.107	06/01/96	0.183	08/06/96	0.084
11/09/95	0.119	01/22/96	0.140	03/28/96	0.106	06/02/96	0.187	08/07/96	0.082
11/10/95	0.101	01/23/96	0.138	03/29/96	0.102	06/03/96	0.193	08/08/96	0.083
11/11/95	0.101	01/24/96	0.136	03/30/96	0.100	06/04/96	0.197	08/09/96	0.083
11/13/95	0.110	01/25/96	0.132	03/31/96	0.096	06/05/96	0.199	08/10/96	0.081
11/14/95	0.122	01/26/96	0.129	04/01/96	0.096	06/06/96	0.200	08/11/96	0.078
11/15/95	0.125	01/27/96	0.127	04/02/96	0.093	06/07/96	0.203	08/12/96	0.078
11/16/95	0.110	01/28/96	0.124	04/03/96	0.092	06/08/96	0.207	08/13/96	0.077
11/17/95	0.125	01/29/96	0.122	04/04/96	0.086	06/09/96	0.214	08/14/96	0.076
11/18/95	0.145	01/30/96	0.117	04/05/96	0.084	06/10/96	0.220	08/15/96	0.075
11/19/95	0.164	01/31/96	0.113	04/06/96	0.085	06/11/96	0.221	08/16/96	0.074
11/20/95	0.195	02/01/96	0.110	04/07/96	0.086	06/12/96	0.222	08/17/96	0.073
11/21/95	0.238	02/02/96	0.107	04/08/96	0.086	06/13/96	0.221	08/18/96	0.072
11/22/95	0.244	02/03/96	0.104	04/09/96	0.086	06/14/96	0.222	08/19/96	0.072
11/23/95	0.282	02/04/96	0.102	04/10/96	0.090	06/15/96	0.219	08/20/96	0.071
11/24/95	0.319	02/05/96	0.101	04/11/96	0.092	06/16/96	0.215	08/21/96	0.071
11/25/95	0.317	02/06/96	0.102	04/12/96	0.098	06/17/96	0.209	08/22/96	0.071
11/26/95	0.340	02/07/96	0.103	04/13/96	0.105	06/18/96	0.205	08/23/96	0.070
11/27/95	0.344	02/08/96	0.105	04/14/96	0.111	06/19/96	0.200	08/24/96	0.070
11/28/95	0.355	02/09/96	0.109	04/15/96	0.119	06/20/96	0.196	08/25/96	0.068
11/29/95	0.396	02/10/96	0.110	04/16/96	0.124	06/21/96	0.192	08/26/96	0.066
11/30/95	0.438	02/11/96	0.110	04/17/96	0.131	06/22/96	0.187	08/27/96	0.062
12/01/95	0.405	02/12/96	0.108	04/18/96	0.136	06/23/96	0.181	08/28/96	0.058
12/02/95	0.370	02/13/96	0.103	04/19/96	0.143	06/24/96	0.177	08/29/96	0.057
12/03/95	0.383	02/14/96	0.102	04/20/96	0.150	06/25/96	0.169	08/30/96	0.057
12/04/95	0.376	02/15/96	0.101	04/21/96	0.155	06/26/96	0.164	08/31/96	0.057
12/05/95	0.367	02/16/96	0.100	04/22/96	0.160	06/27/96	0.159	09/01/96	0.058

Table A-9. 4100 Level Portal Flows (1995-1998) (2/2)

