SOUTH THOMPSON RIVER
WATERSHED MANAGEMENT STUDY

DRAFT FINAL REPORT

Submitted to:

South Thompson/Chase Creek Turbidity Task Force
c/o City of Kamloops
7 Victoria Street West
Kamloops, B.C. V2C 1A2

by:

Northwest Hydraulic Consultants Ltd.
2 - 40 Gostick Place
Vancouver, B.C. V7M 3G2

and

Urban Systems Ltd
7 St. Paul Street West
Kamloops, B.C. V2C 1E9

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1. INTRODUCTION

1.1 Background and Objectives

The City of Kamloops draws most of its water from the River Street Water Treatment Plant on the South Thompson River. Over the past decade, both the average annual turbidity and the number of days that critical values are exceeded have increased steadily, leading to concern about deterioration of the water supply. The Department of Fisheries and Oceans is also concerned about the implications of higher turbidity in the South Thompson River to the fisheries resource.

Under the guidance of the Fraser Basin Management Program, the South Thompson/Chase Creek Turbidity Committee was formed to address the problem. It includes representatives from the City of Kamloops, Thompson-Nicola Regional District, Ministry of Environment, Lands and Parks, Ministry of Forests, Ministry of Agriculture, Environment Canada, Department of Fisheries and Oceans, Shuswap Nations Tribal Council and of residents of the Chase River Valley.

As part of its commitment to this program, the City of Kamloops organized a program to measure turbidity in the main river and its tributaries during the 1994 freshet (April 14 to June 26) and during the 1995 freshet (February 6 to July 17).

The Committee also asked Northwest Hydraulic Consultants Ltd (NHC) and Urban Systems Ltd (USL) to undertake the first phase of a Watershed Management Plan for the South Thompson River. The objectives of this plan are:

1. Identify natural and man-made sediment sources to the South Thompson River and its tributaries, from Chase to Kamloops;

2. Rank or priorize the sediment sources according to their contribution to turbidity in the South Thompson River; and

3. Recommend measures which may be used to reduce erosion and sediment supply and, consequently, the increased turbidity in the South Thompson River.

1.2 Approach

The turbidity measured at the River Street Water Treatment Plant results from clay, silt, and fine sand and organic material maintained in continual suspension by stream turbulence, or from dissolved compounds. It is thought that organic material and dissolved compounds play only a very minor role in elevating turbidity and that most of the observed increase is a result of accelerated supply of inorganic sediment to the South Thompson River. However, there has been no detailed chemical or physical analysis of turbid water samples from the River Street WTP to confirm this assumption.

The grain size distribution of the sediments suspended in the South Thompson River has not been measured but is thought to include sizes ranging from fine clay (less than 0.0002 mm) through coarse silt (up to 0.063 mm) throughout the year and fine and medium sand during the spring freshet. These sediments are the wash load of the river (those sediments that are continually maintained in suspension and are not found in appreciable quantities in the channel bed) and their concentration depends almost entirely on their rate of supply. The South Thompson River is capable of transporting all of the fine silt and clay supplied to it under reasonably normal conditions.

These grain sizes can be generated by surface erosion (rain-splash, rill and inter-rill erosion, slope or sheet wash, frost action and dry ravel), soil creep (slow and continuous movement of the soil induced by settlement, freeze-thaw or loading), episodic failure (rockfalls, debris slides, debris flows and earthflows), gullying, or fluvial activity resulting in bank and valley wall erosion. Bank, bed and valley wall erosion are often the most important processes along large rivers, such as the South Thompson River. All these processes occur naturally but human activities, such as farming, grazing, road construction, urbanization, or forest harvesting can increase their frequency of occurrence or the sediment yield from individual events.

It is thought that very little fine sediment passes through Shuswap Lake and into the South Thompson River so that almost all of the sediment affecting turbidity at the River Street WTP arrives from downstream of Shuswap Lake. It is possible that some fine sediment from tributaries along Little Shuswap Lake may be carried through the lake or, equally, that fine organic material originating in the lake may be carried into the South Thompson River but these are thought to be minor components of the elevated turbidity at the River Street WTP.

We divided the study area into the main river and its tributary watersheds. The relative contribution of the various tributary watersheds was assessed from turbidity or suspended sediment measurements at their mouths, which integrate all the sediment sources in that watershed, land use information, or from air photo interpretation of sediment sources in the sub-watershed. Air photograph interpretation of channel shifting and bank erosion along the South Thompson River, and discussions with individuals familiar with the river, were used to help rank its relative sediment contribution.

2. THE SOUTH THOMPSON WATERSHED

2.1 Physiography and Glacial History

The South Thompson River has a total watershed area of about 18,000 km^2. A little over 2,000 km^2 of this drainage area lies between Shuswap Lake and Kamloops and contributes fine sediment to the South Thompson River at Kamloops. This is the study area for this report (Table 1; Figure 1).

The study area lies mostly in the Thompson Plateau physiographic region though it grades into the Shuswap Highland at its eastern end (Holland 1976). The Plateau is a gently rolling upland with elevations generally ranging from about 1,200 to 1,500 m. The South Thompson Valley, with elevations of less than 400 m, is deeply incised below this surface and divides the study area into a larger southern and a smaller northern part (Figure 1). The highest elevations are in the Monte Hills and in upper Chase Creek, along the southern rim of the watershed.

The study area was covered by at least two glacial advances, the most recent being the Fraser Glaciation which ended about 9,000 years ago (Fulton 1975). This glacial advance, from southeast to northwest, left morainal deposits or bare rock over most of the upland and covered previous glacial and inter-glacial sediments. Surficial sediments in the South Thompson Valley and the valleys of its major tributaries were mostly deposited during glacial retreat and stagnation or after deglaciation. During de-glaciation, lakes formed in the South Thompson and Chase Creek Valleys which lead to deposition of thick glacio-lacustrine deposits. The South Thompson River later incised through these deposits, leaving them as a high terrace on each side of the river (Photo 1). Along much of the valley, the lacustrine terraces are overlain or capped by glacio-fluvial deposits (forming stream and delta terraces) or by post-glacial alluvial fan deposits. Dating of deposits from volcanic ash layers indicates that most of the fan sediments were laid down immediately after de-glaciation with only small quantities of deposition, or often minor entrenchment of the fan surface, since that time (Ryder 1971; Fulton 1975). The lacustrine terraces are deeply gullied.

The recent alluvium in the South Thompson River valley and in the valleys of its major tributaries consists of sand and gravel with silt, muck or peat deposited in low energy environments. A recent survey of bed sediment sampling sites for Environment Canada (nhc 1994) identified several sites where fine sands and silts were deposited along the South Thompson River.

Glacial deposits in the major tributaries to the South Thompson also mostly occurred during glacial retreat and stagnation. Campbell Creek is an under-fit stream flowing in an old meltwater channel. The main sediments exposed within the valley are coarse fan deposits and glacio-fluvial material. Campbell Creek crosses a steep bedrock section during its transition from the Plateau surface to the South Thompson Valley. Downstream of Monte Lake, Monte Creek flows through glacio-fluvial gravels, moraine, fan deposits, and recent alluvium before cutting through the lacustrine terraces and joining the South Thompson River. This final steep reach seems to be the least stable and the most important source of fine sediment.

Chase Creek has somewhat more complex deposits than the other large tributaries. Upper Chase Creek (upstream of Pillar Lake) flows through moraine and bedrock. Lacustrine sediments are exposed near the junction with Charcoal Creek and in Charcoal Creek upstream of China Lake. Downstream of Charcoal Creek, Chase Creek mostly flows in its recent alluvium though the final 5 or 6 km upstream of Chase Falls crosses a mixture of glacio-fluvial terrace deposits and thin lacustrine sediments.

2.2 Grain Sizes of Surficial Deposits

The portion of silt and clay in the various surficial deposits is important because they are the primary constituents contributing to the turbidity measured at the River Street Water Treatment Plant. The lacustrine sediments consist of silt and clay though sand is a major constituent at some sites. These sediments stand nearly vertical when dry but are very susceptible to erosion when wet and are prone to failure by "piping" (Fulton 1975).

The grain size of the matrix of morainal sediments varies widely, depending on the nature of the sediment over-ridden by the ice, but silt and clay ranges from 10% to 70% of the weight of matrix samples and averages around 40 to 50%. The matrix usually makes up much less than half of the overall sample and portion of silt and clay in till is estimated to amount to 5 to 20% by weight.

Glacio-fluvial sediments primarily consist of sand, gravel and cobbles. Silt and clay incorporated in the matrix of the deposits only make up a very small portion of the overall sample (less than 1%). However, the glacio-fluvial sediments, and fan deposits, may also include lenses of silt or till-like material that contain much greater quantities of silt and clay. Recent alluvium, deposited as bars within stream channels, is primarily sand and gravel and contains only small quantities of silt and clay in its matrix (also less than 1%). In larger rivers, such as the South Thompson, some silt and fine sand may be deposited in side channels or in low-energy environments away from the main river. These deposits are generally seasonal and are re-entrained and carried downstream during the freshet.

Stream bank erosion may also be a source of the silt and clay that contributes to turbidity. Alluvial banks along the major streams are often stratified into a lower sand and gravel unit (which, like the channel deposits, generally has little silt and clay) and an upper unit consisting of suspended load deposits. The portion of silt and clay in the upper sand unit has not been measured but is likely to be much greater than in the coarse sediment below, perhaps constituting 10 to 30% or more by weight. Where stream banks are non-alluvial sediments (i.e. till, lacustrine or glacio-fluvial deposits) the portion of silt and clay should correspond to that typically found in these deposits.

2.3 The South Thompson River

The South Thompson River flows 58 km, from Little Shuswap Lake to its junction with the North Thompson River, on a gradient of about 0.0005. The width of the river, from bank to bank, varies from about 150 to 450 or so m and water depths range from a few metres at low water to 5 to 10 m during a large flood. Bed material consists of large cobbles and gravel in the upper river (i.e. near Chase Riffle), often partly covered by deposits of sand that are moving through the reach.

A navigation channel was dredged through part of the upper river bed in the 1950's and it is about 40 to 50 m wide. This channel is still visible, and has not filled with coarse sediment despite almost no maintenance. The bed of the South Thompson River is quite stable and re-surveys of cross sections from the 1970's in the mid-1980's showed only minor scour and deposition.

The channel is also laterally stable, particularly as most of its banks are protected by rip rap installed by CP Rail or by the Ministry of Transportation and Highways. Bank erosion is thought to only provide small quantities of fine sediment to the main river and no active sites were identified by comparing sequential air photographs. Suspension of sediment from the channel bed by power boats and minor bank erosion from waves generated by boat traffic may also be sources of fine sediment erosion and suspension during summer months.

2.4 Major Tributaries to the South Thompson River

The tributaries to the South Thompson River with the largest watersheds are Campbell Creek, Monte Creek, and Chase Creek (Table 1). These all join the main river from the south side of the study area. Niskonlith Creek is the largest tributary from the north side; the majority of its drainage area is upstream of Niskonlith Lake which traps most of its fine sediment supply.

Long profiles of Campbell, Monte and Chase Creeks are included in Appendix A. These three creeks all have similar profiles, with a steep section near their mouths where they leave the uplands to join the South Thompson River. a relatively flat middle section, and a steep upper reach that extends to the upper limit of their watersheds. The steep upper reaches of both Monte and Campbell Creeks drain to large lakes which intercept their sediment load.

In their middle reaches, valley gradients range from 0.005 in Campbell Creek, to 0.006 in Monte Creek, up to 0.01 in Chase Creek. Both Campbell and Monte Creeks are very laterally stable through their middle reaches. One the other hand, Chase Creek, which has the steepest gradient, is unstable and erodes it banks and valley walls.

2.5 Small Tributaries to the South Thompson River

The remaining tributaries to the South Thompson River have drainage areas ranging from less than 1 to about 40 km^2, with the majority of them having drainage areas of less than 10 km^2. Many of the smallest tributaries are gullies that have developed mostly in the lacustrine, glacio-fluvial, and fan sediments along the margins of the South Thompson Valley (Photo 1). Maximum elevations in their drainage basins are usually from 1,000 to 1,200 m.

3. LAND USE

Land use within the South Thompson watershed varies from localized, highly-developed urban settlements such as the City of Kamloops and Village of Chase to much less intense activities, such as cattle gazing, which occur throughout the watershed. Few areas have not been modified by some form of human activity.

Land use can increase turbidity within the main river and its tributaries. Forestry, mining, agriculture, and settlement areas are all land uses which, depending upon how they are developed and managed, can contribute sediment to watercourses. The linkages between land use and naturally-occurring factors discussed elsewhere in this document (i.e. surficial materials and hydrology) are important in determining potential sediment sources. Specific land uses are described in the following sections and shown on the maps in Appendix E.

3.1 Forestry

Forestry practices can increase turbidity in streams in a number of ways. Specific activities can contribute sediment directly to streams, harvesting can reduce slope stability and increase the risk of landsliding, harvesting can aggravate flood peaks and accelerate rates of bank erosion, channel shifting or widening in downstream reaches, and removal of trees along streams can reduce bank strength, increasing rates of bank erosion.

The specific activities that might increase turbidity include road construction (clearing, grading and surfacing, drainage and channel crossings), and logging practices (following and yarding, particularly stream crossings and retaining stream-side vegetation, and silviculture, including scarification, brush control, restocking). Post-harvest practices are also important, particularly hydrologic impacts, hillside and streamside stability, and road maintenance and drainage.

Forests are harvested on both private land and on Crown Land, mostly in the upper elevations of the major tributaries along the south side of the Lower South Thompson Watershed. There is no record of the total area of private land that has been cut; however, the Ministry of Forests keeps records of the harvest on Crown Lands and areas of harvest are shown for the periods from 1965-1974, 1975-84, 1985-94 and that proposed in the five-year development plan.

From 1965 to 1974, logging was concentrated in the Campbell Creek. Logging also occurred in other portion of the watershed, particularly Peterson Creek, Monte and Chase Creek (limited), and in small watersheds north of the South Thompson River (e.g. Moulton, Pemberton, and Niskonlith Creeks).

Between 1975 and 1984, the Monte Creek watershed was the focus of forest harvesting. Large areas were cut both east and west of Monte Creek in the upper and lower portions of this watershed. Less activity occurred in Campbell Creek watershed than from 1965-1974. Openings appear to be substantially smaller than those in the previous decade. Other areas with harvesting activity include Chase Creek watershed, particularly at higher elevations, Niskonlith Creek watershed, and the area between Moulton and McGregor Creek

Less area was harvested between 1985 and 1994 than in previous ten-year periods. Harvesting was concentrated in the Chase Creek watershed, particularly at the higher elevation both east and west of the creek. Some harvesting took place within the Monte, Campbell and Peterson Creek watersheds, and also in the vicinity of Niskonlith, Pemberton and Mouton Creeks north of the South Thompson River.

Table 2 summarizes the area of harvest in the three main tributaries subdivided into the Interior Douglas Fir, Montane Spruce, and Englemann Spruce - Subalpine Fir biogeoclimatic zones. The harvest is separated by biogeoclimatic zone because harvesting in the upper elevation ESSF zone, where most snow accumulates, is thought to have the greatest potential impact for increasing downstream floods.

Based on the data summarized on Table 2, it is thought that timber harvesting has had no effect on peak flows in Campbell Creek. The situation is somewhat more complicated in Monte Creek, where the level of harvest may be sufficient to increase flood flows but diversion and storage in Monte Lake may compensate for the increased water yield. Harvest in the upper elevations of Chase Creek is believed to have increased flows downstream of Pillar Lake. This is discussed further in Vernon Forest District (1992).

Proposed harvest over the next five-year plan (1995-2000) is also shown on a map in Appendix E. These proposed blocks are in various stages of the approval process, ranging from initial planning to approval of cutting permits. All areas shown will not necessarily be approved for harvesting over the next five years.

Significant harvesting is proposed for all three of the major sub-watersheds south of the South Thompson River (Campbell, Monte and Chase Creeks) over a range of elevations. Some harvesting is also proposed for the Peterson Creek watershed. Small watersheds north of the South Thompson River may also see considerable harvesting over the next 5 years, principally in Pemberton and Niskonlith Creek watersheds.

3.2 Mining

Mining can increase the level of turbidity in streams during development (drilling, road construction, overburden removal and waste rock storage), during operation (site drainage, milling processes, tailing disposal, and water use effluent discharge) and following closure (tailings disposal and slope stability).

A map in Appendix E depicts active mines (including aggregate extraction from gravel pits) in the South Thompson watershed. There are only two active mines in the study area; the Harper Ranch and Buse Lake quarries operated by Lafarge Canada Inc. In addition, there are ten major active gravel pits located throughout the watershed.

Few problems relating to turbidity associated with these mining activities are evident. The Lafarge facility utilized a "dry-process" in manufacturing cement, and thus has low water demands or production of wastewater effluent. Care is taken in site development and drainage to minimize the potential for sediment-laden run-off originating from extraction or processing areas to make its way to the South Thompson River. A similar comment applies to gravel pits, where few problems related to sediment introduction to watercourses have been reported.

3.3 Settlement

Urban development may increase turbidity during land development and construction, through land clearing (including riparian areas adjacent to streams), excavation and storage of excavated materials, and alterations to drainage courses or stream patterns. Ongoing Impacts of development on turbidity include alterations to hydrology (e.g. less infiltration, enhanced overland flow volumes/rates, eroded drainage courses, etc.), increased available sediment from road maintenance, cut/fill slopes, ditches, and loss of wetland habitat through land filling or drainage.

The principal settlement areas within the South Thompson watershed are show on a map in Appendix E and include: City of Kamloops, Monte Creek (at confluence of South Thompson River and Monte Creek), Monte Lake, Pritchard, and Chase. There are also a number of rural settlement areas including the Duck Range/Robbins Range area (south of Pritchard/Monte Creek), the Chase Creek valley, the Charcoal Creek valley and the area south of Kamloops towards Stump Lake.

3.4 Agriculture

Agriculture may increase turbidity during land clearing, through removal of streamside vegetation and subsequent instability and erosion, or through increasing peak flows and altering channel morphology. Livestock may also increase turbidity through breaking down stream banks during watering.

A map in Appendix E shows the two principal types of agricultural activity within the South Thompson watershed occur. These are ginseng farming (a recent activity in the area) and livestock wintering. Grazing areas where livestock (cattle) spend the non-winter months are not shown on the map, as they use most of the watershed.

There is little evidence of increased turbidity from these agricultural activities. Some concern has been raised along the north bank of the South Thompson River between Stobart and McGregor Creeks. This area is used by livestock during the winter months and streambank instability and enhanced erosion are thought to have occurred. In response, Ducks Unlimited is undertaking a stock watering project within the riparian area which will reduce bank damage and the introduction of sediment to Stobart Creek and the South Thompson River.

4. HYDROLOGY

The Water Survey of Canada operates, or has operated, gauging stations on a number of streams within the study (Table 3). Their data are the main source of information on the hydrologic regimes of the study streams.

4.1 South Thompson River

The South Thompson River is gauged by the Water Survey of Canada at its *"South Thompson River at Chase, 08LE031"* station which records flows leaving Little Shuswap Lake and entering the South Thompson River (Table 2). Flows at Kamloops are somewhat higher than those recorded at the gauge at Chase because of inflows from tributaries in the study area though these inflows are only thought to increase the mean flow by a percent or so.

Minimum monthly flows on the South Thompson River generally occur in March. Flows rise through April, reach a peak in June, and remain high in July. After July, monthly flows decline consistently until they reach their minimum in March (Figure 2). The annual flood typically occurs near the middle of June but has occurred as early as May 21 and as late as July 12. Based on records to 1994, the mean annual flood is 990 m^3/s.