Date mm/dd/yy	Flow (cms)
09/02/96	0.058
09/03/96	0.060
09/04/96	0.060
09/05/96	0.059
09/06/96	0.059
09/07/96	0.059
09/08/96	0.059
09/09/96	0.059
09/10/96	0.059
09/11/96	0.059
09/12/96	0.058
09/13/96	0.058
09/14/96	0.058
09/15/96	0.057
09/16/96	0.057
09/17/96	0.057
09/18/96	0.057
09/19/96	0.057
09/20/96	0.056
09/21/96	0.056
09/22/96	0.055
09/23/96	0.056
09/24/96	0.056
09/25/96	0.056
09/26/96	0.056
09/27/96	0.056
09/28/96	0.055
09/29/96	0.055
09/30/96	0.055
10/01/96	0.055
10/02/96	0.055
10/03/96	0.055
10/04/96	0.055
10/05/96	0.056
10/06/96	0.056
10/07/96	0.057
10/08/96	0.057
10/09/96	0.058
10/10/96	0.060
10/11/96	0.061
10/12/96	0.063
10/13/96	0.066
10/14/96	0.070
10/15/96	0.074
10/16/96	0.077
10/17/96	0.079
10/18/96	0.083
10/19/96	0.087
10/20/96	0.086
10/21/96	0.086
10/22/96	0.089
10/23/96	0.091
10/24/96	0.093
10/25/96	0.096
10/26/96	0.095
10/27/96	0.094
10/28/96	0.095
10/29/96	0.101
10/30/96	0.098
10/31/96	0.099
11/01/96	0.100
11/02/96	0.101
11/03/96	0.103
11/04/96	0.103
11/05/96	0.103
11/06/96	0.103
11/07/96	0.106
11/08/96	0.106
11/09/96	0.112
11/10/96	0.111
11/11/96	0.110
11/12/96	0.113
11/13/96	0.116
11/14/96	0.121
11/15/96	0.128
11/16/96	0.136
11/17/96	0.143
11/18/96	0.151
11/19/96	0.156
11/20/96	0.164
11/21/96	0.165
11/22/96	0.168
11/23/96	0.166
11/24/96	0.165
11/25/96	0.164
11/26/96	0.161
11/27/96	0.158
11/28/96	0.159
11/29/96	0.155
11/30/96	0.151
12/01/96	0.149
12/02/96	0.144
12/03/96	0.143
12/04/96	0.137
12/05/96	0.137
12/06/96	0.133
12/07/96	0.133
12/08/96	0.132
12/09/96	0.130
12/10/96	0.127
12/11/96	0.123
12/12/96	0.121
12/13/96	0.119
12/14/96	0.117
12/15/96	0.112
12/16/96	0.111
12/17/96	0.107
12/18/96	0.104
12/19/96	0.102
12/20/96	0.100
12/21/96	0.101
12/22/96	0.098
12/23/96	0.095
12/24/96	0.091
12/25/96	0.090
12/26/96	0.088
12/27/96	0.087
12/28/96	0.085
12/29/96	0.084
12/30/96	0.082
12/31/96	0.081
01/01/97	0.094
01/16/97	0.095
01/17/97	0.094
01/18/97	0.097
01/19/97	0.099
01/20/97	0.108
01/21/97	0.102
01/22/97	0.105
01/23/97	0.109
01/24/97	0.113
01/25/97	0.116
01/26/97	0.117
01/27/97	0.117
01/28/97	0.118
01/29/97	0.120
01/30/97	0.121
01/31/97	0.129
02/01/97	0.123
02/02/97	0.125
02/03/97	0.127
02/04/97	0.127
02/05/97	0.127
02/06/97	0.100
02/07/97	0.082
02/08/97	0.081
02/09/97	0.081
02/10/97	0.080
02/11/97	0.079
02/12/97	0.079
02/13/97	0.078
02/14/97	0.076
02/15/97	0.075
02/16/97	0.076
02/17/97	0.076
02/18/97	0.075
02/19/97	0.074
02/20/97	0.076
02/21/97	0.075
02/22/97	0.073
02/23/97	0.070
02/24/97	0.069
02/25/97	0.069
02/26/97	0.067
03/01/97	0.064
03/02/97	0.075
03/03/97	0.176
03/04/97	0.075
07/09/97	0.239
09/10/97	0.065
10/15/97	0.199
10/23/97	0.172
10/25/97	0.160
10/26/97	0.159
10/27/97	0.159
10/28/97	0.156
10/29/97	0.155
10/30/97	0.161
10/31/97	0.148
11/01/97	0.147
11/02/97	0.147
11/03/97	0.155
11/04/97	0.154
11/05/97	0.155
11/06/97	0.161
11/07/97	0.164
11/08/97	0.168
11/09/97	0.172
11/10/97	0.188
11/11/97	0.190
11/12/97	0.191
11/13/97	0.192
11/14/97	0.188
11/15/97	0.186
11/16/97	0.183
11/17/97	0.178
11/18/97	0.172
11/19/97	0.166
11/20/97	0.161
11/21/97	0.155
11/22/97	0.150
11/23/97	0.147
11/24/97	0.143
11/25/97	0.139
11/26/97	0.138
11/27/97	0.140
11/28/97	0.141
11/29/97	0.140
11/30/97	0.139
12/01/97	0.139
12/02/97	0.135
12/03/97	0.135
12/04/97	0.136
12/05/97	0.135
12/06/97	0.134
12/07/97	0.134
12/08/97	0.130
12/09/97	0.128
12/10/97	0.125
12/11/97	0.124
12/12/97	0.122
12/13/97	0.119
12/14/97	0.117
12/15/97	0.114
12/16/97	0.116
12/17/97	0.113
12/18/97	0.108
12/19/97	0.108
12/20/97	0.107
12/21/97	0.103
12/22/97	0.100
12/23/97	0.098
12/24/97	0.095
12/25/97	0.093
12/26/97	0.092
12/27/97	0.090
12/28/97	0.091
12/29/97	0.096
12/30/97	0.091
12/31/97	0.089
01/01/98	0.090
01/02/98	0.089
01/03/98	0.090
01/04/98	0.090
01/05/98	0.091
02/11/98	0.111
04/22/98	0.079
05/12/98	0.278

Table A-10. Jane Creek Flow (1995-1998) (1/3)

Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)	Date mm/dd/yy	Flow (cms)
11/15/95	0.143	03/03/96	0.042	05/08/96	0.064	07/13/96	0.023	09/17/96	0.029	11/22/96	0.056
11/28/95	0.133	03/04/96	0.042	05/09/96	0.061	07/14/96	0.022	09/18/96	0.027	11/23/96	0.056
12/12/95	0.175	03/05/96	0.039	05/10/96	0.057	07/15/96	0.022	09/19/96	0.026	11/24/96	0.051
12/19/95	0.113	03/06/96	0.039	05/11/96	0.053	07/16/96	0.021	09/20/96	0.026	11/25/96	0.048
01/01/96	0.066	03/07/96	0.038	05/12/96	0.058	07/17/96	0.026	09/21/96	0.025	11/26/96	0.048
01/02/96	0.065	03/08/96	0.044	05/13/96	0.085	07/18/96	0.026	09/22/96	0.025	11/27/96	0.077
01/03/96	0.106	03/09/96	0.077	05/14/96	0.075	07/19/96	0.031	09/23/96	0.023	11/28/96	0.108
01/04/96	0.106	03/10/96	0.108	05/15/96	0.071	07/20/96	0.025	09/24/96	0.023	11/29/96	0.065
01/05/96	0.083	03/11/96	0.122	05/16/96	0.069	07/21/96	0.024	09/25/96	0.021	11/30/96	0.071
01/06/96	0.074	03/12/96	0.097	05/17/96	0.084	07/22/96	0.024	09/26/96	0.022	12/01/96	0.069
01/07/96	0.116	03/13/96	0.081	05/18/96	0.136	07/23/96	0.022	09/27/96	0.021	12/02/96	0.060
01/08/96	0.108	03/14/96	0.075	05/19/96	0.122	07/24/96	0.021	09/28/96	0.021	12/03/96	0.051
01/09/96	0.167	03/15/96	0.071	05/20/96	0.105	07/25/96	0.021	09/29/96	0.021	12/04/96	0.050
01/10/96	0.164	03/16/96	0.066	05/21/96	0.097	07/26/96	0.020	09/30/96	0.021	12/05/96	0.046
01/11/96	0.131	03/17/96	0.062	05/22/96	0.093	07/27/96	0.019	10/01/96	0.020	12/06/96	0.045
01/12/96	0.123	03/18/96	0.058	05/23/96	0.087	07/28/96	0.018	10/02/96	0.020	12/07/96	0.042
01/13/96	0.106	03/19/96	0.061	05/24/96	0.081	07/29/96	0.019	10/03/96	0.031	12/08/96	0.041
01/14/96	0.113	03/20/96	0.061	05/25/96	0.078	07/30/96	0.019	10/04/96	0.100	12/09/96	0.040
01/15/96	0.178	03/21/96	0.058	05/26/96	0.074	07/31/96	0.019	10/05/96	0.051	12/10/96	0.048
01/16/96	0.230	03/22/96	0.054	05/27/96	0.073	08/01/96	0.019	10/06/96	0.040	12/11/96	0.042
01/17/96	0.142	03/23/96	0.051	05/28/96	0.071	08/02/96	0.019	10/07/96	0.036	12/12/96	0.038
01/18/96	0.107	03/24/96	0.048	05/29/96	0.064	08/03/96	0.020	10/08/96	0.034	12/13/96	0.036
01/19/96	0.092	03/25/96	0.045	05/30/96	0.060	08/04/96	0.021	10/09/96	0.032	12/14/96	0.035
01/20/96	0.081	03/26/96	0.044	05/31/96	0.058	08/05/96	0.020	10/10/96	0.045	12/15/96	0.035
01/21/96	0.073	03/27/96	0.042	06/01/96	0.054	08/06/96	0.019	10/11/96	0.046	12/16/96	0.034
01/22/96	0.066	03/28/96	0.039	06/02/96	0.053	08/07/96	0.020	10/12/96	0.048	12/17/96	0.033
01/23/96	0.061	03/29/96	0.038	06/03/96	0.051	08/08/96	0.019	10/13/96	0.068	12/18/96	0.033
01/24/96	0.056	03/30/96	0.037	06/04/96	0.051	08/09/96	0.019	10/14/96	0.108	12/19/96	0.032
01/25/96	0.054	03/31/96	0.038	06/05/96	0.050	08/10/96	0.018	10/15/96	0.088	12/20/96	0.031
01/26/96	0.053	04/01/96	0.045	06/06/96	0.048	08/11/96	0.018	10/16/96	0.067	12/21/96	0.031
01/27/96	0.053	04/02/96	0.041	06/07/96	0.048	08/12/96	0.018	10/17/96	0.065	12/22/96	0.031
01/28/96	0.054	04/03/96	0.039	06/08/96	0.048	08/13/96	0.017	10/18/96	0.074	12/23/96	0.030
01/29/96	0.053	04/04/96	0.038	06/09/96	0.046	08/14/96	0.016	10/19/96	0.061	12/24/96	0.029
01/30/96	0.052	04/05/96	0.054	06/10/96	0.046	08/15/96	0.018	10/20/96	0.055	12/25/96	0.029
01/31/96	0.053	04/06/96	0.095	06/11/96	0.046	08/16/96	0.019	10/21/96	0.068	12/26/96	0.029
02/01/96	0.054	04/07/96	0.093	06/12/96	0.044	08/17/96	0.018	10/22/96	0.069	12/27/96	0.029
02/02/96	0.053	04/08/96	0.083	06/13/96	0.042	08/18/96	0.018	10/23/96	0.074	12/28/96	0.028
02/03/96	0.054	04/09/96	0.087	06/14/96	0.042	08/19/96	0.017	10/24/96	0.088	12/29/96	0.028
02/04/96	0.045	04/10/96	0.085	06/15/96	0.040	08/20/96	0.018	10/25/96	0.073	12/30/96	0.028
02/05/96	0.054	04/11/96	0.091	06/16/96	0.038	08/21/96	0.016	10/26/96	0.061	12/31/96	0.053
02/06/96	0.078	04/12/96	0.099	06/17/96	0.038	08/22/96	0.015	10/27/96	0.057	01/01/97	0.157
02/07/96	0.075	04/13/96	0.086	06/18/96	0.038	08/23/96	0.018	10/28/96	0.134	01/02/97	0.114
02/08/96	0.085	04/14/96	0.081	06/19/96	0.036	08/24/96	0.017	10/29/96	0.099	01/03/97	0.073
02/09/96	0.083	04/15/96	0.107	06/20/96	0.036	08/25/96	0.017	10/30/96	0.078	01/04/97	0.052
02/10/96	0.063	04/16/96	0.149	06/21/96	0.035	08/26/96	0.017	10/31/96	0.070	01/05/97	0.044
02/11/96	0.055	04/17/96	0.160	06/22/96	0.033	08/27/96	0.016	11/01/96	0.063	01/06/97	0.040
02/12/96	0.052	04/18/96	0.141	06/23/96	0.032	08/28/96	0.016	11/02/96	0.060	01/07/97	0.039
02/13/96	0.052	04/19/96	0.118	06/24/96	0.032	08/29/96	0.015	11/03/96	0.060	01/08/97	0.037
02/14/96	0.052	04/20/96	0.099	06/25/96	0.032	08/30/96	0.020	11/04/96	0.055	01/09/97	0.037
02/15/96	0.052	04/21/96	0.088	06/26/96	0.031	08/31/96	0.018	11/05/96	0.050	01/10/97	0.037
02/16/96	0.053	04/22/96	0.093	06/27/96	0.031	09/01/96	0.017	11/06/96	0.052	01/11/97	0.035
02/17/96	0.058	04/23/96	0.176	06/28/96	0.030	09/02/96	0.016	11/07/96	0.048	01/12/97	0.031
02/18/96	0.112	04/24/96	0.146	06/29/96	0.028	09/03/96	0.020	11/08/96	0.118	01/13/97	0.029
02/19/96	0.120	04/25/96	0.136	06/30/96	0.027	09/04/96	0.019	11/09/96	0.117	01/14/97	0.028
02/20/96	0.128	04/26/96	0.128	07/01/96	0.026	09/05/96	0.019	11/10/96	0.092	01/15/97	0.026
02/21/96	0.125	04/27/96	0.105	07/02/96	0.025	09/06/96	0.018	11/11/96	0.084	01/16/97	0.027
02/22/96	0.095	04/28/96	0.097	07/03/96	0.025	09/07/96	0.026	11/12/96	0.105	01/17/97	0.068
02/23/96	0.083	04/29/96	0.090	07/04/96	0.026	09/08/96	0.024	11/13/96	0.133	01/18/97	0.070
02/24/96	0.072	04/30/96	0.082	07/05/96	0.026	09/09/96	0.020	11/14/96	0.105	01/19/97	0.173
02/25/96	0.064	05/01/96	0.077	07/06/96	0.025	09/10/96	0.018	11/15/96	0.093	01/20/97	0.148
02/26/96	0.060	05/02/96	0.074	07/07/96	0.025	09/11/96	0.018	11/16/96	0.086	01/21/97	0.085
02/27/96	0.058	05/03/96	0.073	07/08/96	0.024	09/12/96	0.018	11/17/96	0.077	01/22/97	0.068
02/28/96	0.058	05/04/96	0.067	07/09/96	0.024	09/13/96	0.020	11/18/96	0.069	01/23/97	0.058
02/29/96	0.056	05/05/96	0.063	07/10/96	0.024	09/14/96	0.046	11/19/96	0.067	01/24/97	0.051
03/01/96	0.048	05/06/96	0.063	07/11/96	0.024	09/15/96	0.043	11/20/96	0.064	01/25/97	0.049
03/02/96	0.045	05/07/96	0.067	07/12/96	0.023	09/16/96	0.034	11/21/96	0.058	01/26/97	0.048