4.2 Major Tributaries

Water Survey of Canada has operated gauges near the mouths of all the major tributaries though the records at these gauges often only cover a few years (Table 3). On Monte (08LE013) and Niskonlith (08LE016) Creeks, the measurements are from the early part of the century and may not be very representative of existing land use and water diversions. Measurements on Campbell (08LE058) and Chase (08LE005) Creeks are from the 1950's and 1960's and also may not be representative, mostly because forest harvesting in upper Chase Creek has increased flood flows.

All the major tributaries have roughly the same hydrologic regime. The annual flood usually results from snowmelt in the upper watershed (generally above 1,500 m elevation) and usually occur between mid-May and early June, in advance of the peak on the South Thompson River.

Rainstorms produce the annual flood In some years, as occurred in mid-June 1990, and these floods can be much larger than those resulting from snowmelt. Beeson and Doyle (1994) estimate that the maximum flow in June 1990 on Chase Creek was 25 m^3/s, much larger than had been previously recorded.

The following table summarizes our best estimate of the mean annual flood in the four major tributaries and the dilution of that flow (and its accompanying sediment load) by the South Thompson River, based on its mean monthly flow for May of 463 m^3/s:

Stream	Gauge No.	Mean Annual Flood (m^3/s)	Dilution by South Thompson River
Chase Creek	08LE005	10.6	40:1
Niskonlith Creek	08LE016	1.4	330:1
Monte Creek	08LE013	1.2	390:1
Campbell Creek	08LE058	1.4	330:1

Any sediment carried by the major tributaries is greatly diluted by the flow in the main river before it reaches the River Street Water Treatment Plant. However, the flow from Campbell Creek, which enters the main river close to Kamloops, will not be completely dispersed before it reaches the Water Treatment Plant.

4.3 Small Tributaries

Little is known of the discharge regime of the small tributaries as Water Survey of Canada records are short, out of date, and only cover part of the flow year (Table 3). However, the available observations suggest that annual floods result both from snowmelt and from intense rainstorms or local thunderstorms. Many of the smallest tributaries have floods in the late winter or early spring when their low elevation snowpack melts which may occur in January or February. Some of the larger tributaries, such as Neds Creek, may have their annual flood in late April or early May, following mid-elevation snowmelt, but this may not occur consistently from year to year.

It is very difficult to estimate typical flood discharges for the small tributaries. Snowmelt in the late winter or early spring may produce flows ranging from 0.1 to 0.5 m^3/s (100 to 500 L/s) in the large tributaries and may produce no measurable discharge in gullies with small drainage areas. Discharges in the South Thompson River in the late winter and early spring are about 150 m^3/s and dilution ratios would then range from around 300 to 1,500 for individual small tributaries. Again, note that sediment delivered by tributaries near Kamloops will not be completely mixed across the river and the apparent dilution will be much lower than quoted above.

Infrequent thunderstorms probably produce the greatest flows in the small tributaries but there are no measurements of these floods and it is not known how frequently they recur in any one tributary. Peak flows following the thunderstorms are thought to be as much as 2 or 3 m^3/s in those tributaries with reasonably large drainage basins. These thunderstorm floods are particularly important to sediment production from the small tributaries because they are capable of producing large quantities of sediment during the storm and also because they may de-stabilize the tributary so that chronic sediment production continues for many years afterwards.

The tributaries drain to both the left and right bank of the South Thompson River and mixing of their sediment across the stream partly determines the effect of their inflow on turbidity at the River Street WTP. Distances to complete mixing in the South Thompson River are expected to range from 20 to 30 km, depending on discharge in the main stream. Consequently, streams that within 5 to 10 km or so upstream of the intake on the right (or north) bank may only produce a minor elevation of turbidity at the River Street WTP even if they provide very turbid inflows. Conversely, streams entering on the left (south) bank within 10 km of the River Street WTP will have a much greater effect because their turbid inflows are not completely mixed across the section.

5. TURBIDITY AND SUSPENDED SEDIMENT TRANSPORT

Our discussion has emphasized the supply of inorganic sediment to the South Thompson River, but there are no measurements of sediment concentrations or sediment loads on any of the streams in the Lower South Thompson River watershed by the Sediment Survey. Instead, turbidity has been measured daily at the intake of the River Street Water Treatment Plant (which measures the turbidity in the South Thompson River), and weekly during the snowmelt freshets of 1994 and 1995 on some of tributaries to the South Thompson River.

Turbidity is a measure of the "cloudiness" of water produced by the scattering of light by water molecules, dissolved solids and suspended matter and is an apparent optical property. The instruments used to measure turbidity were calibrated in Nephelometric Turbidity Units (NTU) to a laboratory formazin standard. The measured turbidity responds to both the concentration of suspended sediments and to their grain size distribution. At equal concentrations, suspended clay and silt scatter more light than suspended sands, and the measured turbidities from the clay and silt may be more than 10 times that of the sand. Turbidity may be directly related to suspended sediment concentration only if particle size distributions remain constant.

5.1 River Street Water Treatment Plant Turbidity Measurements

Daily turbidity readings at the River Street WTP, for 1985 to 1993, are included in Appendix B. (They were collected by a variety of instruments over the period of record.) The daily values were used to summarize annual turbidity in two ways; 1) as the mean annual turbidity, based on an average of all daily values, and 2) as the number of days when the turbidity exceeds 5 NTU. Both mean turbidity and the number of days over 5 NTU increased fairly consistently from 1985 to 1993 before declining in 1994 and 1995 (Figure 3).

In order to determine the source of the increased turbidity we classified all days where the turbidity reading in NTU exceeded 5, as follows:

- ***Low-Elevation Snowmelt:*** Describes turbidity events that occurred between the start of November and the end March on days when the maximum temperatures recorded at the Kamloops A climate station rose to well above zero after a long period of below zero temperatures and precipitation. Rainfall augments snowmelt during some of these events. It is assumed that these turbidity events result entirely from snowmelt and rainfall producing high flows, erosion and suspended sediment transport from small tributaries and gullies.

- ***High-Elevation Snowmelt -- Major Tributaries:*** Applied to turbidity events that occurred from mid-April to the end of May. It is assumed that these events are associated with high-elevation snowmelt in the major tributaries causing high flows, erosion and suspended sediment transport. Rainfall may augment snowmelt discharges in the major tributaries as well as causing sediment discharge from small tributaries. The combined snowmelt-rainfall events were classified separately.

- ***Peak Flow -- South Thompson River:*** Applied to turbidity events that occurred during or immediately prior to the peak of the freshet on the South Thompson River. It is assumed that the increased turbidity results from sediment carried from Little Shuswap Lake, entrainment of sediment deposited along the South Thompson River and bank erosion along the main river, with some sediment supply from tributaries. When these turbidity events coincided with rainfall at the Kamloops A climate station they were classified as rainstorms.

- ***Rainstorms:*** Applied to turbidity events that are associated with rainfall at the Kamloops A climate station. As discussed above, rainfall sometimes occurs during the peak flows from the major tributaries and the South Thompson River. The turbidity events classified as primarily rainstorm-derived are those occurring after the South Thompson freshet or prior to the period when snowmelt peaks might be expected in the major tributaries. It is assumed that elevated turbidity results from high flows, erosion and suspended sediment transport from the small tributaries, as the brief, intense summer rainstorms are not thought to produce floods in the major tributaries. The June 11,1990 storm is an exception, as it produced unusually high discharges in the major tributaries and also in the small tributaries.

- ***Unknown:*** Some turbidity events in the summer, fall and winter are neither associated with a rainstorm at the Kamloops A station nor with high temperatures that indicate snowmelt. These events may result from rainfall that is not recorded at the Kamloops A station, or other unknown causes.

Appendix B describes all the turbidity events from 1987 to 1993 and plots both precipitation and discharge in the South Thompson River with the daily turbidity records.

Table 4 summarizes the number of days exceeding 5 and 10 NTU at the River Street Intake for the various types of turbidity events for 1987 to 1993. The major sources of turbidity events seem to be snowmelt that produced floods from small tributaries, rainstorms that produced floods from small tributaries, unknown or unclassified events, and rainstorms during snowmelt on the major tributaries. The most intense events (i.e. the highest maximum turbidity) results from snowmelt and rainstorms in the small tributaries.

The analysis indicates that the main source of turbidity is the small tributaries to the South Thompson River and that the increased turbidity in recent years seems to have resulted from the increased number and intensity of turbidity events during snowmelt and summer rainstorms. Large but rare rainstorms, such as occurred in June 1990, produce large floods and elevated turbidity from the large and small tributaries which may maintain turbidity levels above 5 NTU at the River Street Intake for more than 30 days.

5.2 1994 and 1995 Turbidity Monitoring Programs

The City of Kamloops organized the collection of weekly turbidity measurements on the South Thompson River and some of its tributaries during the 1994 and 1995 freshets. Water samples were collected at various sites and returned to the City of Kamloops laboratory for analysis. Appendix C summarizes the weekly measurements and includes a map of the sampling sites.

In 1994, turbidity rose rapidly on Chase, Monte, and Stobbart Creeks at the start of the snowmelt freshet, and peaked on the April 21 site visit. High values in the tributaries were associated with turbidity exceeding 10 NTU at the River Street Intake though values less than 5 NTU were recorded at the SES Intake in Dallas. (The low value at the S.E. Intake suggests that Stobart Creek was the main cause of the elevated turbidity at River Street.) Turbidity declined after the end of April in most creeks, reaching a minimum in late May. Stobart Creek was the main exception and its turbidity remained well over 1,000 NTU throughout May while turbidity at the River Street Intake remained near 5 NTU and that the SES Intake in Dalles was below 5 NTU.

Samples from various locations in Chase Creek helped to define which stream reaches are important in providing the suspended sediment that elevates turbidity. Measurements in Table 5 indicate that it is the reach extending about 8 km or so upstream of the Turtle Valley bridge that was the main source of turbidity during the snowmelt freshets in April and May 1994.

Turbidity rose again in mid-June on most creeks, reaching a peak around the June 20 or June 26 sampling date. It is thought that the general rise in turbidity may have resulted from increased flows, and erosion, following rainfall of 16.6 mm between June 16 and 26, as recorded at Kamloops A climate station. The largest recorded rise was on Neskonlith Creek, which increased from around 5 NTU in mid June to 755 NTU on June 20th (Table 5). The large rise is unusual because this creek drains directly from Neskonlith Lake and there are few sediment sources along the lower river. A large rise also occurred on Monte Creek, while there was only a small rise in turbidity on Campbell Creek (Appendix C). No increase was observed on Chase Creek.

High values in the tributaries were associated with turbidity readings well in excess of 10 NTU at the River Street WTP and SES Intake. However, the turbidity in the main river at the outlet of Little Shuswap Lake was also very high (110 NTU), suggesting either a "flush" of fine sediment from upstream creeks or organic material carried in from Shuswap Lake. The increase in turbidity at the River Street Plant seems associated more with the high turbidity entering the South Thompson River from Little Shuswap Lake than with that in the tributaries. For instance, the maximum turbidity in Monte Creek on June 20 is not associated with high turbidity at the South Thompson River at Lafarge Bridge Site, which is just downstream of Monte Creek (Appendix C). While this may result from incomplete mixing of Monte Creek's inflow, the elevated turbidities at the Lafarge Bridge Site seem better correlated with high values at the outlet of Little Shuswap Lake.

In 1995, the sampling program started in early February and initially added two sites on the South Thompson River -- upstream and downstream of Harper Creek -- and one on Juniper Creek. Also, somewhat different sites were sampled on Chase Creek, upstream of the Village of Chase (Table 6; Appendix C).

From early February until late May, turbidity readings at the River Street Intake ranged from 3 to 9 NTU. Turbidity exceeded 5 NTU on February 6, primarily because of low elevation snowmelt that produced high turbidity in Stobart, Juniper and Monte Creeks. The observed turbidity in Stobart

Creek remained very high, though variable, and it seems to have been the major cause, likely with Juniper Creek, of turbidity exceeding 5 NTU through the late winter and early spring.

The highest turbidity readings in the major tributaries occurred on May 15, when the turbidity recorded in Chase Creek was about twice that in Monte Creek and three times that in Campbell Creek (Table 6). Turbidity at the River Street Intake rose over 5 NTU on this date and during the following week. Not all the rise in turbidity resulted from elevated values in the major tributaries. Inflows from the smaller tributaries, such as Juniper and Stobart Creeks, were also important as turbidity in the main river continued to increase downstream, from the Pritchard Bridge to the River Street Intake.

Turbidity remained moderate in Stobart Creek in late May and through June but that recorded at the River Street Intake declined below 5 NTU. This may have occurred because contributions from other tributaries declined greatly or because mixing of the sediment from Stobart Creek across the main river to the south bank was less effective during the lower discharges in the main river.

Sampling stations on Chase Creek indicated that most of the turbidity was generated in the reach between Charcoal Creek and the Turtle Valley Bridge, as it was in 1994. Erosion of lacustrine sediment near Charcoal Creek may be an important source of the fine sediment that elevates turbidity as is bank erosion along Chase Creek. Peak turbidities seem to have lasted about 2 weeks during the early part of May 1995.

6. RANKING OF THE TRIBUTARIES

The weekly turbidity sampling program examined the four major tributaries to the South Thompson River, two of the small tributaries, inflows from Little Shuswap Lake into the upper South Thompson River and several stations on the main river. As discussed in the previous section, these data can be used to assess the relative significance of some tributaries to increased turbidity at the River Street Intake. Sediment sources within these major tributaries were then identified from aerial photograph interpretation and aerial overflights.

Only two of the small tributaries have had their turbidity measured. Consequently, other tributaries that might be unstable and provide quantities of fine sediment to the South Thompson River were described from aerial photograph analysis. Their potential to generate sediment and to increase turbidity at the River Street Intake was assessed and ranked.

6.1 Major Tributaries

Stream reaches of the major tributaries are described in Appendix D and their role in elevating turbidity at the River Street Intake is summarized below:

- *Campbell Creek:* The highest turbidities in Campbell Creek usually occur at the same time as those in Chase Creek but both peak discharges and measured turbidities are much lower. This creek is thought to only contribute in a very minor way to elevated turbidities at the River Street Intake.

- *Monte Creek:* Monte Creek has high turbidity at about the same time as Chase Creek, but has lower peak discharges and peak turbidities. Monte Creek also recorded high turbidity early in 1995 (during early snowmelt) and late in 1994 (during a summer rainstorm). Monte Creek is a minor source during the high-elevation snowmelt freshet but may be more important during the low-elevation snowmelt and summer rainstorms. It is our feeling that the sediment that produces the elevated turbidity arrives from gullies and landslide scars along the valley wall of the steep, lower reach (Photo 2).

- *Chase Creek:* Chase Creek produces its highest turbidity and its greatest flows during the high-elevation snow melt freshet which usually occurs around the middle of May. In some years the creek may have two or more freshet peaks, each with elevated turbidity.

  It is thought that the snowmelt freshet from Chase Creek contributes to a small turbidity event at the River Street Intake in most years, usually augmented by sediment inflows from small tributaries near the intake. During the snowmelt freshet, turbidity remains elevated for a week or two but may remain high much longer following large rainstorms floods, as occurred in June 1990.

  During 1994 and 1995, most turbidity was generated in the reach between Charcoal Creek and the Turtle Valley Bridge by erosion of lacustrine deposits and of channel banks (Photos 3 and 4). However, during large rainstorms floods it is thought that sediment generated by landslides and road failures (Photo 5) in the upper Chase Creek watershed (upstream of Pillar Lake) assumes more importance.

6.2 Erosion in Small Tributaries

Appendix D summarizes the air photograph analysis of the various small tributaries (including some gullies that were not shown on the 1:50,000 NTS Maps) and classifies their channels reaches using the following variables:

STREAM EROSION (describe channel pattern to show increasing bank erosion rates)

Class 1: Very stable, straight or sinuous, no erosion, vegetated banks, etc
Class 2: Meandering, unstable banks, large bars.
Class 3: Wandering, eroding banks, irregular channel avulsions
Class 4: Braided or anastomosed

GULLY EROSION (describe bed degradation and bank slumping)

Class 1: No obvious erosion, vegetated banks and bed
Class 2: Terraces, but well vegetated (previously degraded)
Class 3: Terraces, partly vegetated (may be a delta/fan)
Class 4: Obvious recent degradation, unstable banks and bed, no vegetation (large fan in South Thompson River)

VALLEY WALL EROSION (describe supply of sediment to streams)

Class 1: stable, vegetated, little or no sediment to stream.
Class 2: a few slides or failures entering streams, sections of unstable wall or roads.
Class 3: more than Class 2
Class 4: most slides/failures/roads affecting stream.

Appendix D also notes whether the tributary has built a fan or delta into the South Thompson River and whether or not it consists of reasonably recent deposits.

6.3 Ranking of the Small Tributaries

Tributary streams in Appendix D are ranked by their sediment production potential (ranging from very low to high based on the air photograph analysis) and by their potential to elevate turbidity at the River Street Intake. Tributaries downstream of the intake or on the right (north) bank near the intake have no potential to elevate turbidity. On the other hand, tributaries on the south bank immediately upstream of the intake have the potential to greatly elevate turbidity because sediment introduced to the main river by them will be not be well-mixed. For tributaries that are more than 10 to 20 km upstream of the intake (where their sediment contribution is well-mixed across the main river) their potential to elevate turbidity at the intake depends on their drainage area (as a measure of discharge and subsequent dilution of their sediment load).

Based on the above analysis the small tributaries that contribute most significantly to elevated turbidity at the River Street Intake are:

- *Juniper Creek:* Air photograph analysis did not identify this channel as particularly unstable but miscellaneous turbidity measurement indicated that it can contribute very turbid water to the left bank of the South Thompson River, just upstream of the S.E. Intake. Further investigation is needed to identify the main sources of the turbidity.

- *Stobart Creek:* Following an intense, local thunderstorm a gully on the Harper Ranch began to degrade and since has contributed up to 100,000 m^3 of fine sediment (primarily silt) to the South Thompson River. Irrigation practices on Harper Ranch are also thought to contribute to flow in the gully.

Headcutting in the gully has been arrested by armouring of the knickpoint at its upstream end. Turbidity recorded on the stream during 1995 was somewhat lower than in 1994. However, lateral erosion along the gully is anticipated to maintain the supply of sediment from this gully to the South Thompson River.

Other creeks that could potentially supply sediment to the South Thompson River and increase turbidity at the River Street Intake are:

- McGregor Creek (Km 18.6 right bank);
- Dry Creek (Km 34.65 left bank);
- Moulton Creek (Km 34.85 right bank);
- Neds Creek (Km 36.50 left bank); and
- Pemberton Creek (Km 38.40 right bank).

These creeks are thought to be currently less important than Juniper and Stobart Creeks but could be activated by a intense thunderstorm or other event.

7. RECOMMENDATIONS FOR REDUCING TURBIDITY

7.1 Chase Creek

The major potential sources of fine sediment delivery to Chase Creek are the logged areas in upper Chase Creek, lacustrine sediments exposed downstream of Charcoal Creek, and alluvial channel banks from Charcoal Creek to the Turtle Valley Bridge. Our recommendations are:

Upper Chase Creek: A helicopter overflight indicates that an old road on the north (left) bank of upper Chase Creek is a source of sediment to Chase Creek. We recommend that funding under the Watershed Restoration Program be used to de-activate this and other roads and rehabilitate landslides or gullies affected by forest harvesting.

Glacial Deposits near Charcoal Creek: Charcoal Creek, downstream of China Lake, is deeply incised into glacio-fluvial sediments, likely as a result of an unusual release from China Lake though this has not been confirmed. These sediments seem to be stable at present and do not contribute fine material to Charcoal Creek (Photo 6). Downstream of Charcoal Creek, Chase Creek flows in a broad channel over gravel deposits and is in contact with lacustrine sediments (Photo 3). Through this reach, Chase Creek appears to be degrading or incising into its deposits and may be reasonably stable. We do not recommend any in-channel works but recommend continued monitoring of this section of the river.