Table A-11. Jane Creek Flow (1995-1998) (2/3)

Date mm/dd/yy	Flow (cms)
01/27/97	0.044
01/28/97	0.039
01/29/97	0.066
01/30/97	0.172
01/31/97	0.088
02/01/97	0.068
02/02/97	0.059
02/03/97	0.051
02/04/97	0.046
02/05/97	0.041
02/06/97	0.038
02/07/97	0.035
02/08/97	0.032
02/09/97	0.030
02/10/97	0.028
02/11/97	0.027
02/12/97	0.026
02/13/97	0.024
02/14/97	0.029
02/15/97	0.046
02/16/97	0.045
02/17/97	0.060
02/18/97	0.048
02/19/97	0.044
02/20/97	0.037
02/21/97	0.033
02/22/97	0.030
02/23/97	0.029
02/24/97	0.029
02/25/97	0.029
02/26/97	0.027
02/27/97	0.025
02/28/97	0.024
03/01/97	0.024
03/02/97	0.025
03/03/97	0.023
03/04/97	0.021
03/05/97	0.021
03/06/97	0.022
03/07/97	0.025
03/08/97	0.022
03/09/97	0.023
03/10/97	0.023
03/11/97	0.022
03/12/97	0.021
03/13/97	0.020
03/14/97	0.018
03/15/97	0.020
03/16/97	0.017
03/17/97	0.052
03/18/97	0.212
03/19/97	0.297
03/20/97	0.145
03/21/97	0.084
03/22/97	0.069
03/23/97	0.061
03/24/97	0.053
03/25/97	0.055
03/26/97	0.060
03/27/97	0.052
03/28/97	0.046
03/29/97	0.045
03/30/97	0.042
03/31/97	0.041
04/01/97	0.038
04/02/97	0.035

Date mm/dd/yy	Flow (cms)
04/03/97	0.033
04/04/97	0.030
04/05/97	0.030
04/06/97	0.029
04/07/97	0.028
04/08/97	0.027
04/09/97	0.028
04/10/97	0.028
04/11/97	0.029
04/12/97	0.029
04/13/97	0.033
04/14/97	0.034
04/15/97	0.082
04/16/97	0.246
04/17/97	0.130
04/18/97	0.088
04/19/97	0.088
04/20/97	0.146
04/21/97	0.105
04/22/97	0.092
04/23/97	0.111
04/24/97	0.102
04/25/97	0.106
04/26/97	0.158
04/27/97	0.161
04/28/97	0.127
04/29/97	0.117
04/30/97	0.105
05/01/97	0.096
05/02/97	0.088
05/03/97	0.114
05/04/97	0.127
05/05/97	0.193
05/06/97	0.182
05/07/97	0.144
05/08/97	0.128
05/09/97	0.129
05/10/97	0.129
05/11/97	0.137
05/12/97	0.148
05/13/97	0.150
05/14/97	0.152
05/15/97	0.153
05/16/97	0.142
05/17/97	0.127
05/18/97	0.111
05/19/97	0.104
05/20/97	0.094
05/21/97	0.090
05/22/97	0.100
05/23/97	0.103
05/24/97	0.097
05/25/97	0.094
05/26/97	0.093
05/27/97	0.089
05/28/97	0.096
05/29/97	0.110
05/30/97	0.111
05/31/97	0.142
06/01/97	0.122
06/02/97	0.115
06/03/97	0.116
06/04/97	0.118
06/05/97	0.106
06/06/97	0.100
06/07/97	0.094

Date mm/dd/yy	Flow (cms)
06/08/97	0.086
06/09/97	0.080
06/10/97	0.076
06/11/97	0.072
06/12/97	0.068
06/13/97	0.065
06/14/97	0.062
06/15/97	0.062
06/16/97	0.066
06/17/97	0.100
06/18/97	0.083
06/19/97	0.078
06/20/97	0.075
06/21/97	0.081
06/22/97	0.088
06/23/97	0.095
06/24/97	0.089
06/25/97	0.089
06/26/97	0.087
06/27/97	0.084
06/28/97	0.078
06/29/97	0.074
06/30/97	0.070
07/01/97	0.067
07/02/97	0.063
07/03/97	0.060
07/04/97	0.057
07/05/97	0.058
07/06/97	0.055
07/07/97	0.054
07/08/97	0.139
07/09/97	0.105
07/10/97	0.084
07/11/97	0.077
07/12/97	0.071
07/13/97	0.067
07/14/97	0.063
07/15/97	0.061
07/16/97	0.057
07/17/97	0.055
07/18/97	0.052
07/19/97	0.050
07/20/97	0.047
07/21/97	0.048
07/22/97	0.046
07/23/97	0.043
07/24/97	0.043
07/25/97	0.042
07/26/97	0.041
07/27/97	0.039
07/28/97	0.038
07/29/97	0.037
07/30/97	0.036
07/31/97	0.036
08/01/97	0.035
08/02/97	0.034
08/03/97	0.033
08/04/97	0.032
08/05/97	0.032
08/06/97	0.032
08/07/97	0.031
08/08/97	0.030
08/09/97	0.028
08/10/97	0.028
08/11/97	0.027
08/12/97	0.027

Date mm/dd/yy	Flow (cms)
08/13/97	0.027
08/14/97	0.026
08/15/97	0.025
08/16/97	0.025
08/17/97	0.024
08/18/97	0.024
08/19/97	0.023
08/20/97	0.025
08/21/97	0.027
08/22/97	0.025
08/23/97	0.026
08/24/97	0.026
08/25/97	0.027
08/26/97	0.050
08/27/97	0.048
08/28/97	0.037
08/29/97	0.032
08/30/97	0.030
08/31/97	0.029
09/01/97	0.028
09/02/97	0.027
09/03/97	0.026
09/04/97	0.027
09/05/97	0.026
09/06/97	0.025
09/07/97	0.025
09/08/97	0.024
09/09/97	0.024
09/10/97	0.024
09/11/97	0.025
09/12/97	0.026
09/13/97	0.025
09/14/97	0.058
09/15/97	0.075
09/16/97	0.053
09/17/97	0.108
09/18/97	0.066
09/19/97	0.052
09/20/97	0.049
09/21/97	0.047
09/22/97	0.046
09/23/97	0.045
09/24/97	0.044
09/25/97	0.046
09/26/97	0.080
09/27/97	0.091
09/28/97	0.107
09/29/97	0.080
09/30/97	0.122
10/01/97	0.195
10/02/97	0.222
10/03/97	0.158
10/04/97	0.154
10/05/97	0.153
10/06/97	0.129
10/07/97	0.113
10/08/97	0.128
10/09/97	0.157
10/10/97	0.210
10/11/97	0.140
10/12/97	0.117
10/13/97	0.106
10/14/97	0.096
10/15/97	0.097
10/16/97	0.092
10/17/97	0.085