Channel Erosion -- Charcoal Creek to Turtle Valley Bridge: Chase Creek is eroding its banks at a number of sites over this 12 km long reach, particularly at the "outside" or "apices" of bends (Figure 4). None of the individual sites contributes enough sediment to justify constructing bank protection works.

Instead, we recommend long-term erosion control through re-establishment of riparian vegetation. A corridor of trees should be established to a distance of 10 to 20 m from the river banks and a covenant established so that this land will remain as a riparian corridor. Part of the erosion problems have resulted from enhancement of flood peaks as a result of harvesting in the upper watershed and the Watershed Restoration Program could perhaps fund planting of appropriate species.

7.2 Juniper Creek

The cause(s) of elevated turbidity in Juniper Creek are not known but the watershed is urbanized and urban development and drainage practices may contribute to erosion. We recommend a program to identify, map and rank the relative importance of sediment sources in this watershed (primarily from field visits) and development and costing of a remedial program to reduce sediment supply from the most important sources.

7.3 Stobart Creek

Sediment contributions from Stobart Creek mostly result from severe gullying on Harper Ranch (Figure 5). Headward progress of the gully has been arrested by armouring of the knickpoint but lateral erosion is expected to continue the contribution of sediment (though at a reduced rate compared to that when the gully was headcutting) from the gully to the South Thompson River. There are a number of alternative approaches to reducing lateral erosion in the gully. These include:

- *Diversion:* Watson Engineering Ltd (1995) proposed installation of a pipe to divert water around the gully and into the main channel downstream, via an energy dissipation structure.

- *Channel Lining*: Place an impervious liner along the channel bed to prevent further degradation and lateral shifting.

- *Sediment Trapping:* Watson Engineering Ltd also proposed development of a sediment trap on lower Stobart Creek to capture future sediment. Note that the pond would need to be quite large to settle the predominantly silt-sized sediment and would also need to store the 50,000 to 100,000 m^3 of sediment which could be contributed by lateral erosion of the gully.

- *In-Gully Works:* Construction of check dams along the gully to stabilize the channel bed, promote aggradation to stabilize the valley walls, and reduce lateral attack on the valley walls. The check dams can consist of mounds of coarse shot rock (on a filter cloth) or gabion structures, if these can be constructed safely in the channel.

- *Revegetation:* Revegetation is not a suitable option on its own because of the difficulty of re-establishing plants and because sediments on the gully walls and floor are very unstable. Revegetation may work successfully with in-gully structures or other approaches which reduce erosion.

7.4 The South Thompson River and Major Tributaries

Small sediment sources along the main river and its large tributaries contribute to the overall turbidity at the River Street WTP but are generally not of enough importance to justify stabilizing them through typical engineering practices. Re-vegetation may work successfully on these sites, particularly along the South Thompson River where erosion may result from wave action rather than undercutting or direct attack by the main river.

7.5 Land Use Practices

Forestry: The Province of B.C. has worked to improve forest practices, culminating in the *Forest Practices Code Act* of 1995. The Code sets out a wide variety of regulations and standards which direct forest activities on Crown Land. In many cases, these directions are quite detailed (i.e. forest road layout, harvesting methods and equipment). Rather than providing such details in the context of this report, it is deemed sufficient to note that forestry land use practices and associated activities must adhere to the Code within the following areas:

- planning and prescriptions (i.e. forest development plans, silviculture prescriptions)
- engineering practices (i.e. forest road layout, design, construction and maintenance)
- timer harvesting (i.e. methods, equipment, trail design)
- biodiversity and aquatic resources management (i.e. riparian management areas)
- silviculture practices (i.e. site preparation, soil rehabilitation)

The Forest Practices Code also concerns itself with the impacts of past and proposed harvesting in particular watersheds. Assessments can be conducted to determine the type and extent of water-related problems within a watershed and to recognize the possible hydrologic implication of additional development. The Watershed Restoration Program was initiated to remedy damage in watersheds from past forestry activities. As noted above (see Section 7.1), this approach may be useful in addressing some concerns with the Chase Creek watershed. The Forest Practices Code provides a suitable framework for managing forest harvesting to maintain good water quality at the River Street WTP. Additional improvements to water quality may be achieved in some tributary watersheds by establishing riparian reserves along steep Class S4, S5, and S6 streams which are not fish-bearing but may be significant contributors of fine sediment to downstream reaches.

There is currently little regulation of forestry activities on private land, which comprises a substantial proportion of the South Thompson watershed. Local government does have the ability to institute tree-cutting bylaws pursuant to Section 987 of the Municipal Act. This is an approach which could be considerate by the Thompson Nicola Regional District, who have jurisdiction over land use through much of the area.

Mining: Mining does not appear to increase turbidity at this time. Should any further mining development occur within the watershed, erosion and sediment control must be addressed. Steps which should be taken to address this insure are outlined below under 'Settlement'.

Agriculture: As noted in Section 3.5, there is little evidence that agriculture is increasing turbidity levels within the watershed. However, one area of concern is high concentration of livestock at winter feed lots near watercourses, which is covered by the Code of Agricultural Practice for Waste Management. The Code suggests that:

- seasonal feeding areas much be at least 30 m from the bank of a water course; and
- seasonal feeding ares must be operated in a way that does not cause pollution (the definition of pollution could include turbidity).

These measures will help in reading any potential turbidity problems. The Ducks Unlimited project near the confluence of Stobart Creek and the South Thompson River provides a prototype of how to properly protect riparian areas and reduce sediment introduction through development of an alternative livestock watering system, fencing of sensitive riparian areas and re-vegetation of disturbed banks with native trees and shrubs.

There are also steps which can reduce livestock impact on watercourses on range lands. These include placing fences around stream and riparian areas, locating salt blocks well away from streams and providing watering sites. Further direction on such steps is set out in the forest Practices Code.

Few concerns are evident with respect to ginseng operations and turbidity levels. As new operations commence they should provide vegetated leave strips along watercourses and practice other erosion and sediment control measures.

Settlement: The *Land Development Guidelines for the Protection of Aquatic Habitat* and *Stream Stewardship: A guide for Planners and Developers,* both developed by the Department of Fisheries and Oceans and the Ministry of Environment, Lands and Parks describe various techniques to manage sediment as part of development. We summarize below some specific recommendations that are suitable for new and existing development. Specific action s include:

- provide vegetated "leave stirps" along watercourses. As a general rule such leave strips should be 15 m in width (from high water mark)

- practice erosion and sediment control including:
  -prior planning of development of fit site conditions, minimize soil description and retain vegetation
  -re-vegetate and protect (i.e. plant cover) denuded ares and bare soils
  -divert run-off from denuded areas
  -minimize the length and steepness of slopes to reduce erosion potential
  -minimize run-off velocities and erosive energy (i.e. low gradient ditches and channels)
  -retain eroded sediments on site with control structures (i.e. traps, fences, control ponds)
  -schedule development to minimize risk of potential erosion (i.e. during dry months)

- undertake stormwater management practices
  - pursue objective of maintaining, as closely as possible, the pre-development flow pattern in the receiving watercourse through various measures such as those listed below:

  - stormwater detention ponds
  - detention systems for heavily urbanized areas (i.e. roof top detention, parking lot or park areas, etc.)
  - infiltration systems
  - constructed wetlands (act as detention and treatment mechanisms)

- properly plan and conduct in-stream work
  - undertake in-stream work during periods with least potential for disturbance and erosion.
  - minimize duration of in-stream activity
  - avoid placement of fine-grained, easily eroded materials within the wetted perimeter of the stream
  - minimize disturbance to stream-banks where equipment enters and leaves a watercourse. Reconstruct and revegetate disturbed areas.

8. SUMMARY AND CONCLUSIONS

The South Thompson River is the main source of water for Kamloops. Measurements of turbidity at the River Street Water Treatment Plant indicated that the annual average turbidity and the number of days that turbidity exceeded 5 NTU had increased fairly consistently since the early 1980's. This deterioration in the water quality on the South Thompson River has concerned the City of Kamloops and the Department of Fisheries and Oceans.

An analysis of daily turbidity records, in conjunction with climate records from the Kamloops A station and discharge records from the Water Survey of Canada, suggested that most of the turbidity events, and the most extreme events, resulted from low-elevation snowmelt and from summer rainstorms. Both the snowmelt and the summer rainstorms are thought to produce floods, and erosion, in small tributaries leading directly to the main river. The larger tributaries, particularly Chase Creek, contribute turbid water during the melt of the high-elevation snowpack, primarily in late April and May. Large rainstorms, such as occurred in June 1990, produce erosion in the large and the small tributaries, and can elevate turbidity at the River Street Intake above 5 NTU for a month or more.

A program of weekly turbidity measurements on some tributaries and along the main river by the City of Kamloops, combined with air photograph analysis, identified the major contributors to elevated turbidity at the River Street Intake. Chase Creek is the most important of the large tributaries. The fine sediment that elevates turbidity in this creek comes from erosion of old logging roads and natural failures in upper Chase Creek, erosion of lacustrine and other glacial sediments near Charcoal Creek and erosion of channel banks between Charcoal Creek and the Turtle Valley Bridge. We recommend rehabilitation of roads and clearcuts in upper Chase Creek and re-establishment of riparian vegetation along the reach from Charcoal Creek to Turtle Valley Bridge.

Juniper and Stobart Creeks are the most important of the small tributaries though several other small streams may also contribute sediment that elevates turbidity. Juniper Creek has not been investigated in detail and we recommend investigation of sediment sources and development of a remedial program.

Stobart Creek contributes fine-grained lacustrine sediment as a result of severe gullying on Harper

Ranch. Headward erosion of the gully has been stopped but lateral erosion is expected to continue to contribute fine sediment to the South Thompson River. A variety of methods are available to reduce lateral erosion and the contribution of fine sediment to the South Thompson River. The most practical of these may be development of check-dams combined with re-vegetation of the gully walls.

9. REFERENCES

Beeson, C.E. and P.F. Doyle. 1995. Comparison of bank erosion at vegetated and non-vegetated channel bends. submitted to Water Resources Bulletin.

Fulton, R.J. 1975. Quaternary geology and geomorphology, Nicola-Vernon Area, British Columbia. Geological Survey of Canada Memoir 380. 50 pp and maps.

Holland, S.S. 1976. Landforms of British Columbia: a physiographic outline. British Columbia Department of Mines and Petroleum Resources Bulletin 48. 138 pp.

Northwest Hydraulic Consultants Ltd. 1994. Determination of sediment deposition zones: Fraser River Basin. Environment Canada. Fraser River Action Plan Report DOE-FRAP 1994-32.

Ryder, J.M. 1971. The stratigraphy and morphology of para-glacial alluvial fans in south-central British Columbia. Canadian Journal of Earth Sciences 8: 279-298.

Vernon Forest District. 1992 (May). Upper Chase Creek background information and preliminary hydrological assessment. Unpublished Report. 11 pp.

Watson Engineering Ltd. 1995. Harper/Stobbart Creek silt problem. Letter to the City of Kamloops, attention of M. Warren, dated February 27, 1995. 4 pp and tables and figures.

TABLES

Table 1: Tributaries to the South Thompson River Kamloops to Shuswap Lake

Distance from Kamloops (km)	Bank	Stream Name	Basin Area			Main Channel				Max. Basin Elevation (m)
			Total (km²)	Upstream of Lakes (km²)	% Lake Controlled	Length (km)	Minimum Elevation (m)	Maximum Elevation (m)	Average Slope	
--	--	South Thompson R.	2011.9	1059.5	52.7	58.1	Rise < contour interval of 100 ft			1875
Downstream of River Street WTP										
0.65	LB	Peterson Ck.	131.9	75.8	57.5	34.8	350	1722	0.04	1875
0.65	LB	Peterson Ck d/s of Jacko Lake.	94.0	37.9	40.3	16.7	350	899	0.03	1204
2.40	LB	Joyce Gulch	5.3	0.0	0.0	6.1	350	960	0.10	1052
Upstream of River Street WTP										
4.50	LB		9.0	0.0	0.0	6.6	350	1052	0.11	1113
5.25	RB		1.8	0.0	0.0	1.6	350	518	0.11	991
5.70	RB		1.4	0.0	0.0	1.2	350	503	0.13	991
5.95	LB		4.0	0.0	0.0	3.1	350	716	0.12	1052
6.55	RB		2.0	0.0	0.0	2.3	350	747	0.17	1021
7.60	RB		2.6	0.0	0.0	3.5	350	1052	0.20	1173
8.05	RB		0.9	0.0	0.0	1.7	350	533	0.11	899
8.40	LB		2.7	0.0	0.0	2.4	350	610	0.11	991
9.25	RB		5.2	0.0	0.0	1.8	350	488	0.08	1143
9.65	LB		4.1	0.0	0.0	4.6	350	1021	0.15	1143
10.10	LB		11.5	0.0	0.0	4.9	350	960	0.12	1143
11.40	RB		1.2	0.0	0.0	2.6	350	899	0.21	1082
11.40	LB	Juniper Ck.	13.1	0.0	0.0	5.5	350	564	0.04	1113
11.85	RB		1.8	0.0	0.0	2.5	350	792	0.18	930
13.95	RB	Stobbart Ck.	21.7	4.6	21.0	7.4	350	594	0.03	1478
18.60	RB	McGregor Ck.	32.2	4.2	12.9	9.9	350	991	0.06	1478
19.00	LB	Campbell Ck.	574.6	494.3	86.0	56.2	350	1356	0.02	1722
19.00	LB	Campbell Ck. d/s of Walker Lk.	218.8	138.1	63.1	19.5	350	686	0.02	1722
25.30	LB		0.2	0.0	0.0	1.0	350	442	0.09	533
25.55	LB		1.1	0.0	0.0	1.2	350	411	0.05	625
25.80	RB		7.9	0.3	3.3	3.1	350	930	0.19	1295
26.00	LB		1.2	0.0	0.0	1.8	350	503	0.08	655
26.40	LB		1.9	0.0	0.0	2.4	350	533	0.08	655
27.65	LB	Monte Ck.	220.9	26.3	11.9	37.2	350	1600	0.03	1722
28.95	RB	Swain Ck.	5.0	1.2	24.2	2.0	350	808	0.23	1113
30.30	LB		1.9	0.0	0.0	1.9	350	503	0.08	747
32.05	RB		7.5	1.8	23.2	4.3	350	869	0.12	1082
32.60	LB		3.4	0.0	0.0	1.7	350	564	0.13	777
33.60	LB		5.0	0.0	0.0	4.4	350	686	0.08	808
34.00	LB		2.5	0.0	0.0	3.3	350	655	0.09	777
34.65	LB	Dry Ck.	19.7	1.8	9.2	6.0	350	747	0.07	1356
34.85	RB	Moulton Ck.	17.8	0.5	2.7	10.1	350	899	0.05	1326
35.55	RB		0.4	0.0	0.0	0.8	350	411	0.08	503
35.80	RB		2.6	0.0	0.0	1.9	350	503	0.08	686
36.30	RB		0.6	0.0	0.0	1.0	350	442	0.09	564
36.50	LB	Neds Ck.	42.0	0.0	0.0	8.2	350	960	0.07	1753
37.65	RB		8.1	0.0	0.0	5.9	350	686	0.06	1234
38.40	RB	Pemberton Ck.	20.8	5.0	24.0	10.8	350	1021	0.06	1295
39.70	RB	Gore Ck.	3.6	0.0	0.0	2.8	350	564	0.08	777
41.00	LB	Martin Ck.	30.3	0.0	0.0	8.2	350	1326	0.12	1509
43.90	LB	Harper Ck.	17.7	9.4	53.3	5.0	350	686	0.07	1509
47.15	RB	Gulch Ck.	24.3	1.1	4.5	11.2	350	930	0.05	1295
47.85	RB	Niskonlith Ck.	101.3	98.2	96.9	18.9	350	1387	0.05	1570
47.85	RB	Niskonlith Ck. d/s of Niskonlith Lk.	3.1	0.0	0.0	2.8	350	503	0.05	716
57.90	LB	Chase Ck.	292.1	96.1	32.9	42.9	350	1570	0.03	1753

Table 2: Timber Harvest in Monte, Campbell and Chase Creeks

Stream Name	Snowpack Zone (1)	Area (km²)	Cut Type	Harvested Area (km²) 1985-1994	1975-1985	< 1975	Current ECA (2)
Monte Creek	Minimal	194.49	clearcut	6.56	34.10	1.86	
			selective	56.89	0.00	0.00	36%
	Low	27.49	clearcut	3.21	2.93	1.75	
			selective	0.09	0.00	0.00	23%
	Moderate	2.93	clearcut	0.32	0.42	0.36	
			selective	0.00	0.00	0.00	25%
	Total	220.90		67.07	37.44	3.97	
Campbell Creek	< 1450 m	218.80	clearcut	3.17	10.16	2.50	
			selective	0.00	0.00	0.00	6%

1. Minimal snowpack zone is the Interior Douglas Fir at elevations below 1,450 m. Low snowpack zone is the Montane Spruce zone at elevations from 1,450 to 1,650 m. Moderate snowpack zone is the Englemann Spruce - Subalpine Fir biogeoclimatic zone at elevations above 1,650 m.
2. ECA calculated by assuming that selective cut was 50% removal and that no hydrologic recovery had occurred.

Stream Name	Snowpack Zone (1)	Area (km²)	Cut Type	Harvested Area (km²) 1985-1994	1975-1985	< 1975	Current ECA (3)
Upper Chase Creek	Minimal	3.7					15.0%
	Low	8.4					5.9%
	Moderate	55.9					29.7%

3. ECA is equivalent Clearcut Area, as calculated by the Vernon Forest District (1992).

Table 3: Gauging Stations in the Lower South Thompson Watershed

Stream Name	Drainage Area (km2) (1)	WSC Gauge Data: Gauge Name	Gauge No.	Drainage Area (km2) (2)	Years of Record	Status
SOUTH THOMPSON RIVER						
South Thompson River	18,200	at Chase	08LE031	16,200	1911-14 MS; 15-55 MC; 56-58MS 71-72 MC; 73-94 RC	natural
		at Monte Creek	08LE069	16,600	58-70 MC	natural
MAJOR TRIBUTARIES						
Chase Creek	292	near Chase	08LE005	279	1911-12; 15-23; 63-68 MS	regulated at Pillar Lake
Monte Creek	221	near Monte Lake	08LE012	61	1911-18; 20-30; 48-54; 80 MS	regulated at Monte Lake
		above Monte Lake Diversion	08LE103	64	1981-94 MS	natural
		near Monte Creek	08LE013	184	11-30; 80 MS	regulated at Monte Lake
		diversion to Monte Lake	08LE011	-	1911; 13-18; 20-30; 45-54 MS	regulated
- North Paxton Creek		above diversions	08LE099	-	1979-80	regulated
- Robbins Creek		near Robbins Range	08LE022	16	1919-27 MS	natural
		above Disidero Creek	08LE078	32	1968; 71-72; 76-79 MS	natural
		near Monte Lake (lower stn)	08LE018	39	1911-12 MS	regulated
Campbell Creek	575	near Barnhart Vale (upper)	08LE037	285	1917-27; 48-51 MS	natural
		below Scuitto Creek	08LE058	521	1949-51; 62-67 MS	regulated
		near Barnhart Vale	08LE002	518	1911-15 MS	natural
		near Monte Creek	08LE003	-	1911-12	natural
- Scuitto Creek		near Barnhart Vale	08LE036	122	1917-18; 22-23; 26; 48 MS	natural
Niskonlith Creek	101	above Niskonlith Lake	08LE032	31	1921; 23-27 MS	natural
		Niskonlith Lake Spillway	08LE050	-	1945-50 MS	regulated
		near Shuswap	08LE016	130	1911-14 MS	regulated
- Loakin Creek		above Indian diversion	08LE033	52	1918-27 MS	natural
		(Indian Diversion) near Shuswap	08LE051	-	1934-50 MS	regulated
SMALL TRIBUTARIES						
Pemberton Creek (Km 38.4)	21	near Pritchard	08LE017	21	1911-12 MS	natural
Martin Creek (Km 41.0)	30	near Pritchard	08LE010	39	1911; 18-22 MS	natural
Moulton Creek (Km 34.85)	18	near Pritchard	08LE014	16	1911-12 MS	natural
Neds Creek (Km 36.5)	42	near Pritchard (upper stn)	08LE034	5	1918-21; 24-27 MS	regulated
		near Pritchard (lower stn)	08LE015	16	1912; 17-21; 24-27 MS	regulated
Peterson Creek (Km 0.65)	132	above Jacko Creek	08LE102	21	1981-86 RS	natural
		near Kamloops	08LE035	65	1917-22 MS	regulated
		near Knutsford	08LE061	103	1950-52 MS	natural
- Jacko Creek		near Kamloops	08LE009	11	1912-13 MS	natural

1. Drainage area to the mouth of the stream (see Table 1).
2. Drainage area at the Water Survey of Canada gauge (WSC 1990).