Date mm/dd/yy	Flow (cms)
10/18/97	0.077
10/19/97	0.072
10/20/97	0.067
10/21/97	0.062
10/22/97	0.059
10/23/97	0.056
10/24/97	0.054
10/25/97	0.052
10/26/97	0.076
10/27/97	0.063
10/28/97	0.065
10/29/97	0.117
10/30/97	0.191
10/31/97	0.125
11/01/97	0.104
11/02/97	0.096
11/03/97	0.141
11/04/97	0.114
11/05/97	0.113
11/06/97	0.154
11/07/97	0.126
11/08/97	0.105
11/09/97	0.095
11/10/97	0.085
11/11/97	0.077
11/12/97	0.071
11/13/97	0.066
11/14/97	0.061
11/15/97	0.057
11/16/97	0.054
11/17/97	0.053
11/18/97	0.052
11/19/97	0.048
11/20/97	0.051
11/21/97	0.048
11/22/97	0.047
11/23/97	0.088
11/24/97	0.087
11/25/97	0.067
11/26/97	0.061
11/27/97	0.081
11/28/97	0.146
11/29/97	0.193
11/30/97	0.164
12/01/97	0.113
12/02/97	0.095
12/03/97	0.082
12/04/97	0.072
12/05/97	0.066
12/06/97	0.063
12/07/97	0.059
12/08/97	0.056
12/09/97	0.050
12/10/97	0.049
12/11/97	0.047
12/12/97	0.046
12/13/97	0.044
12/14/97	0.047
12/15/97	0.046
12/16/97	0.092
12/17/97	0.090
12/18/97	0.064
12/19/97	0.055
12/20/97	0.052
12/21/97	0.047
12/22/97	0.044

Date mm/dd/yy	Flow (cms)
12/23/97	0.043
12/24/97	0.041
12/25/97	0.039
12/26/97	0.039
12/27/97	0.038
12/28/97	0.046
12/29/97	0.118
12/30/97	0.114
12/31/97	0.092
01/01/98	0.077
01/02/98	0.061
01/03/98	0.052
01/04/98	0.044
01/05/98	0.039
01/06/98	0.036
01/07/98	0.031
01/08/98	0.031
01/09/98	0.029
01/10/98	0.030
01/11/98	0.029
01/12/98	0.030
01/13/98	0.030
01/14/98	0.054
01/15/98	0.053
01/16/98	0.036
01/17/98	0.046
01/18/98	0.061
01/19/98	0.094
01/20/98	0.061
01/21/98	0.046
01/22/98	0.039
01/23/98	0.135
01/24/98	0.176
01/25/98	0.132
01/26/98	0.140
01/27/98	0.095
01/28/98	0.081
01/29/98	0.100
01/30/98	0.100
01/31/98	0.078
02/01/98	0.068
02/02/98	0.079
02/03/98	0.067
02/04/98	0.065
02/05/98	0.097
02/06/98	0.080
02/07/98	0.077
02/08/98	0.082
02/09/98	0.089
02/10/98	0.072
02/11/98	0.066
02/12/98	0.115
02/13/98	0.136
02/14/98	0.088
02/15/98	0.069
02/16/98	0.059
02/17/98	0.053
02/18/98	0.079
02/19/98	0.131
02/20/98	0.124
02/21/98	0.113
02/22/98	0.078
02/23/98	0.061
02/24/98	0.052
02/25/98	0.047
02/26/98	0.042

Table A-12. Jane Creek Flow (1995-1998) (3/3)

Date mm/dd/yy	Flow (cms)
02/27/98	0.037
02/28/98	0.036
03/01/98	0.038
03/02/98	0.034
03/03/98	0.031
03/04/98	0.029
03/05/98	0.026
03/06/98	0.025
03/07/98	0.023
03/08/98	0.023
03/09/98	0.024
03/10/98	0.025
03/11/98	0.033
03/12/98	0.052
03/13/98	0.074
03/14/98	0.078
03/15/98	0.072
03/16/98	0.067
03/17/98	0.058
03/18/98	0.050
03/19/98	0.048
03/20/98	0.046
03/21/98	0.051
03/22/98	0.087
03/23/98	0.079
03/24/98	0.079
03/25/98	0.069
03/26/98	0.062
03/27/98	0.057
03/28/98	0.051
03/29/98	0.046
03/30/98	0.043
03/31/98	0.041
04/01/98	0.039
04/02/98	0.037
04/03/98	0.034
04/04/98	0.032
04/05/98	0.035
04/06/98	0.035
04/07/98	0.035
04/08/98	0.033
04/09/98	0.030
04/10/98	0.029
04/11/98	0.031
04/12/98	0.030
04/13/98	0.029
04/14/98	0.029
04/15/98	0.026
04/16/98	0.025
04/17/98	0.024
04/18/98	0.029
04/19/98	0.029
04/20/98	0.028
04/21/98	0.031
04/22/98	0.038
04/23/98	0.052
04/24/98	0.057
04/25/98	0.047
04/26/98	0.045
04/27/98	0.046
04/28/98	0.052
04/29/98	0.059
04/30/98	0.070
05/01/98	0.080
05/02/98	0.087
05/03/98	0.086
05/04/98	0.083
05/05/98	0.082
05/06/98	0.081
05/07/98	0.077
05/08/98	0.075
05/09/98	0.071
05/10/98	0.067
05/11/98	0.063
05/12/98	0.060
05/13/98	0.057
05/14/98	0.059
05/15/98	0.062
05/16/98	0.053
05/17/98	0.048
05/18/98	0.046
05/19/98	0.043
05/20/98	0.042
05/21/98	0.040
05/22/98	0.039
05/23/98	0.040
05/24/98	0.042
05/25/98	0.052
05/26/98	0.046
05/27/98	0.063
05/28/98	0.051
05/29/98	0.046
05/30/98	0.041
05/31/98	0.040
06/01/98	0.038
06/02/98	0.036
06/03/98	0.034
06/04/98	0.033
06/05/98	0.033
06/06/98	0.031
06/07/98	0.029
06/08/98	0.028
06/09/98	0.027
06/10/98	0.028
06/11/98	0.027
06/12/98	0.026
06/13/98	0.025
06/14/98	0.024
06/15/98	0.024
06/16/98	0.024
06/17/98	0.023
06/18/98	0.023

Table A-13. Pressure Data (1/2)

Date	pipes open (x) 4"	6"	10"	pressure (psi) 4"	6"	10"
05/09/80		x			40	
05/16/80		x			60	40
05/23/80		x		40	60	50
05/30/80				50	55	45
06/06/80	x			70	75	70
06/13/80	x			100	90	90
06/20/80	x			130	125	125
06/27/80	x			140	130	130
07/04/80	x				135	140
07/11/80	x			140	135	135
07/18/80	x			140	140	140
07/25/80	x			125	125	125
08/01/80	x			120	100	100
08/08/80	x			85	85	85
08/15/80	x			65	65	65
08/22/80	x				62	62
08/29/80	x				45	45
09/05/80	x				42	42
09/12/80	x				30	30
09/19/80	x			20	20	25
09/26/80	x			23	18	18
10/03/80	x			20	25	25
10/10/80	x			18	20	20
10/17/80	x			18	20	20
10/24/80	x			20	20	20
10/31/80	x			20	20	20
11/07/80	x			23	23	23
11/14/80	x			50	50	50
11/21/80	x			60	60	60
11/28/80	x			80	80	80
12/05/80	x			90	90	90
12/12/80	x			80	80	80
12/19/80	x			90	90	90
12/26/80	x			100	100	100
01/02/81	x			170	170	170
01/09/81	x			190	190	190
01/16/81	x			180	180	180
01/23/81	x			155	155	155
01/30/81	x			155	155	155
02/06/81	x			118	118	118
02/13/81	x			107	107	107
02/20/81	x			100	100	100
02/27/81	x			90	90	90
03/06/81	x			90	90	90
03/13/81	x			75	75	75
03/20/81	x			60	60	60
03/27/81	x			60	60	60
04/03/81		x		10	10	10
04/10/81		x		90		10
04/17/81		x		0		
04/24/81		x				0
05/01/81		x				10
05/08/81		x				15
05/15/81		x				30
05/22/81		x			40	
05/29/81		x		55		50
06/05/81		x		55	55	55
06/12/81		x				
06/19/81		x		65		65
06/26/81		x		54		54
07/03/81		x		50		50
07/10/81		x		45		45
07/17/81		x		25		25
07/24/81		x		15		15
07/31/81		x		10		10
08/07/81		x		10		10
08/14/81		x			0	
08/21/81		x			0	
08/28/81		x			0	
09/04/81		x			0	
09/11/81		x			0	
09/18/81		x			0	
09/25/81		x			0	
10/02/81		x			0	
10/09/81		x			0	
10/16/81		x			20	
10/23/81		x		20		20
10/30/81		x		10		10
11/06/81		x		80	80	80
11/13/81		x		80		80
11/20/81		x		80		80
11/27/81		x		65		65
12/04/81		x		65		
12/11/81		x		60		
12/18/81		x			55	
12/25/81		x			30	
01/01/82		x			17	
01/08/82		x		10		10
01/15/82		x		5		5
01/22/82		x		0	0	
01/29/82		x		0	0	
02/05/82		x		0		0
02/12/82		x		0		0
02/19/82		x		0		0
02/26/82		x		0		0
03/05/82		x		0		0
03/12/82		x		0		0
03/19/82		x		0	0	0
03/26/82		x		0		0
04/02/82		x		0		0
04/09/82		x		0		0
04/16/82		x		0		0
04/23/82		x		0		0
04/30/82		x		0		0
05/07/82		x		0		0
05/14/82		x		0		0
05/21/82		x		0		0
05/28/82		x		26		26
06/04/82		x		70		80
06/11/82		x		84		82
06/18/82		x		125		125
06/25/82	x				200	200
07/02/82	x				265	265
07/09/82						
07/16/82	x				305	305
07/23/82	x				290	290
07/30/82	x				270	270
08/06/82	x				240	240
08/13/82	x				230	230
08/20/82	x				165	165
08/27/82	x				165	165
09/03/82	x				100	100
09/10/82	x			65	65	65
09/17/82	x			45	45	45
09/24/82	x				25	25
10/01/82	x				20	20
10/08/82	x				20	20
10/15/82	x				15	15
10/22/82		x			12	
10/29/82		x		30		30
11/05/82		x			50	
11/12/82		x			50	
11/19/82		x		35		
11/26/82		x		25		
12/03/82		x		35		35
12/10/82		x		30		30
12/17/82		x		30		30
12/24/82		x		30		30
12/31/82		x		0		0
01/07/83		x		0		0
01/14/83		x		0		0
01/21/83		x		25		25
01/28/83		x				
02/04/83		x		12		
02/11/83		x		25		25
02/18/83		x		25		25
02/25/83		x		25		25
03/04/83		x		30		30
03/11/83		x		27		27
03/18/83		x		35	35	35
03/25/83		x		25		25
04/01/83		x		30		30
04/08/83		x		20		20
04/15/83		x		25	0	25
04/22/83		x		15		15
04/29/83		x		20		20
05/06/83		x		30		30
05/13/83		x		40		40
05/20/83		x		40		40
05/27/83		x		65		65
06/03/83	x				140	150
06/10/83	x				225	225
06/17/83	x				260	260
06/24/83	x				270	270
07/01/83	x				280	280
07/08/83	x					270
07/15/83	x					275
07/22/83	x					280
07/29/83	x					275
08/05/83	x					260
08/12/83	x					230
08/19/83	x					
08/26/83						
09/02/83	x					
09/09/83						
09/16/83	x					
09/23/83	x					
09/30/83						40
10/07/83		x				
10/14/83		x		0		0
10/21/83		x		0		0
10/28/83		x		0		0
11/04/83		x		0		0
11/11/83		x		10		10
11/18/83		x		30		30
11/25/83		x		40		40
12/02/83		x			30	
12/09/83		x		25		25
12/16/83		x		10		10
12/23/83		x			10	
12/30/83		x		0		0
01/06/84		x		0		5
01/13/84		x		10		8
01/20/84		x		10		8
01/27/84		x		12		12
02/03/84		x		10		10
02/10/84		x		10		8
02/17/84	x	x				8