Table 4: Summary of Turbidity Events: River Street Water Treatment Plant 1987 to 1993

Year	Snowmelt			Rainstorm			Major Tributary			Major Trib with Rainstorm			South Thompson River			Unknown		
	Days over 5 NTU	Days over 10 NTU	Average Maximum	Days over 5 NTU	Days over 10 NTU	Average Maximum	Days over 5 NTU	Days over 10 NTU	Average Maximum	Days over 5 NTU	Days over 10 NTU	Average Maximum	Days over 5 NTU	Days over 10 NTU	Average Maximum	Days over 5 NTU	Days over 10 NTU	Average Maximum
1987	8	3	12.7	6	0	6.8	6	0	8.2	6	2	19.1	0	0		14	5	12.0
1988	20	0	7.2	1	0	5.1	0	0		12	0	6.2	4	0	9.6	8	0	7.2
1989	15	6	23.7	12	0	6.7	8	1	7.3	7	0	7.1	3	0	5.5	12	2	7.9
1990	14	2	8.6	12	6	26.4	21	4	10.8	29	12	12.6	2	0	9.3	30	2	6.9
1991	3	3	39.0	2	2	29.0	1	0	6.4	0	0		0	0		3	2	16.7
1992	1	0	6.0	4	2	13.7	0	0		0	0		0	0		9	3	8.9
1993	35	16	31.1	59	23	13.4	3	1	10.1	4	2	9.8	0	0		9	3	9.6
TOTAL	***96***	***30***	***18.3***	***96***	***33***	***14.4***	***39***	***6***	***8.6***	***58***	***16***	***11.0***	***9***	***0***	***8.1***	***85***	***17***	***9.9***

Table 5: Summary of the 1994 Turbidity Program

Site No	Stream	1994 Turbidity Measurements (1) No. Samples	Average NTU	Maximum NTU	Minimum NTU
Weekly Sampling Program -- April 14 to June 26, 1994					
ST#1	South Thompson River at River Street WTP	7	14	39 (April 21)	1.3 (April 14)
ST#2	South Thompson River at S.E.S. Intake, Dallas	10	11	58.5 (June 12)	1.5 (April 14)
ST#3	Stobbart Creek at mouth	12	>1,000	>1,000 (various)	1.3 (April 14)
ST#4	Campbell Ck at Hwy #1	12	16	48.6 (June 20)	4 (April 21)
ST#5	South Thompson River at Lafarge Bridge	10	18	127 (June 12)	2.1 (June 4)
ST#6	Monte Creek at Campground	11	74	457 (June 20)	2.2 (June 4)
ST#7	South Thompson River at Pritchard Bridge	10	41	244 (June 26)	1.1 (June 4)
ST#8	Neskonlith Creek at mouth	10	127	755 (June 20)	1.3 (May 23)
ST#9	South Thompson River at outlet of Little Shuswap Lake	11	31	110 (June 26)	1.4 (May 28)
ST#10	Chase Creek at mouth	12	38	214 (April 21)	2.1 (May 23)
Weekly Sampling Program -- April 14 to May 28, 1994					
Chase #1	Chase Ck, Highway #1 Bridge	8	63	175 (April 25)	2.5 (May 28)
Chase #2	Chase Ck, Turtle Valley Bridge	9	56	195 (April 20)	3.3 (May 28)
Chase #3	Chase Ck, 3 km South of Chase #2	8	42	136 (April 20)	5.4 (April 18)
Chase #4	Chase Ck, 8 km South of Chase #2	8	12	46 (April 20)	2.1 (May 28)
Chase #5	Chase Ck, at Charcoal Ck	9	6	19 (May 8)	0.9 (May 28)
Chase #6	Charcoal Ck, at Chase Ck	9	8	32 (April 20)	1.6 (May 28)
Chase #7	Chase Ck, Bridge near Pillar Lake	9	7	23 (May 8)	1.3 (May 28)

1. Turbidity measurements collected and analyzed by the City of Kamloops.

Table 6: Summary of the 1995 Turbidity Program

Site No	Stream	1995 Turbidity Measurements (1)			
		No. Samples	Average NTU	Maximum NTU	Minimum NTU
Weekly Sampling Program – February 6, to July 17, 1995					
ST#1	South Thompson River at River Street WTP	23	4.5	8.89 (Feb 20)	1.37 (July 17)
ST#2	South Thompson River at S.E.S. Intake, Dallas	23	5.7	22.1 (April 3)	1.83 (July 10)
ST#3	Stobbart Creek at mouth	24	597	4,300 (Feb 6)	10.9 (May 23)
ST#4	Campbell Ck at Hwy #1	23	8.2	34.7 (May 15)	2.21 (May 1)
ST#5	South Thompson River at Lafarge Bridge	24	2.7	6.7 (Feb 6)	1.47 (March 6)
ST#6	Monte Creek at Campground	24	24.2	239 (Feb 27)	1.57 (July 17)
ST#7	South Thompson River at Pritchard Bridge	23	1.6	4.11 (May 15)	0.92 (March 6)
ST#8	Neskonlith Creek at mouth	16	1.4	2.09 (June 26)	0.72 (April 18)
ST#9	South Thompson River at outlet of Little Shuswap Lake	24	1.5	6.31 (March 20)	0.47 (Feb 13)
ST#10	Chase Creek at mouth	24	16.2	135 (May 15)	0.97 (July 17)
ST#11	South Thompson River upstream of Harper Ck	1	-	-	-
ST#12	South Thompson River downstream of Harper Ck	1	-	-	-
ST#13	Juniper Creek at S.E.S. Intake	1	-	34,600 (Feb 6)	-
Weekly Sampling Program – February 6, to July 17, 1995					
Chase #1	Chase Ck, Highway #1 Bridge	24	15.7	134 (May 15)	0.95 (July 17)
Chase #2	Chase Ck, Turtle Valley Bridge	19	15.8	105 (May 15)	1.03 (July 17)
Chase #3	Chase Ck, bridge 6.8 km from Chase #2	24	10.3	103 (May 15)	0.46 (Feb 13)
Chase #4	Not Used				
Chase #5	Chase Ck, at Charcoal Ck	24	2.0	13.7 (May 15)	0.2 (Feb 13)
Chase #6	Charcoal Ck, at Chase Ck	24	3.2	8.25 (May 15)	0.41 (Feb 13)
Chase #7	Chase Ck, Bridge at Moser Road	20	3.4	12.5 (May 15)	0.78 (July 17)

1. Turbidity measurements provided by the City of Kamloops.

FIGURES

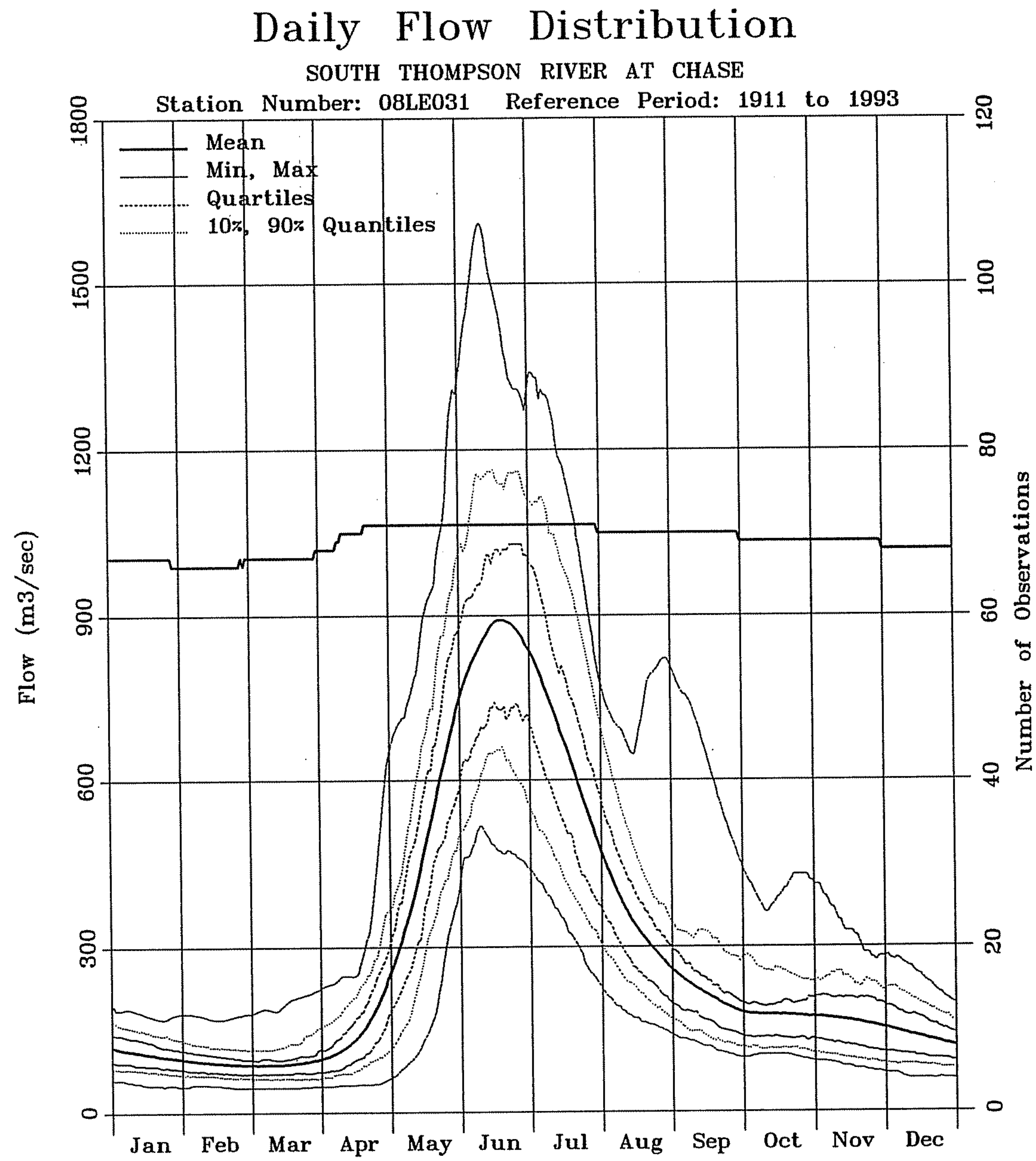
FIGURE 1

study area

SOUTH THOMPSON RIVER WATERSHED MANAGEMENT STUDY

November 30, 1995

URBANSYSTEMS



1 Mar 96	Software TOOLKIT 2.0 developed by SISB, Environment Canada

Figure 2

Mean Annual Turbidity

at the River Street Water Treatment Plant

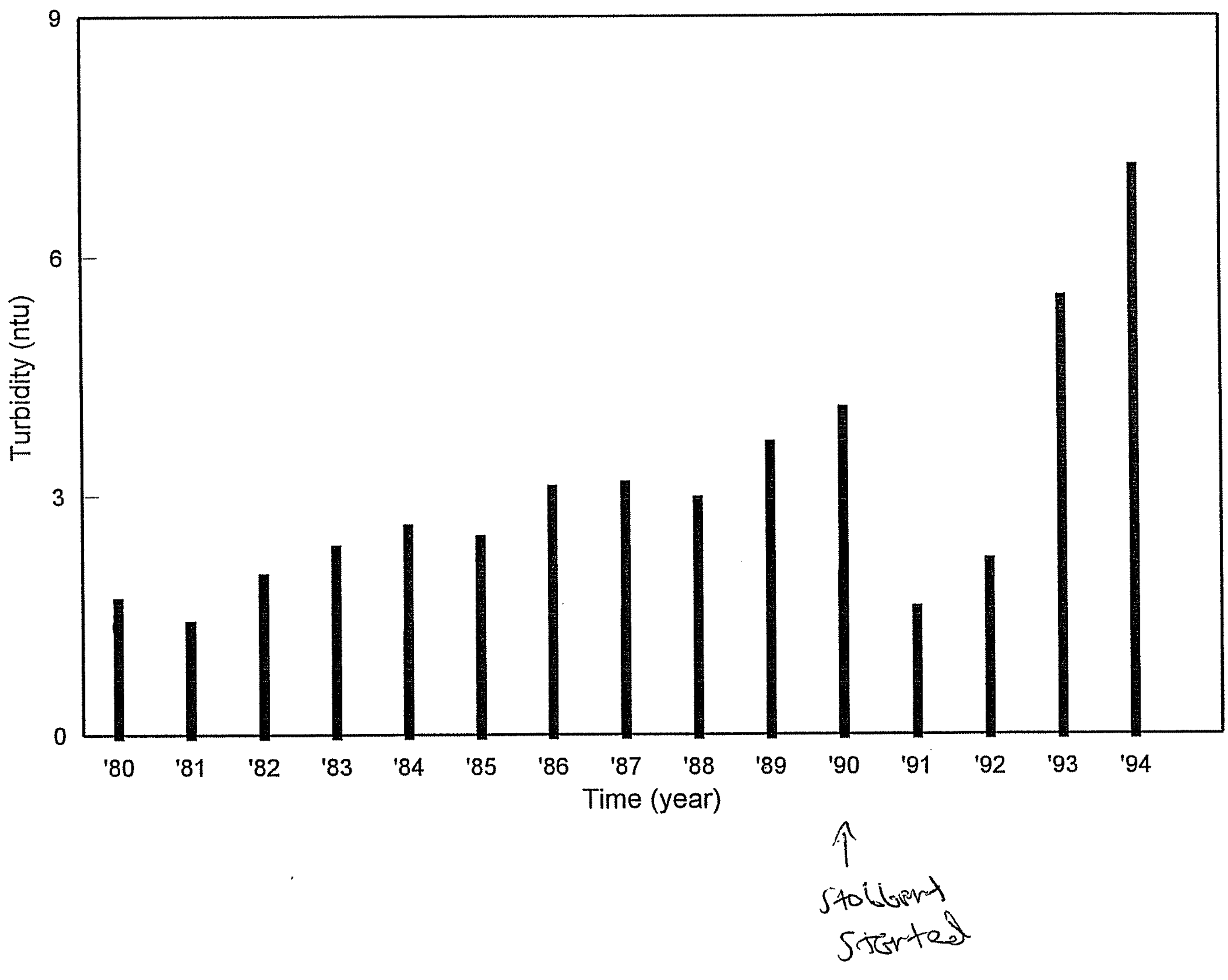


Figure 3

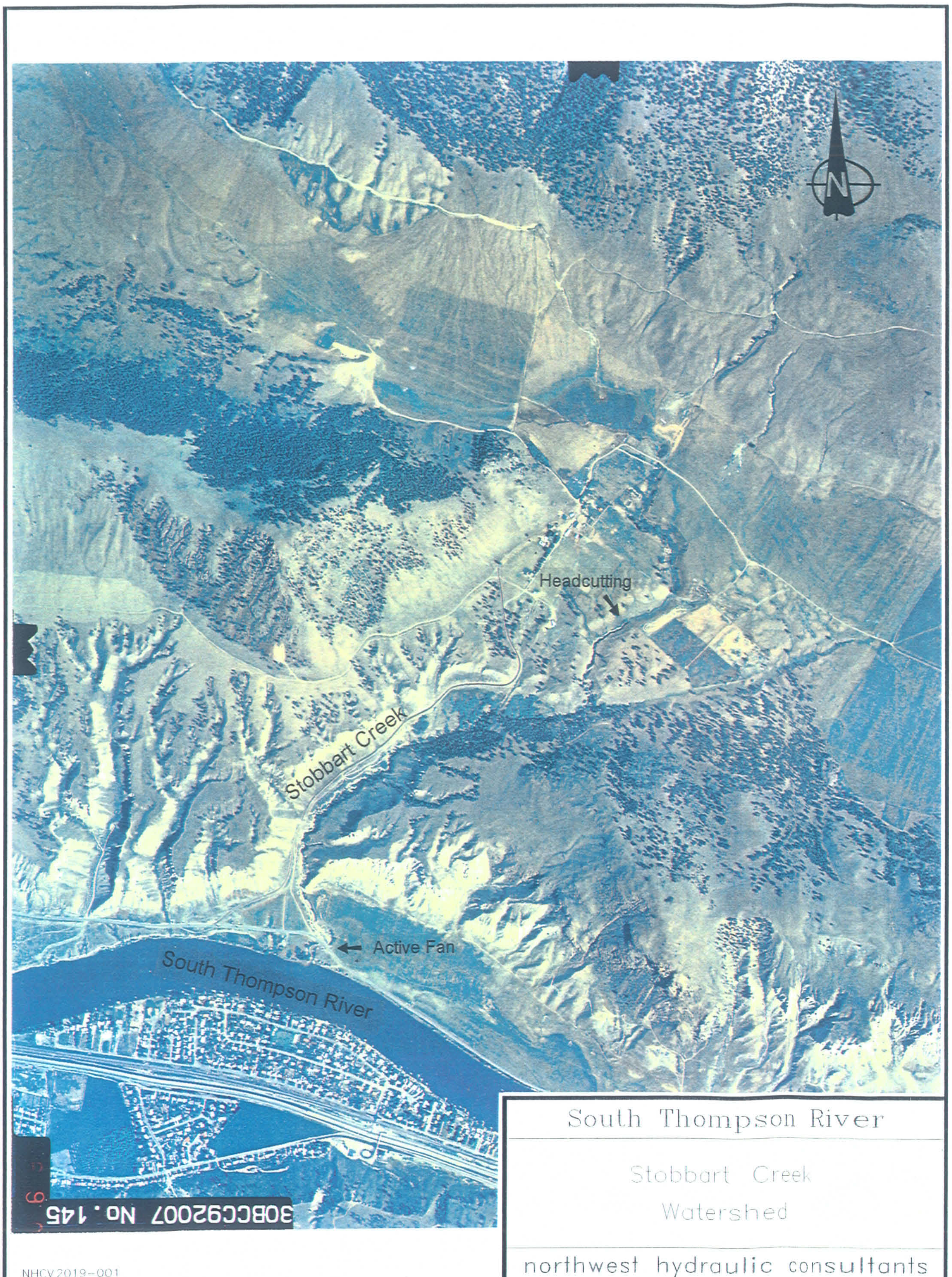
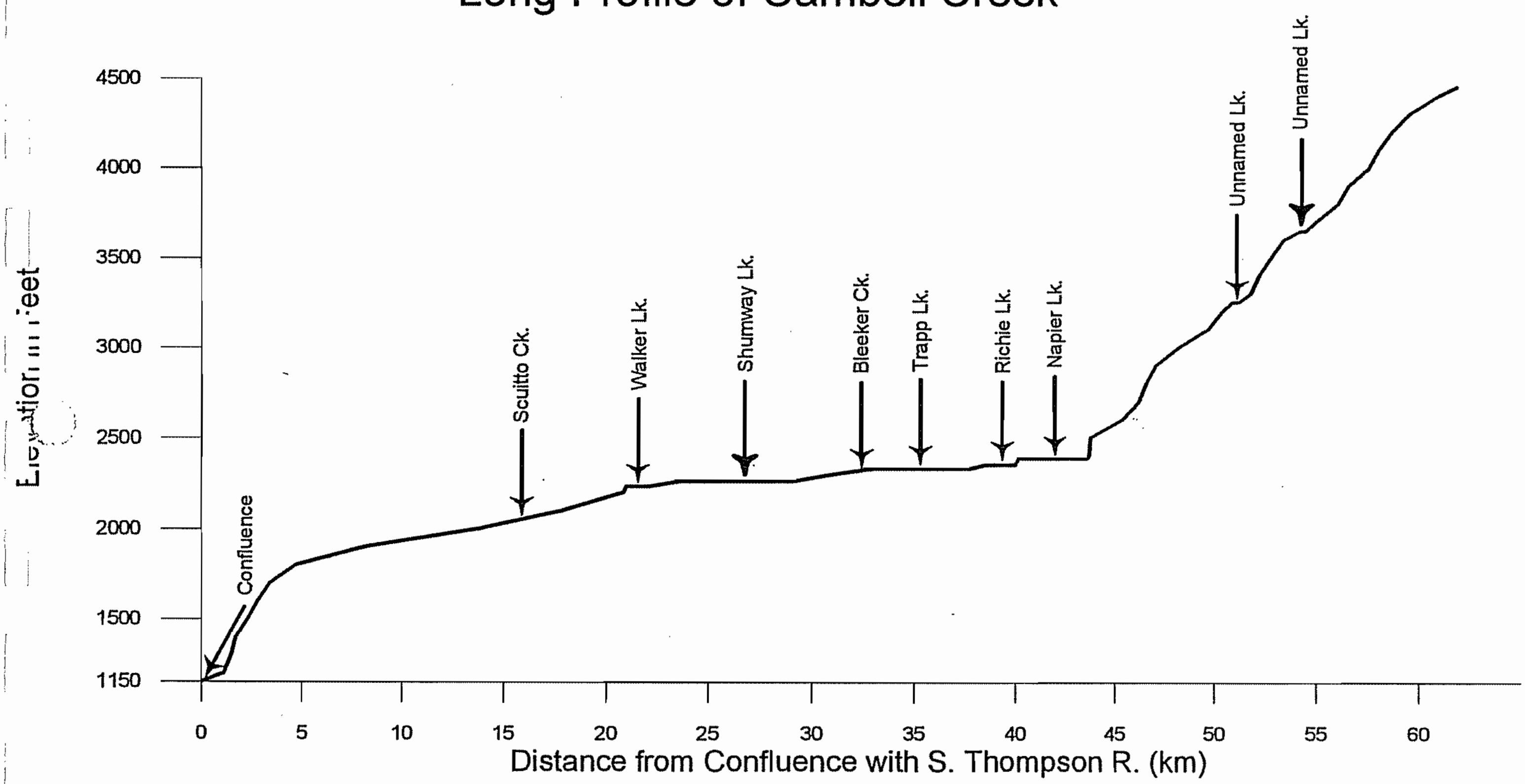

N
Headcutting
Stobbart Creek
Active Fan
South Thompson River
South Thompson River
Stobbart Creek
Watershed
northwest hydraulic consultants
NHCV2019-001

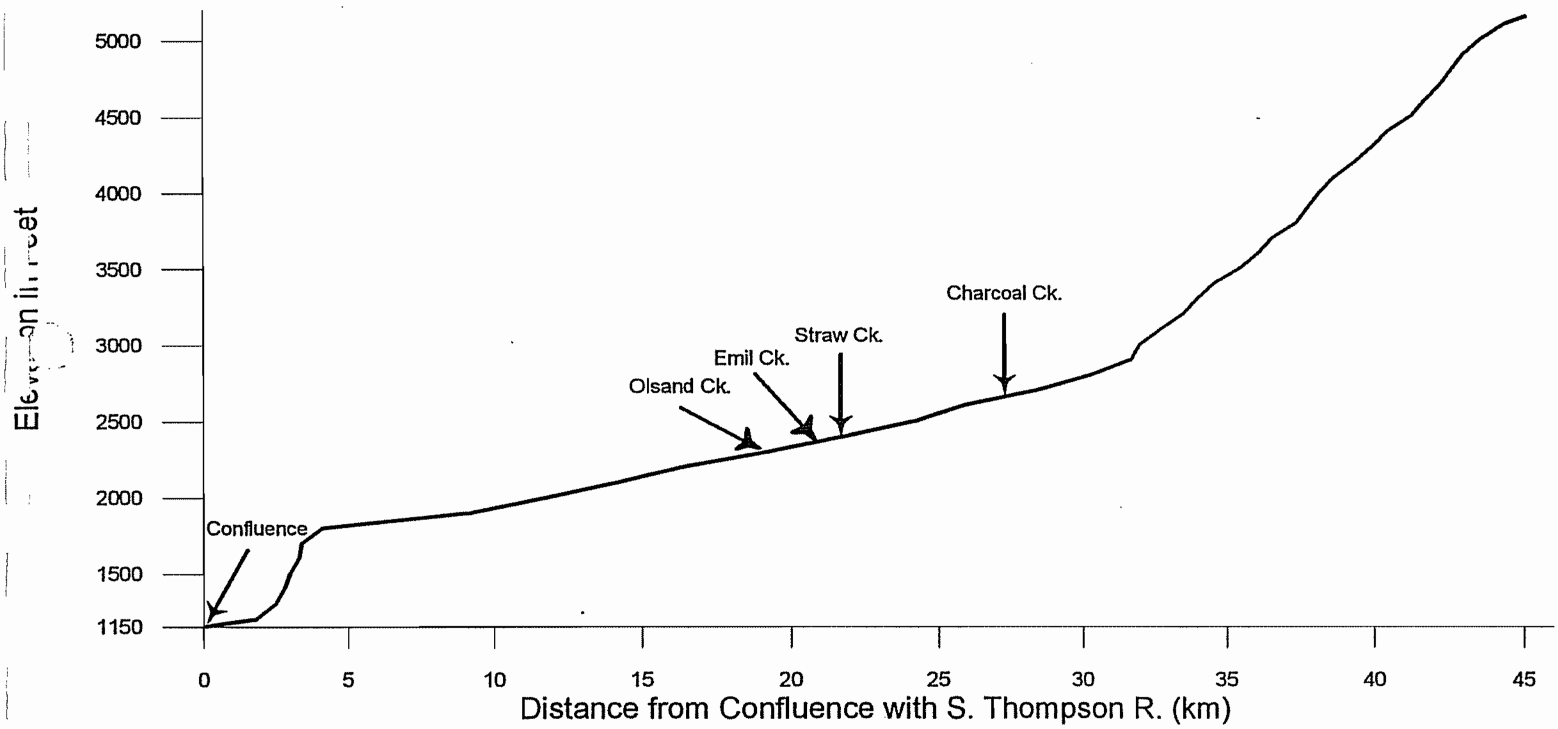
Figure 4

APPENDIX 'A'

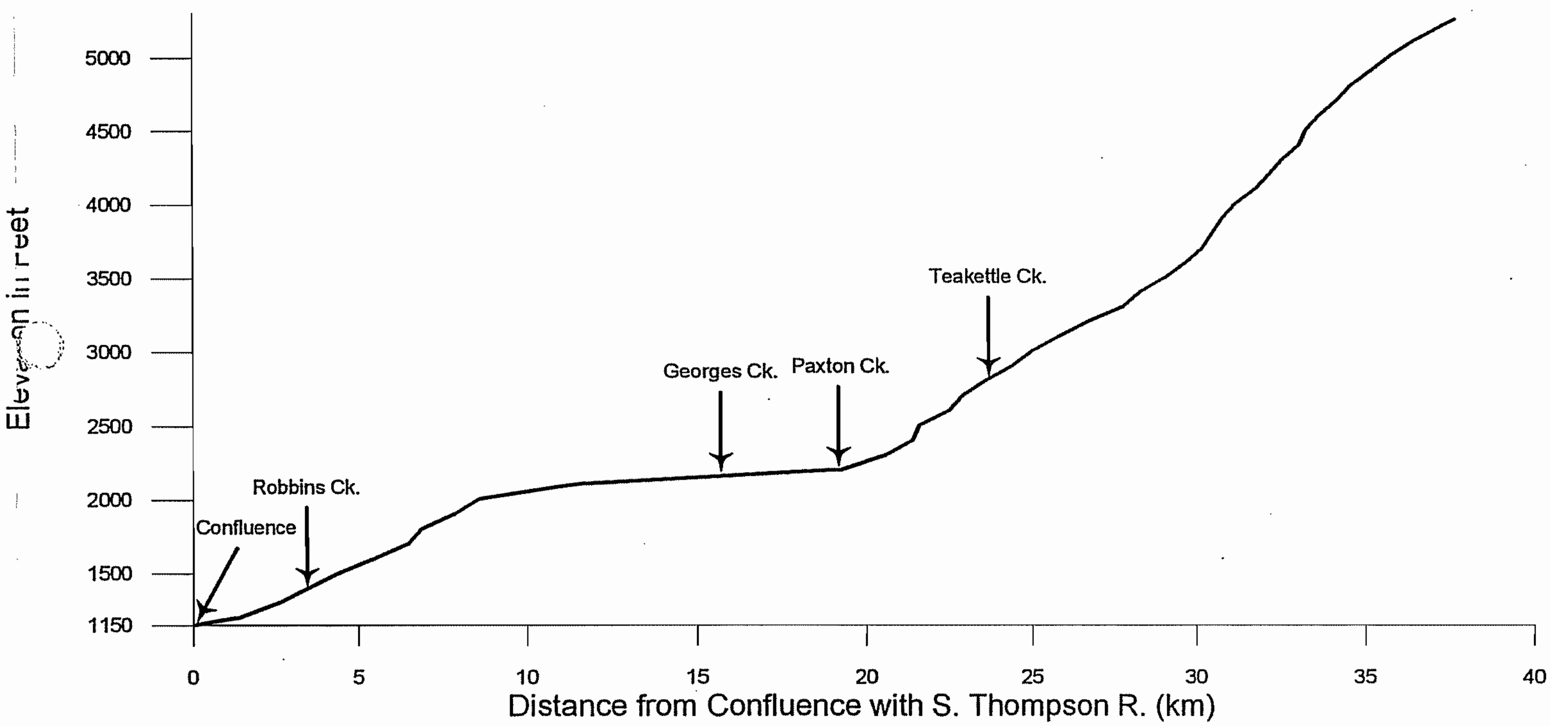
Long Profile of Cambell Creek



Long Profile of Chase Creek



Long Profile of Monte Creek



APPENDIX 'B'

Appendix B1: Summary of Turbidity Events -- River Street Water Treatment Plant January 1987 to December 1994

Turbidity Event		Days above	Days above	Maximum	Probable Cause of Turbidity Event		Snowmelt or Rainfall Event	
Start	End	5 NTU	10 NTU	NTU	Primary Type	Secondary Type	Maximum Value	Event Duration
01/11/87	01/14/87	2	1	19.3	snowmelt		+ 5.3°C	01/10 - 01/12
02/09/87	02/10/87	2	1	10.0	snowmelt		+6.8°C	02/03 - 02/10
02/18/87	02/19/87	2	0	7.5	snowmelt		+4.0°C	02/18 - 02/19
03/07/87	03/08/87	2	1	14.0	snowmelt		+13.5°C	02/25 -
03/27/87	03/27/87	1	0	6.8	rainstorm		1.6 mm	03/25
04/13/87	04/13/87	1	0	9.2	peak flow -- major tributary			
05/01/87	05/07/87	4	2	33.0	peak flow -- major tributary	rainstorm	19.4 mm	04/28 - 05/01
05/08/87	05/12/87	5	0	7.1	peak flow -- major tributary			
05/19/87	05/20/87	2	0	5.2	peak flow -- major tributary	rainstorm	2.4 mm	05/18 - 05/19
07/28/87	07/28/87	1	0	9.7				
09/18/87	09/20/87	1	1	20.0				
10/03/87	10/05/87	1	1	20.0				
12/09/87	12/10/87	2	0	7.3				
12/13/87	12/17/87	5	0	6.8	rainstorm		1 mm	12/07 - 12/10
12/19/87	12/24/87	6	0	7.0				
12/26/87	12/27/87	2	2	10.0				
12/30/87	12/30/87	1	1	10.0				
01/31/88	01/31/88	1	0	5.8	snowmelt	rainstorm	+7.5°C	01/28 - 01/29
02/02/88	02/02/88	1	0	6.6				
02/12/88	02/12/88	1	0	5.6	snowmelt		+6.0°C	02/11 -
02/16/88	02/20/88	5	0	6.5	snowmelt	rainstorm	+6.6°C	02/11 -
02/22/88	02/28/88	7	0	9.7	snowmelt	rainstorm	+6.6°C	02/11 -
03/02/88	03/07/88	6	0	8.3	snowmelt		+6.6°C	02/24 -
03/14/88	03/14/88	1	0	7.7				
03/27/88	03/27/88	1	0	5.1	rainstorm		2.4 mm	03/26
04/05/88	04/06/88	2	0	7.8				
04/20/88	04/20/88	1	0	6.5	peak flow -- major tributary	rainstorm	9.5 mm	04/16 - 04/18
04/27/88	04/27/88	1	0	7.1	peak flow -- major tributary	rainstorm	4.8 mm	04/24 - 04/25
05/06/88	05/07/88	2	0	6.0	peak flow -- major tributary	rainstorm	5.4 mm	05/02 - 05/06
05/14/88	05/15/88	2	0	5.9	peak flow -- major tributary	rainstorm	3.6 mm	05/13
05/22/88	05/22/88	1	0	5.5	peak flow -- major tributary	rainstorm	1.2 mm	05/22
07/19/88	07/20/88	2	0	9.1	peak flow -- S. Thompson			
08/14/88	08/15/88	2	0	10.0	peak flow -- S. Thompson			
11/14/88	11/14/88	1	0	5.8				
11/18/88	11/18/88	1	0	7.5				
12/25/88	12/26/88	2	0	7.6				
01/03/89	01/03/89	1	0	8.0				
01/30/89	02/03/89	5	4	57.0	snowmelt	rainstorm	+ 8.1°C	01/29 - 01/30
02/07/89	02/07/89	1	1	12.0				
03/07/89	03/10/89	2	0	5.2	snowmelt	rainstorm	+ 9.5°C	03/05 - 03/10
03/11/89	03/21/89	6	2	24.0	snowmelt	rainstorm	+ 9.5°C	03/05 -
03/23/89	03/24/89	2	0	8.5	snowmelt		+10.2°C	03/05 -
04/01/89	04/01/89	1	0	6.5				
04/16/89	04/16/89	1	0	7.6	peak flow -- major tributary			
04/25/89	04/25/89	1	0	6.1	peak flow -- major tributary			
04/30/89	04/30/89	1	0	5.6	peak flow -- major tributary			
05/08/89	05/13/89	5	1	10.0	peak flow -- major tributary			
05/17/89	05/17/89	1	0	6.5	peak flow -- major tributary	rainstorm	8.6 mm	05/16 - 05/17
05/19/89	05/20/89	2	0	6.5	peak flow -- major tributary	rainstorm	8.6 mm	05/16 - 05/20
05/24/89	05/27/89	4	0	8.3	peak flow -- major tributary	rainstorm	11.7 mm	05/22 - 05/27
06/01/89	06/02/89	2	0	5.6	peak flow -- S. Thompson			
06/11/89	06/11/89	1	0	5.4	peak flow -- S. Thompson	rainstorm	1.7 mm	06/09
06/29/89	06/29/89	1	0	5.3	rainstorm	peak flow -- S. Thompson	6.2 mm	06/24 - 07/01
07/21/89	07/21/89	1	0	8.3				
07/29/89	07/30/89	2	0	5.3				
08/30/89	08/30/89	1	0	5.0	rainstorm		3.8 mm	08/25 - 08/30
09/17/89	09/17/89	1	0	9.7	rainstorm		2.8 mm	09/16 - 09/17
09/23/89	09/23/89	1	1	10.0				
10/10/89	10/10/89	1	0	5.5	rainstorm		5.9 mm	10/10
10/13/89	10/14/89	2	0	9.8	rainstorm		2.4 mm	10/12 - 10/14
10/18/89	10/20/89	2	0	5.6	rainstorm		2.2 mm	10/17
10/27/89	10/27/89	1	0	5.0	rainstorm		4.8 mm	10/23 - 10/26
11/03/89	11/04/89	2	0	8.5	rainstorm		7.4 mm	11/02 - 11/04
11/10/89	11/10/89	1	0	5.8	rainstorm		2.2 mm	11/10
11/18/89	11/18/89	1	0	6.2				
11/26/89	11/27/89	2	0	5.2				
12/20/89	12/21/89	2	0	9.5				

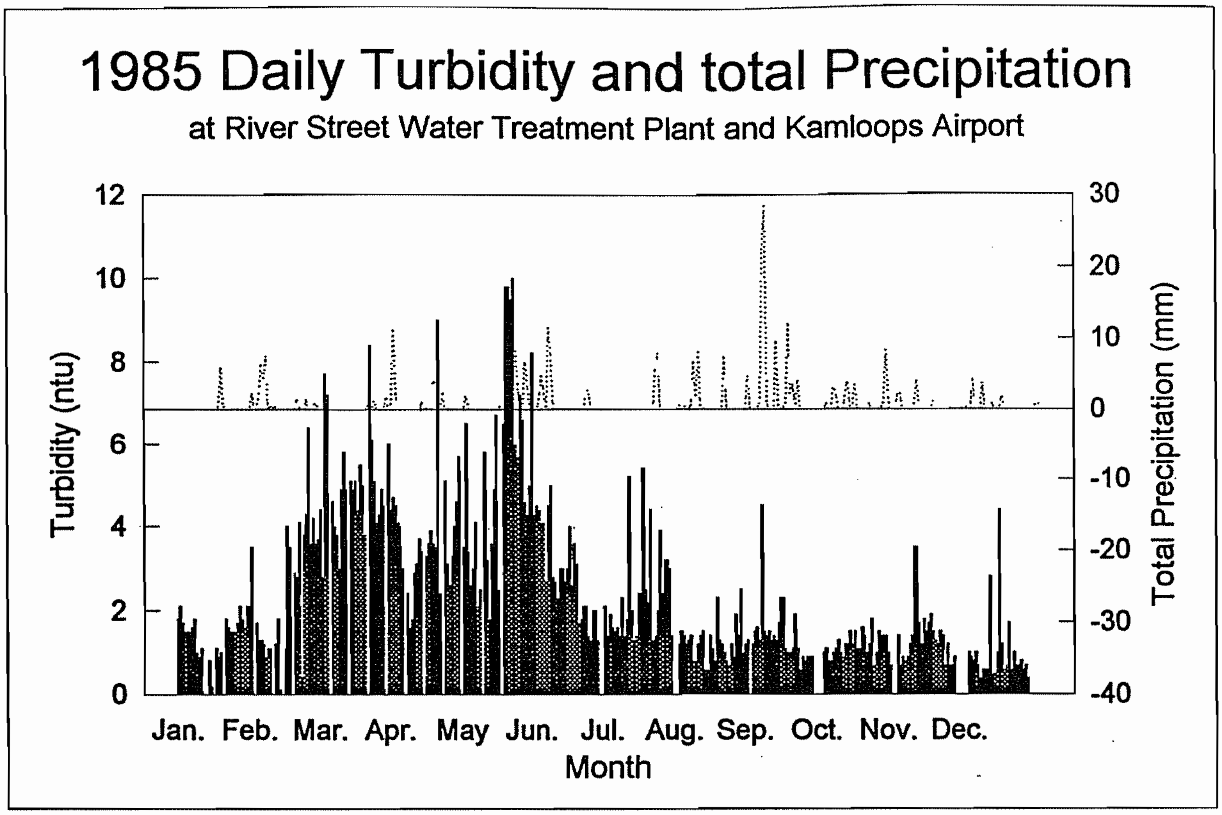
Appendix B1: Summary of Turbidity Events -- River Street Water Treatment Plant January 1987 to December 1994