Table A-14. Pressure Data (2/2)

Date	pipes open (x)			pressure (psi)		
	4"	6"	10"	4"	6"	10"
02/24/84	x	x				5
03/02/84	x	x				5
03/09/84	x	x				0
03/16/84	x	x				0
03/23/84	x	x				5
03/30/84	x	x				5
04/06/84	x	x				5
04/13/84	x	x				10
04/20/84	x	x				10
04/27/84	x	x				10
05/04/84	x	x				5
05/11/84	x	x				
05/18/84	x	x				0
05/25/84	x	x				10
06/01/84	x	x				10
06/08/84	x	x				15
06/15/84	x	x				15
06/22/84		x				35
06/29/84		x				45
07/06/84		x				100
07/13/84		x		130		130
07/20/84		x		80		75
07/27/84		x		60		60
08/03/84		x		45		45
08/10/84		x		35		35
08/17/84		x		20		20
08/24/84		x		10		8
08/31/84		x		10		8
09/07/84		x		0		0
09/14/84		x		0		0
09/21/84		x		0		0
09/28/84		x		0		0
10/05/84		x		0		0
10/12/84		x		15		15
10/19/84		x		35		35
10/26/84		x		35		35
11/02/84		x		28		28
11/09/84		x		15		15
11/16/84		x				
11/23/84		x		15		15
11/30/84		x		5		5
12/07/84		x		5		5
12/14/84		x		0		0
12/21/84		x				
12/28/84		x				
01/04/85		x				
01/11/85		x				
01/18/85		x				
01/25/85		x		0		0
02/01/85		x		0		0
02/08/85		x				
02/15/85		x		0		0
02/22/85		x		0		0
03/01/85		x		0		0
03/08/85		x		0		0
03/15/85		x		0		0
03/22/85		x		0		0
03/29/85		x		0		0
04/05/85		x		0		0
04/12/85		x		0		0
04/19/85		x		0		0
04/26/85		x		0		0
05/03/85		x		10		10
05/10/85		x		15		15
05/17/85						
05/24/85						
05/31/85		x		10		
06/07/85		x				80
06/14/85		x				80
06/21/85		x				80
06/28/85		x				80
07/05/85		x		60		60
07/12/85		x		35		35
07/19/85		x		20		20
07/26/85		x		5	20	20
08/02/85		x				
08/09/85		x				
08/16/85		x		0		0
08/23/85		x				
08/30/85		x		0		0
09/06/85		x		0		0
09/13/85		x		0		0
09/20/85		x				
09/27/85		x		0		0
10/04/85		x		0		0
10/11/85		x		0		0
10/18/85		x		0		0
10/25/85		x		10		10
11/01/85		x		10		20
11/08/85		x		20		10
11/15/85		x		10		20
11/22/85		x		0		0
11/29/85		x		0		0
12/06/85		x				
12/13/85		x		0		0
12/20/85						
12/27/85		x		0		0
01/03/86		x		0		0
01/10/86		x		0		0
01/17/86		x		0		0
01/24/86		x		0		0
01/31/86		x		10		10
02/07/86		x		10		10
02/14/86		x		10		10
02/21/86		x		0		0
02/28/86		x		10		10
03/07/86		x		20		20
03/14/86		x		30		30
03/21/86		x		20		20
03/28/86		x		20		20
04/04/86		x		20		20
04/11/86		x		20		20
04/18/86		x		20		20
04/25/86		x		20		20
05/02/86		x		20		20
05/09/86		x		20		20
05/16/86		x		15		15
05/23/86		x		20		20
05/30/86		x		55		60
06/06/86		x		100		105
06/13/86		x		100		105
06/20/86		x		100		100
06/27/86		x		100		100
07/04/86		x				
07/11/86		x				
07/18/86		x				
07/25/86		x		10		10
08/01/86		x		10		10
08/08/86		x		10		10
08/15/86		x		10		10