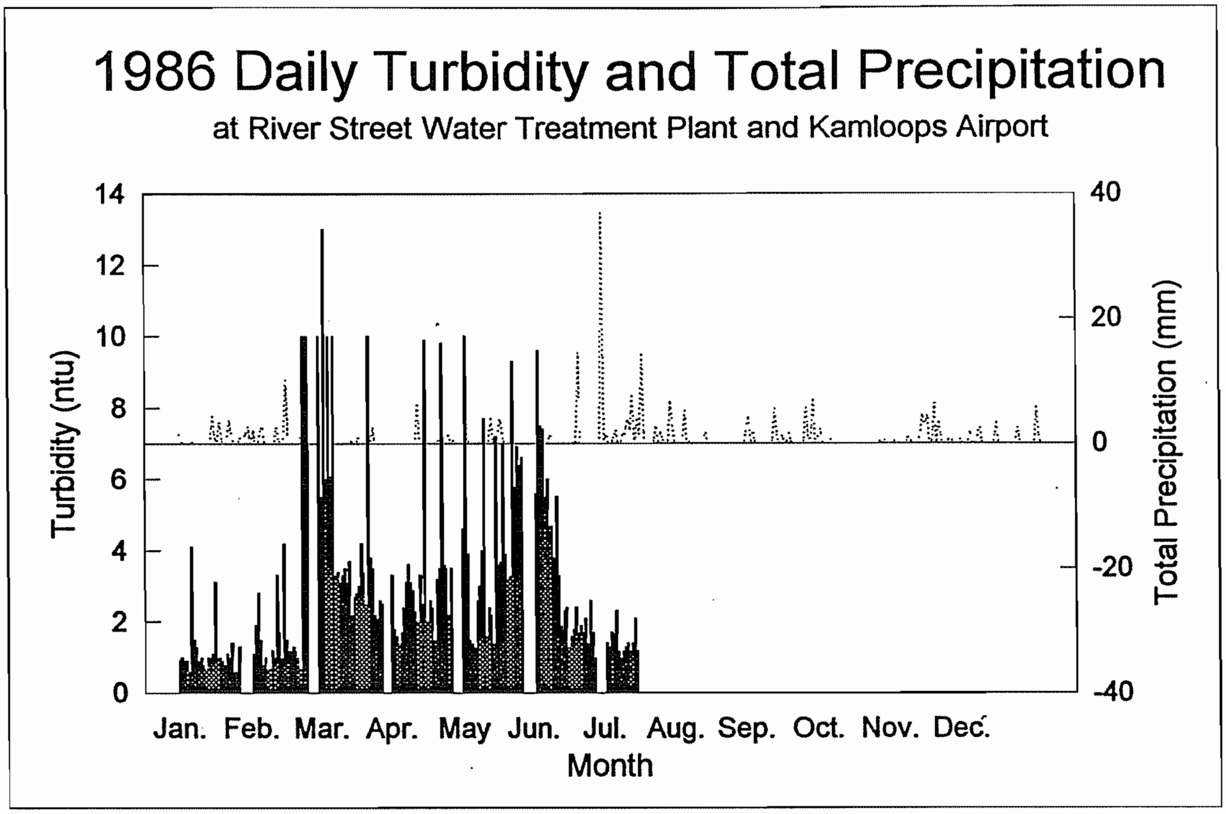
Turbidity Event		Days above	Days above	Maximum	Probable Cause of Turbidity Event		Snowmelt or Rainfall Event	
Start	End	5 NTU	10 NTU	NTU	Primary Type	Secondary Type	Maximum Value	Event Duration
01/05/90	01/05/90	1	0	7.1	snowmelt		+3.1°C	01/05 -
01/12/90	01/12/90	1	0	5.3				
01/21/90	01/24/90	4	0	7.0				
01/29/90	01/31/90	3	0	9.8				
02/06/90	02/09/90	3	0	8.4	snowmelt		+6.2°C	02/03 - 02/06
02/14/90	02/15/90	2	0	7.5	snowmelt	rainstorm	+3.7°C	02/10 - 02/11
02/22/90	02/25/90	3	1	10.0	snowmelt		+2.4°C	02/22, 02/25
03/02/90	03/07/90	5	1	10.0	snowmelt		+9.5°C	02/25 -
03/10/90	03/29/90	14	2	10.0				
04/01/90	04/02/90	2	0	6.3				
04/04/90	04/06/90	2	0	7.4				
04/09/90	04/14/90	5	1	13.0	peak flow -- major tributary			
04/17/90	04/29/90	11	3	11.0	peak flow -- major tributary			
05/04/90	05/08/90	5	0	8.4	peak flow -- major tributary			
05/12/90	05/14/90	3	0	6.7	peak flow -- major tributary	rainstorm	2.8 mm	05/10 - 05/14
05/19/90	05/22/90	4	2	10.0	peak flow -- major tributary	rainstorm	3.8 mm	05/16 - 05/22
05/27/90	05/31/90	5	0	7.8	peak flow -- major tributary	rainstorm	8.4 mm	05/22 - 05/31
06/06/90	06/07/90	2	0	9.3	peak flow -- S. Thompson	rainstorm	2.8 mm	06/03 - 06/06
06/11/90	06/26/90	15	10	29.0	peak flow -- major tributary	rainstorm	12.1 mm	06/09 - 06/19
07/01/90	07/09/90	7	2	10.0	rainstorm		20.4 mm	06/29 - 07/06
07/14/90	07/14/90	1	0	5.1				
07/18/90	07/19/90	2	0	5.6				
07/22/90	07/26/90	2	2	52.2	rainstorm		22.9 mm	07/23
08/25/90	08/27/90	1	1	30.0	rainstorm		5.4 mm	08/21 - 08/25
08/31/90	08/31/90	1	0	6.9	rainstorm		3.4 mm	08/29 - 08/31
10/02/90	10/04/90	1	1	33.0	rainstorm		2.0 mm	10/03 - 10/04
10/29/90	10/29/90	1	0	5.4				
02/04/91	02/06/91	1	1	78.0	snowmelt	rainstorm	+ 9.4°C	02/01 - 02/06
02/07/91	02/09/91	1	1	18.0	snowmelt	rainstorm	+ 6.4°C	02/06 - 02/28
03/26/91	03/28/91	1	1	21.0	snowmelt		+ 8.4°C	03/06 -
05/06/91	05/06/91	1	0	6.4	peak flow -- major tributary			
08/26/91	08/28/91	1	1	32.0	rainstorm		11.8 mm	08/24 - 08/26
10/21/91	10/23/91	1	1	25.0	rainstorm		4.9 mm	10/21 - 10/23
10/28/91	10/30/91	1	1	21.0				
11/14/91	11/16/91	1	1	24.0				
11/18/91	11/18/91	1	0	5.0				
01/09/92	01/09/92	1	0	6.0	snowmelt		+2.3°C	01/09 -
07/05/92	07/05/92	1	0	5.4	rainstorm		8.2 mm	07/04 - 07/05
07/19/92	07/19/92	1	1	13.5				
08/10/92	08/10/92	1	0	7.5				
08/18/92	08/18/92	1	0	7.2				
08/20/92	08/20/92	1	0	6.6				
08/23/92	08/23/92	1	0	7.2				
08/27/92	08/29/92	1	1	15.7				
09/02/92	09/04/92	1	1	23.2	rainstorm		15.6 mm	09/03 - 09/04
09/08/92	09/08/92	1	0	5.5				
09/13/92	09/13/92	1	0	5.9	rainstorm		10.4 mm	09/12 - 09/14
11/08/92	11/10/92	1	1	20.4	rainstorm		15.4 mm	11/06 - 11/08
11/16/92	11/16/92	1	1	10.7				
12/15/92	12/16/92	1	0	6.4				
02/05/93	02/05/93	1	0	6.0	snowmelt		+1.7°C	02/05 - 02/06
02/09/93	02/09/93	1	0	7.6				
02/11/93	02/14/93	2	1	18.3	snowmelt		+ 5.9°C	02/11 - 02/13
02/16/93	02/18/93	1	1	18.2				
03/01/93	03/16/93	14	9	35.1	snowmelt		+ 8.5°C	03/01 - 03/14
03/18/93	04/06/93	18	6	65.0	snowmelt		+ 15.2°C	03/19 -
04/11/93	04/11/93	1	0	7.5	peak flow -- major tributary			
04/14/93	04/14/93	1	0	5.3	peak flow -- major tributary			
04/18/93	04/22/93	3	1	14.4	peak flow -- major tributary	rainstorm	3.4 mm	04/19 - 04/22
04/24/93	04/26/93	1	1	17.6	peak flow -- major tributary			
04/29/93	04/29/93	1	1	5.2	peak flow -- major tributary	rainstorm	1.2 mm	04/29
05/04/93	06/02/93	30	17	46.2	rainstorm	peak flow -- major tributary	13.8 mm	05/29 - 06/01
06/06/93	06/07/93	2	0	5.9	rainstorm	peak flow -- S. Thompson	17.4 mm	06/07
06/14/93	06/14/93	1	0	6.4	rainstorm	peak flow -- S. Thompson	4.0 mm	06/11 - 06/14
06/26/93	06/26/93	1	0	9.0	rainstorm		5.8 mm	06/22 - 06/26
07/03/93	07/03/93	1	0	5.2	rainstorm		8.4 mm	06/29 - 07/03
07/08/93	07/11/93	2	1	18.9	rainstorm		3.6 mm	07/06 - 07/11

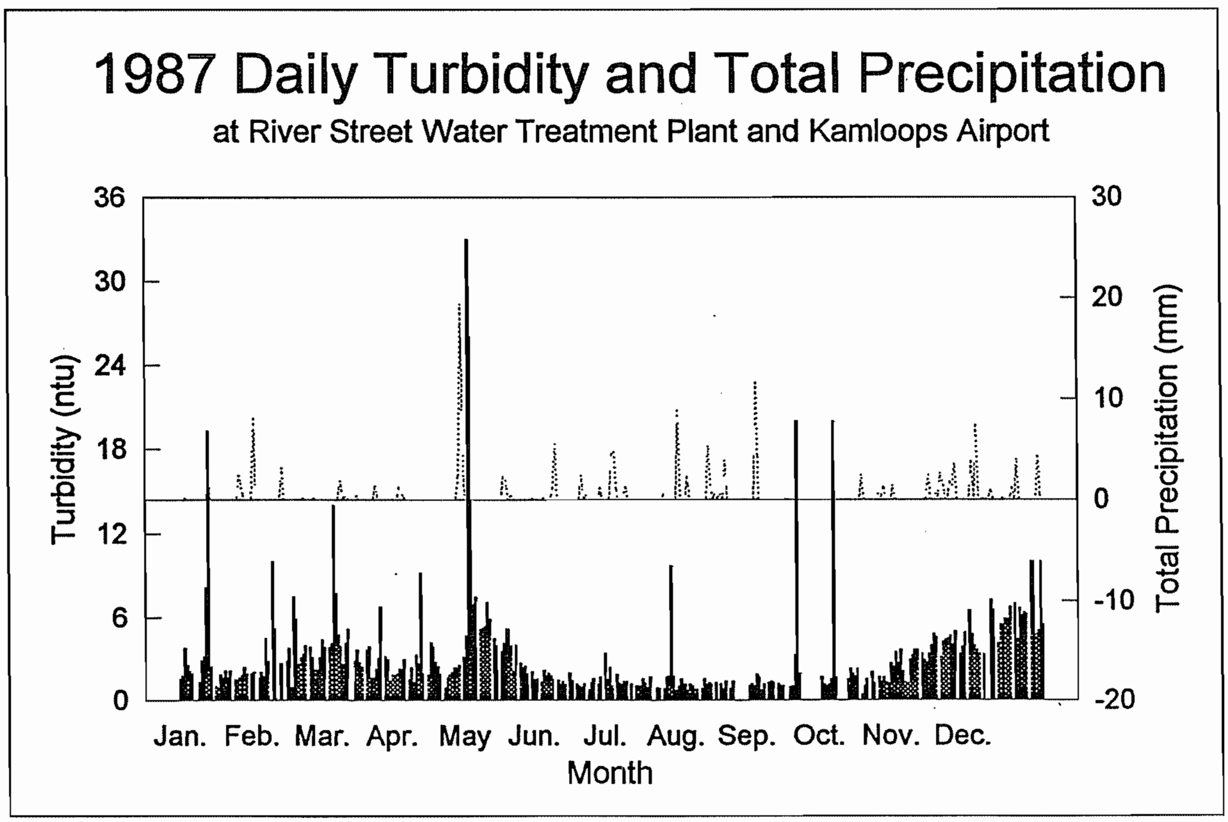
Appendix B1: Summary of Turbidity Events -- River Street Water Treatment Plant
January 1987 to December 1994

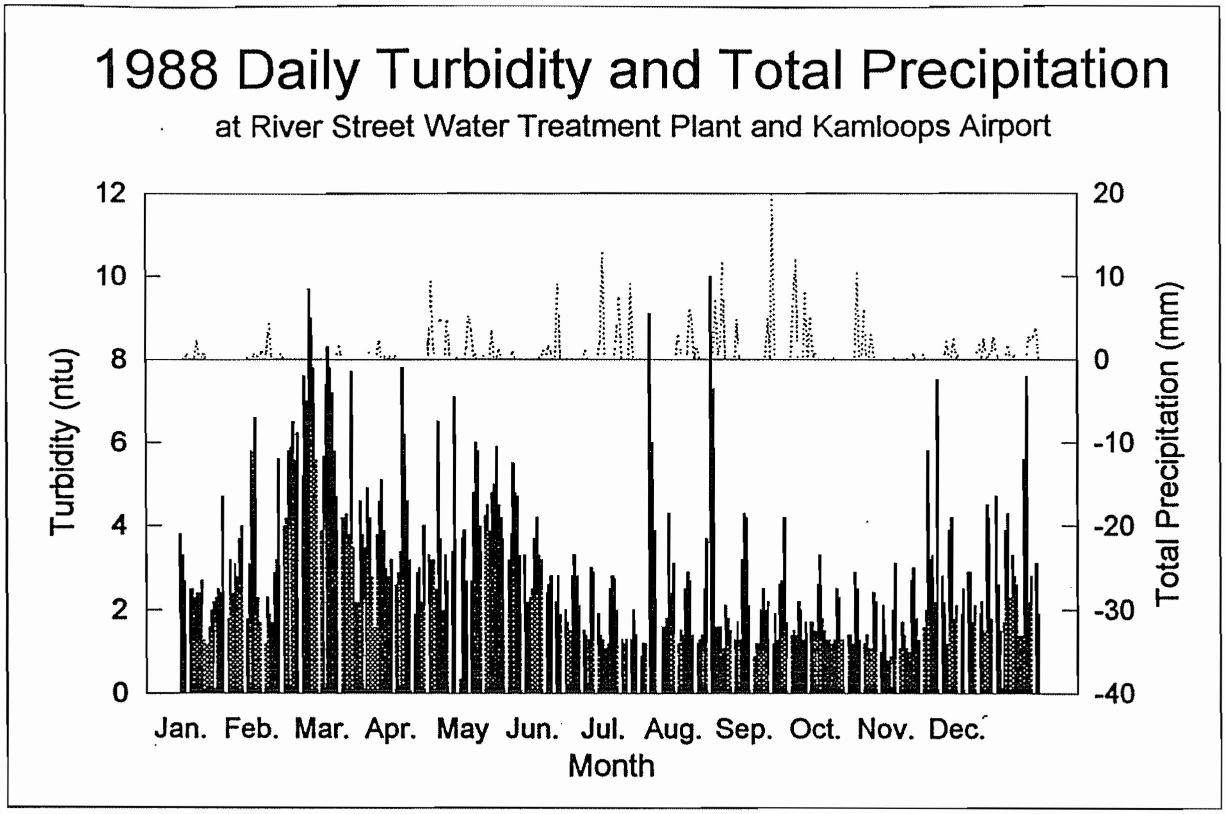
Turbidity Event		Days above	Days above	Maximum	Probable Cause of Turbidity Event		Snowmelt or Rainfall Event	
Start	End	5 NTU	10 NTU	NTU	Primary Type	Secondary Type	Maximum Value	Event Duration
07/17/93	07/17/93	1	0	7.3	rainstorm		3.3 mm	07/16 - 07/17
07/19/93	07/21/93	1	1	21.7	rainstorm		3.3 mm	07/16 - 07/21
07/23/93	07/23/93	1	0	8.2	rainstorm		3.1 mm	07/20 - 07/24
07/28/93	07/29/93	2	0	6.1	rainstorm		9.6 mm	07/28 - 07/29
08/05/93	08/05/93	1	0	5.9				
08/11/93	08/11/93	1	0	5.6	rainstorm		3.4 mm/ 700 m³/s	08/10
08/15/93	08/15/93	1	0	5.2	rainstorm		2.6 mm/ 750 m³/s	08/13 - 08/17
09/14/93	09/16/93	2	1	32.6	rainstorm		8.7 mm/ 700 m³/s	09/14 - 09/15
09/27/93	09/27/93	1	1	10.3				
10/05/93	10/05/93	1	0	9.1				
11/03/93	11/05/93	2	0	6.8				
11/22/93	11/25/93	3	1	12.9	rainstorm		3.6 mm	11/21
11/29/93	12/03/93	4	0	8.7	rainstorm		8.2 mm	11/30 - 12/02
12/07/93	12/15/93	5	1	12.2	rainstorm		5.6 mm	12/07 - 12/14
12/23/93	12/23/93	1	1	10.0				
12/27/93	12/27/93	1	0	8.8				
12/29/93	12/31/93	1	1	15.7	rainstorm		1.3 mm	12/28 - 12/31
01/03/94	01/12/94	6	1	21.7	(1)			
01/18/94	01/19/94	2	0	6.0				
01/22/94	01/22/94	1	0	8.6				
01/25/94	01/26/94	2	0	5.4				
02/02/94	02/02/94	1	0	7.4				
02/07/94	02/09/94	3	1	13.3				
02/15/94	02/17/94	2	0	5.9				
02/20/94	02/24/94	3	1	23.4				
02/27/94	03/05/94	5	3	100.0				
03/07/94	03/07/94	1	0	6.1				
03/10/94	03/10/94	1	0	5.9				
03/14/94	03/14/94	1	0	5.3				
03/20/94	03/23/94	2	1	16.6				
04/05/94	04/05/94	1	0	7.5				
04/12/94	04/13/94	2	0	8.1				
04/18/94	04/27/94	8	4	90.6				
04/28/94	05/05/94	7	1	16.4				
05/06/94	05/20/94	12	3	11.3				
08/04/94	08/12/94	7	3	26.1				
08/12/94	08/12/94	1	0	5.4				
10/14/94	10/14/94	1	0	5.2				

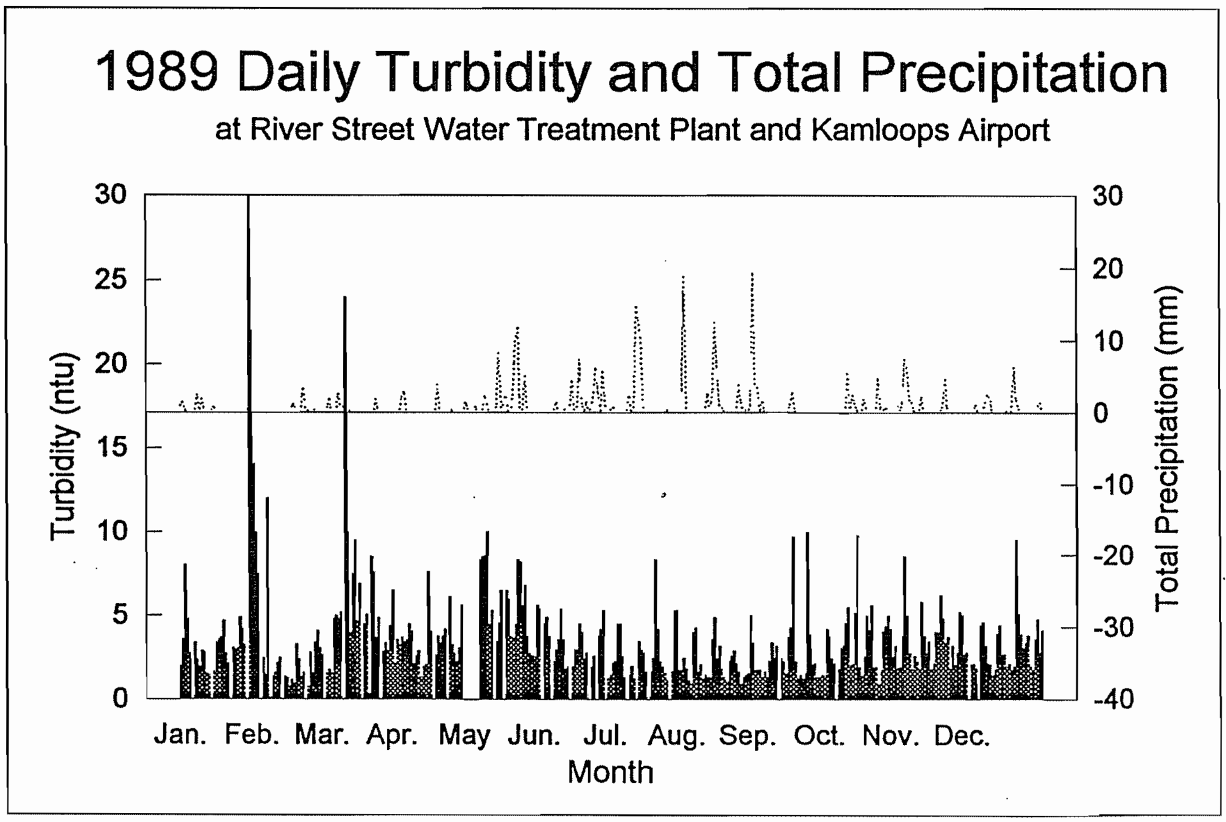
1. Rainfall and climate data not available for 1994 at time of preparation of this table.

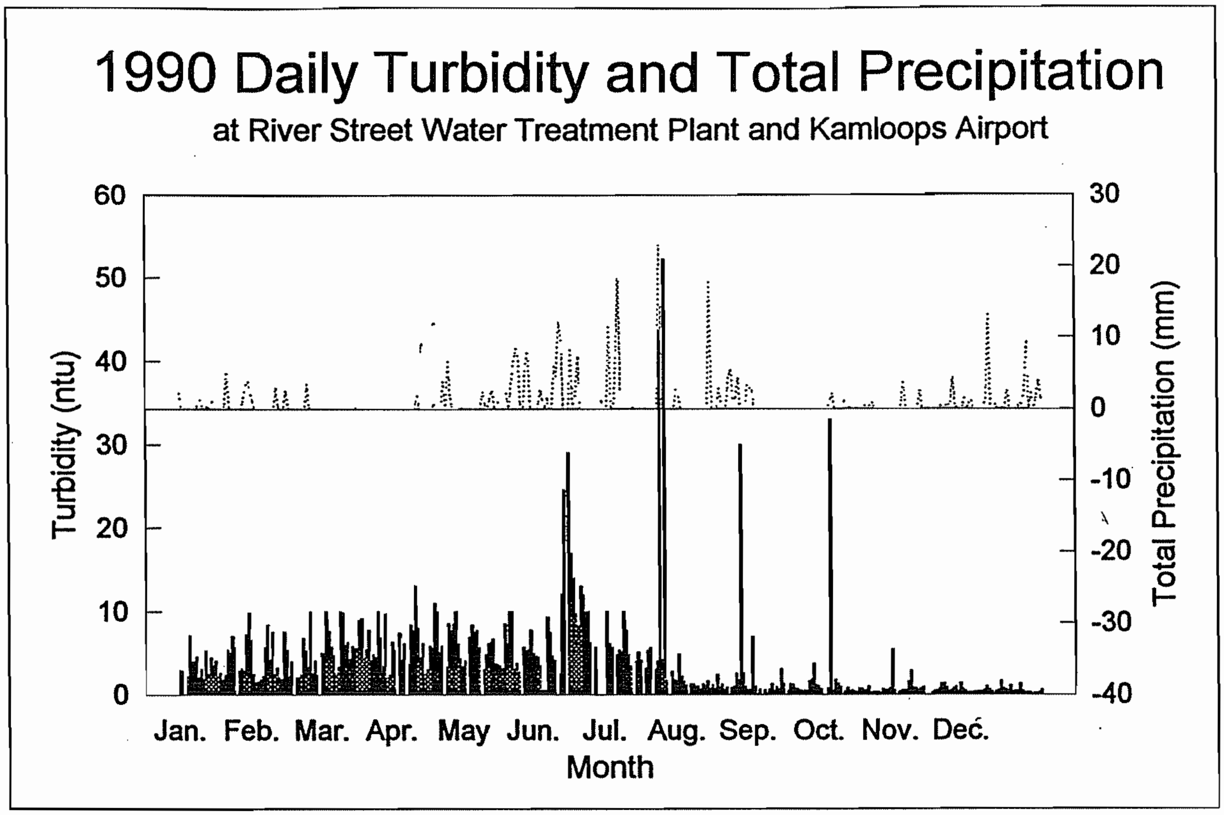

1985 Daily Turbidity and total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
Total Precipitation (mm)
12
10
8
6
4
2
0
30
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

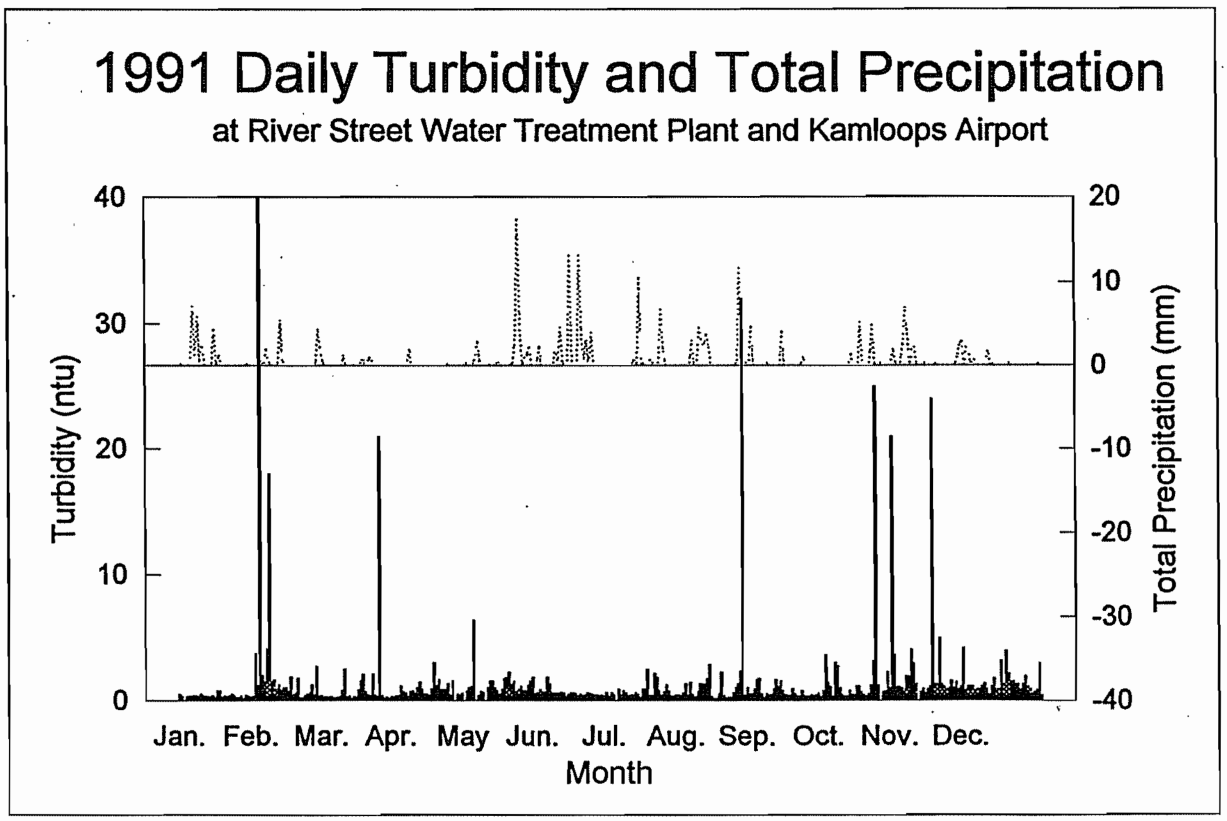

1986 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
Total Precipitation (mm)
14
12
10
8
6
4
2
0
40
20
0
-20
-40
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month

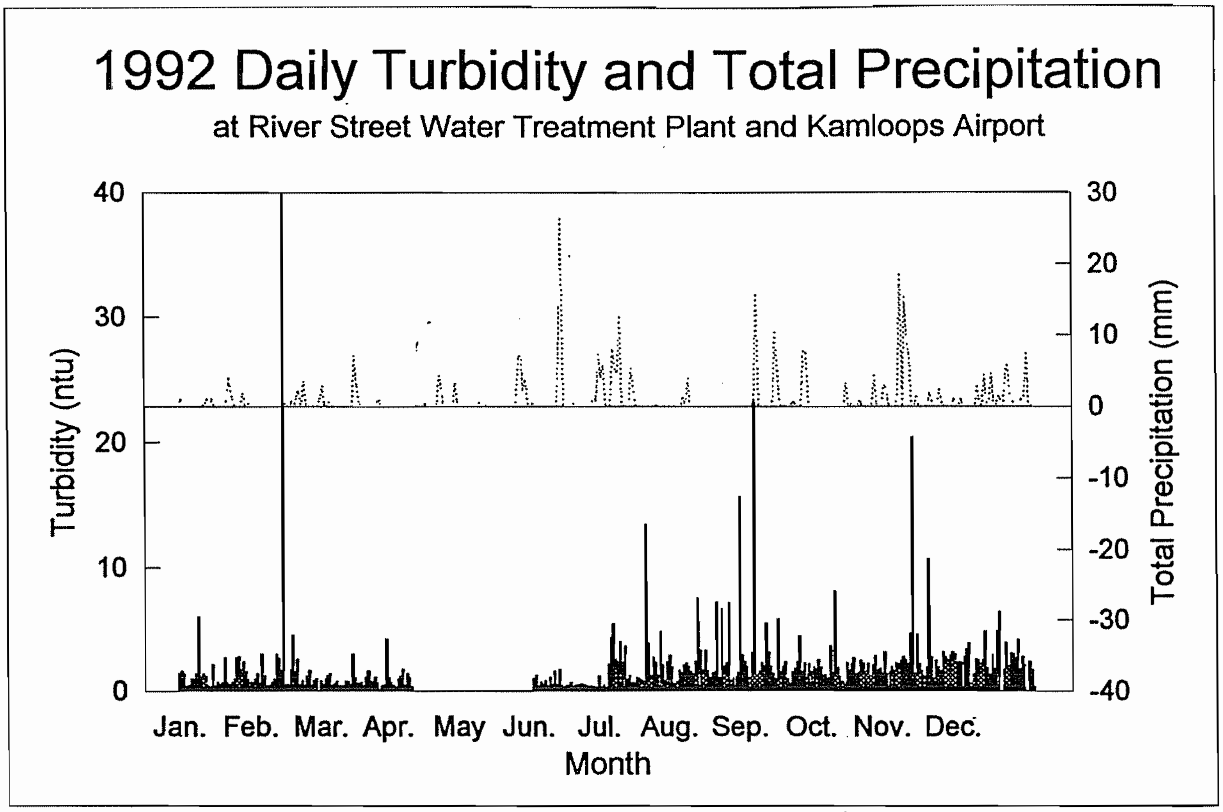

1987 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
Total Precipitation (mm)
36
30
24
18
12
6
0
30
20
10
0
-10
-20
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month

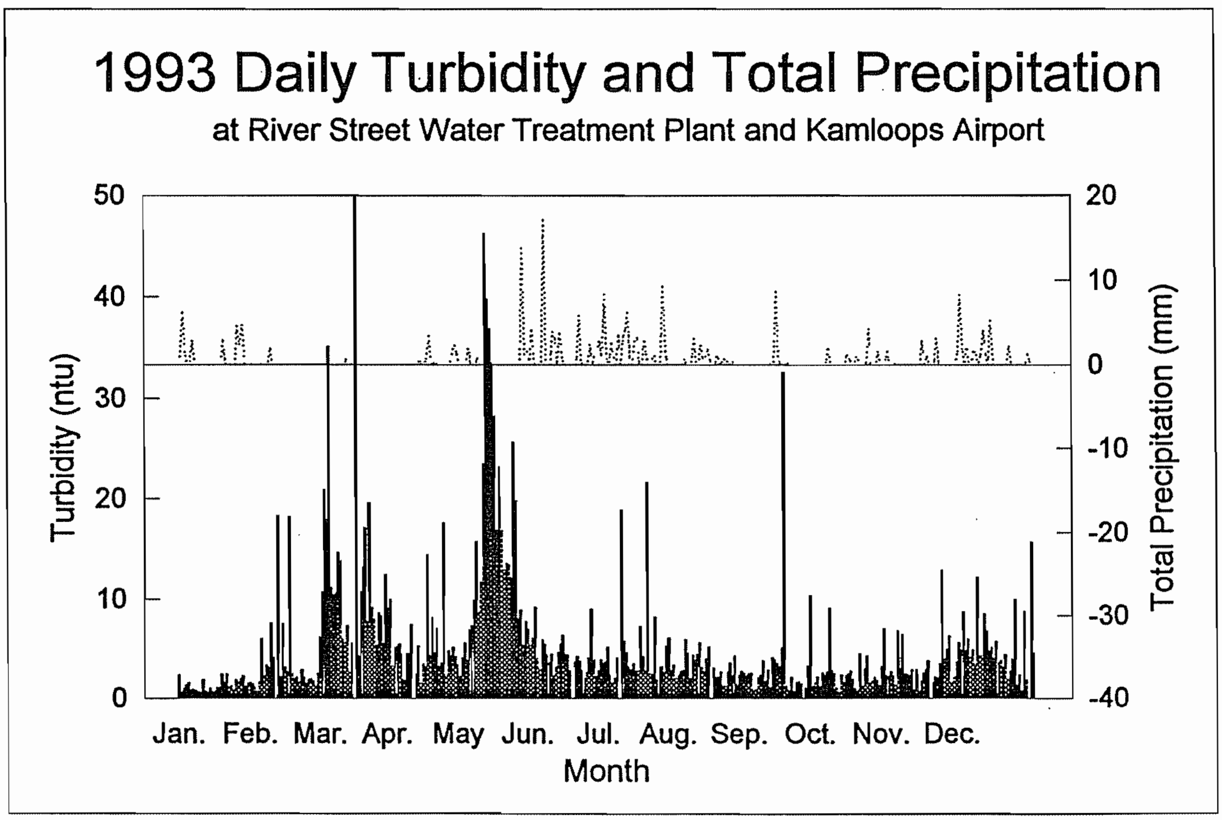

1988 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
Total Precipitation (mm)
12
10
8
6
4
2
0
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

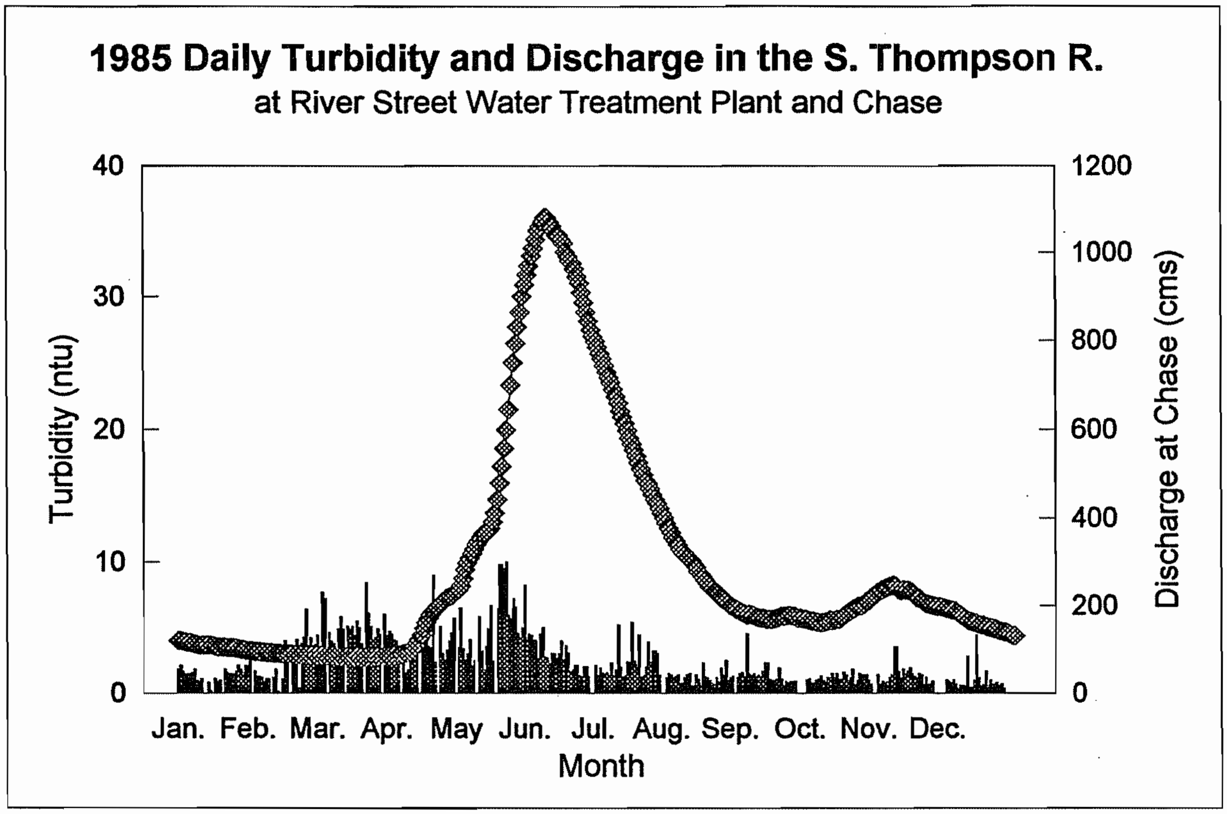

1989 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
Total Precipitation (mm)
30
25
20
15
10
5
0
30
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

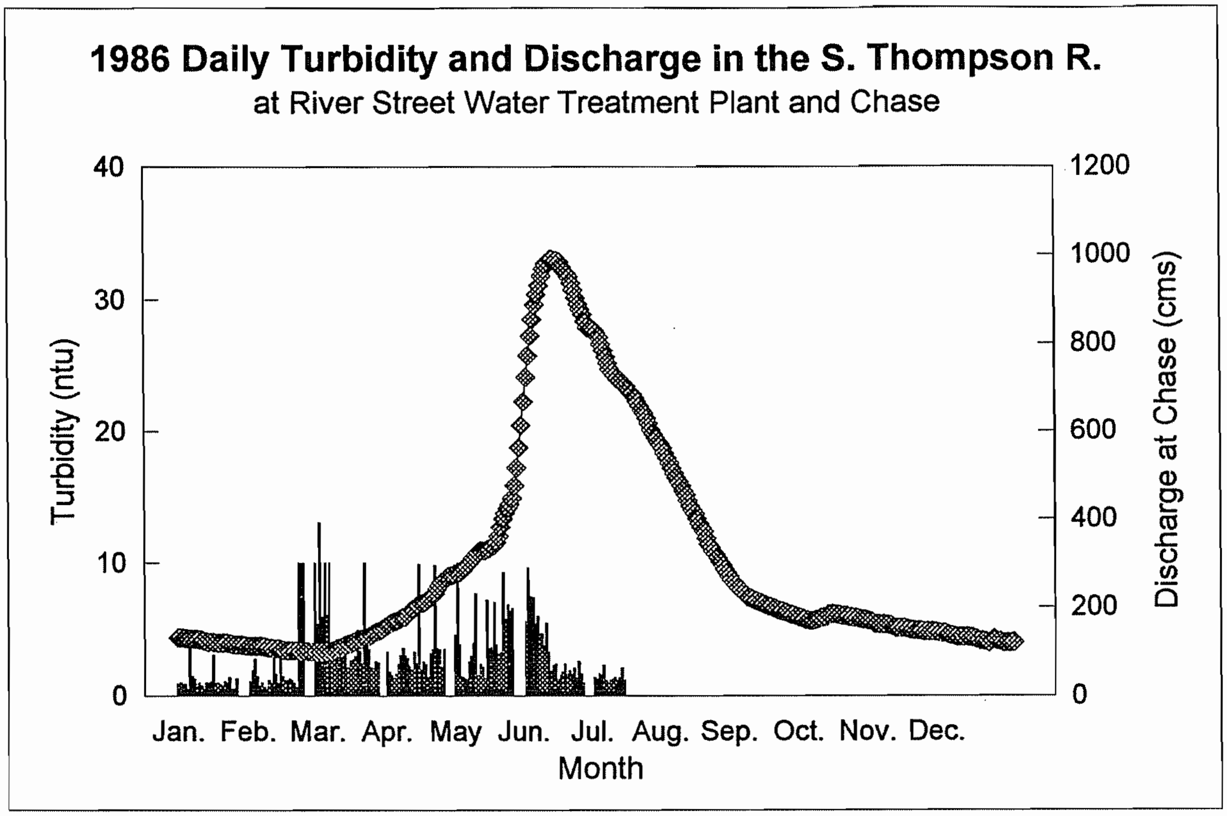

1990 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
60
50
40
30
20
10
0
Total Precipitation (mm)
30
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

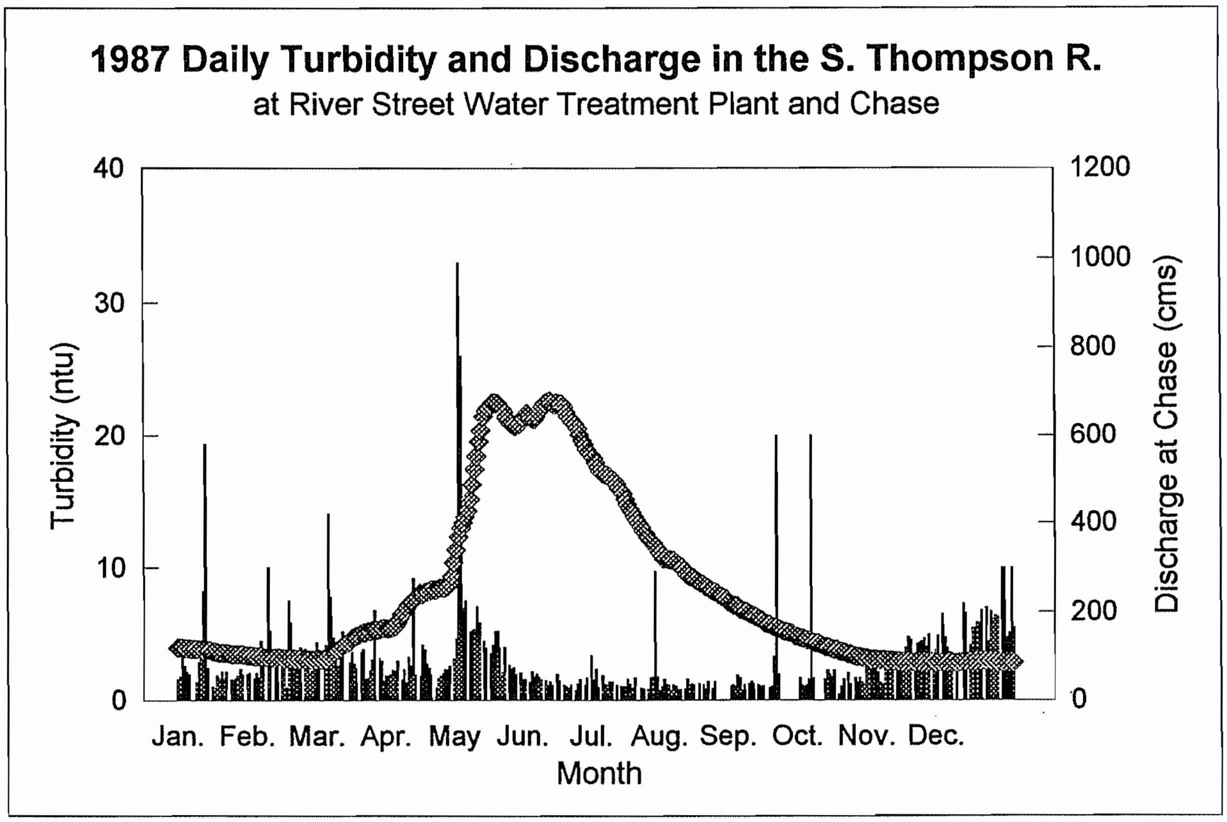

1991 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
40
30
20
10
0
Total Precipitation (mm)
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

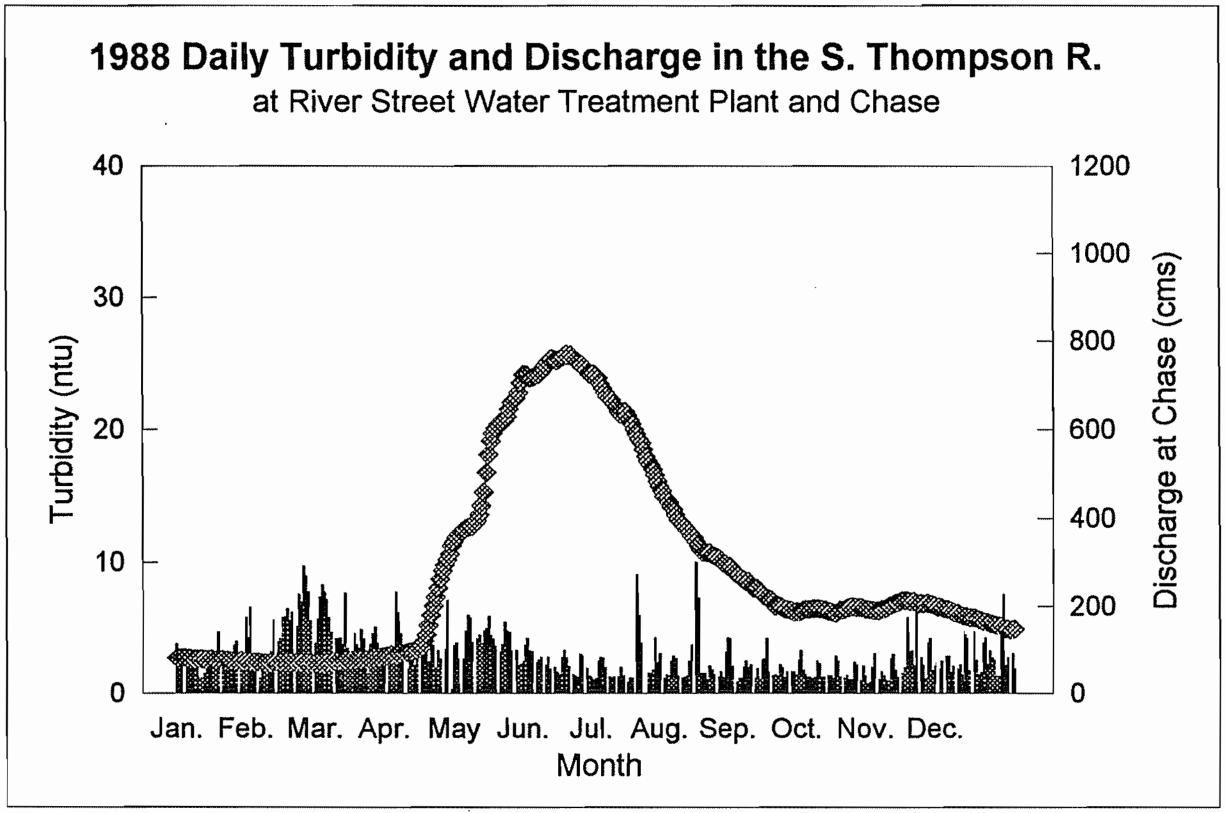

1992 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
40
30
20
10
0
Total Precipitation (mm)
30
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

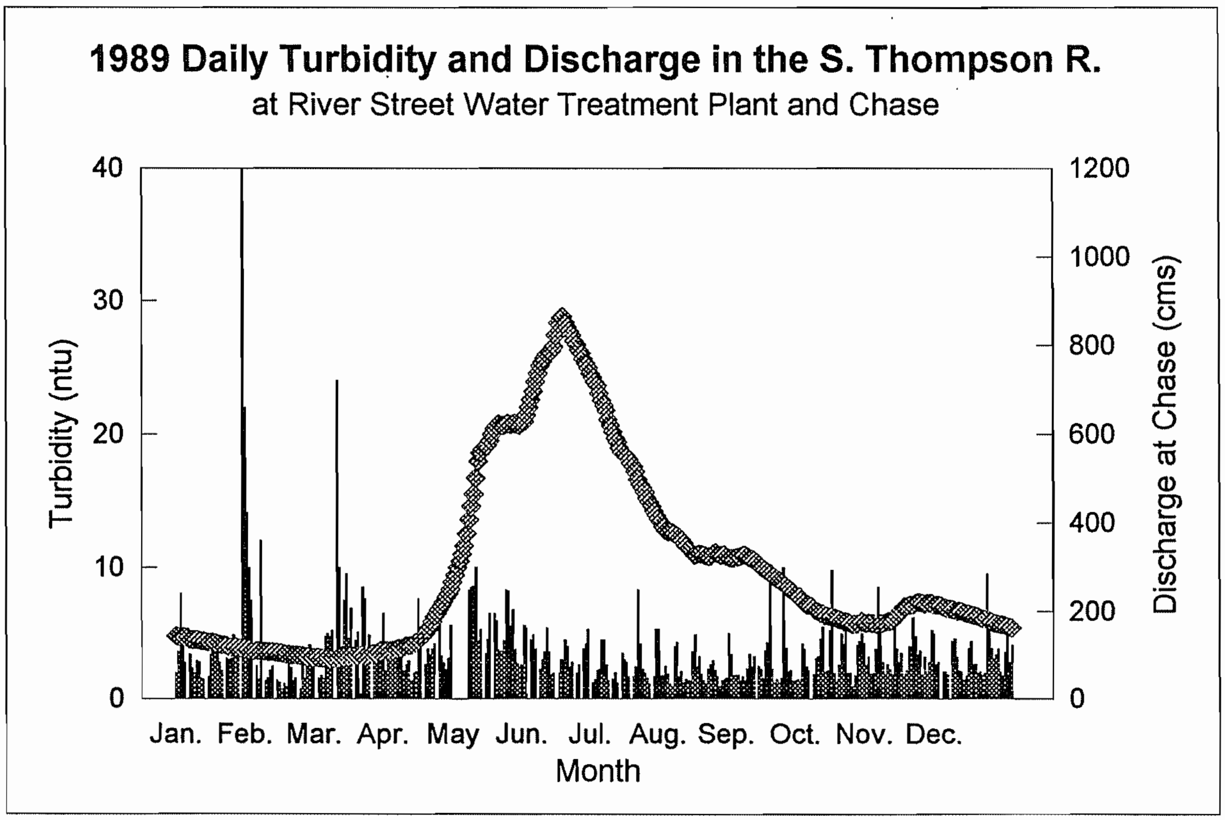

1993 Daily Turbidity and Total Precipitation
at River Street Water Treatment Plant and Kamloops Airport
Turbidity (ntu)
50
40
30
20
10
0
Total Precipitation (mm)
20
10
0
-10
-20
-30
-40
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

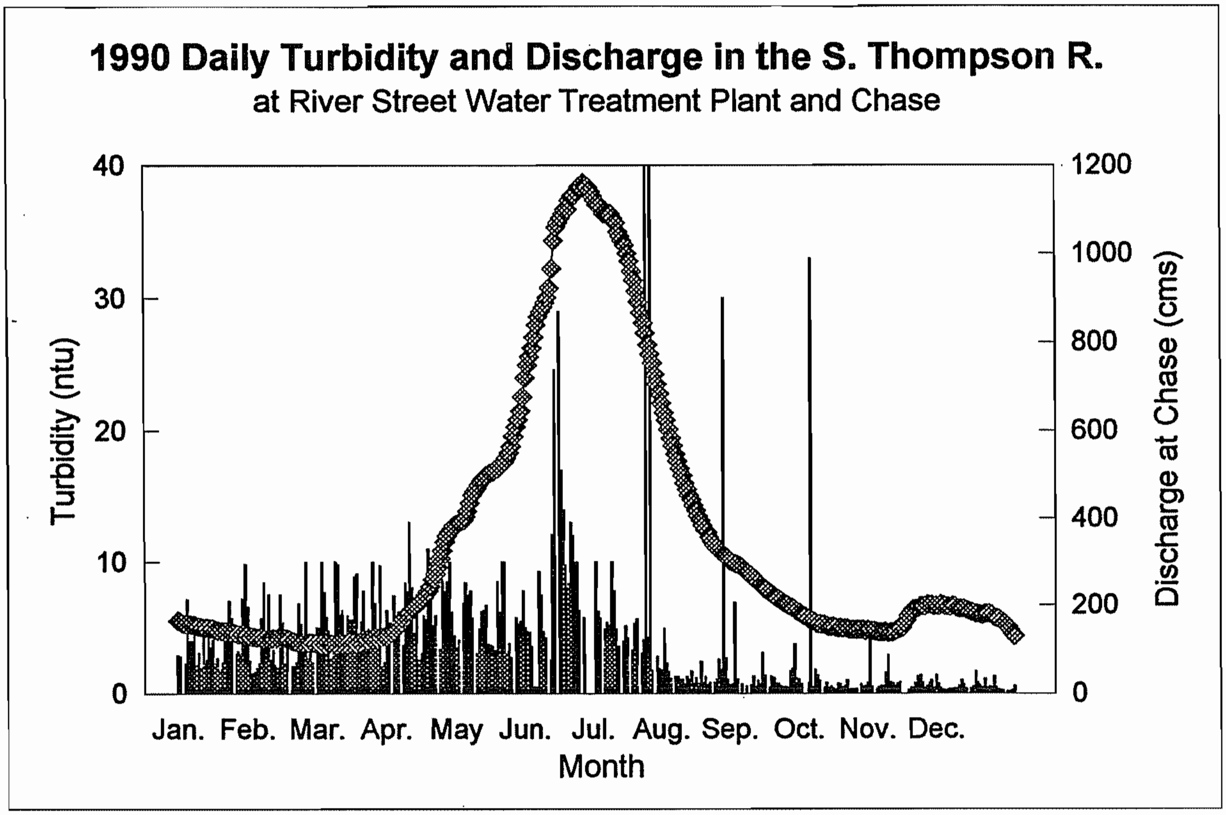

1985 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
Discharge at Chase (cms)
40
30
20
10
0
1200
1000
800
600
400
200
0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

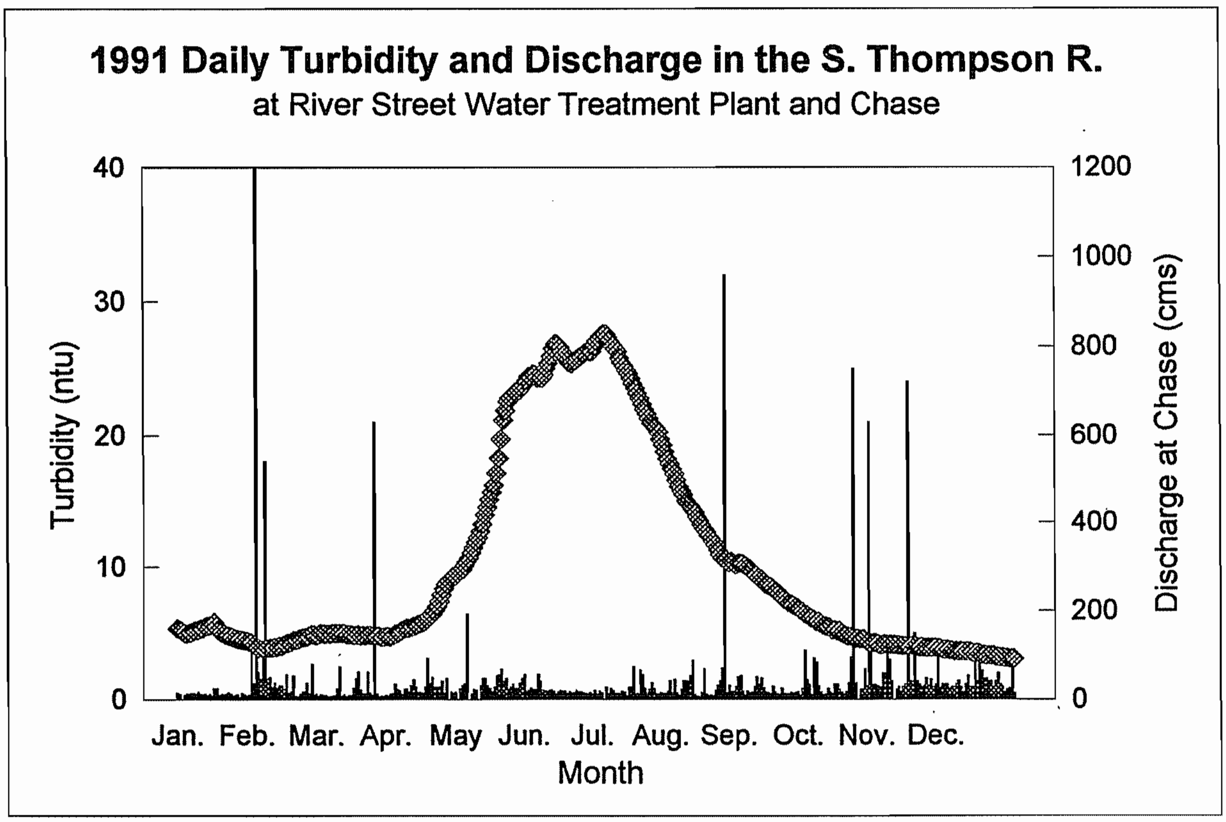

1986 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
0
10
20
30
40
Discharge at Chase (cms)
0
200
400
600
800
1000
1200
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

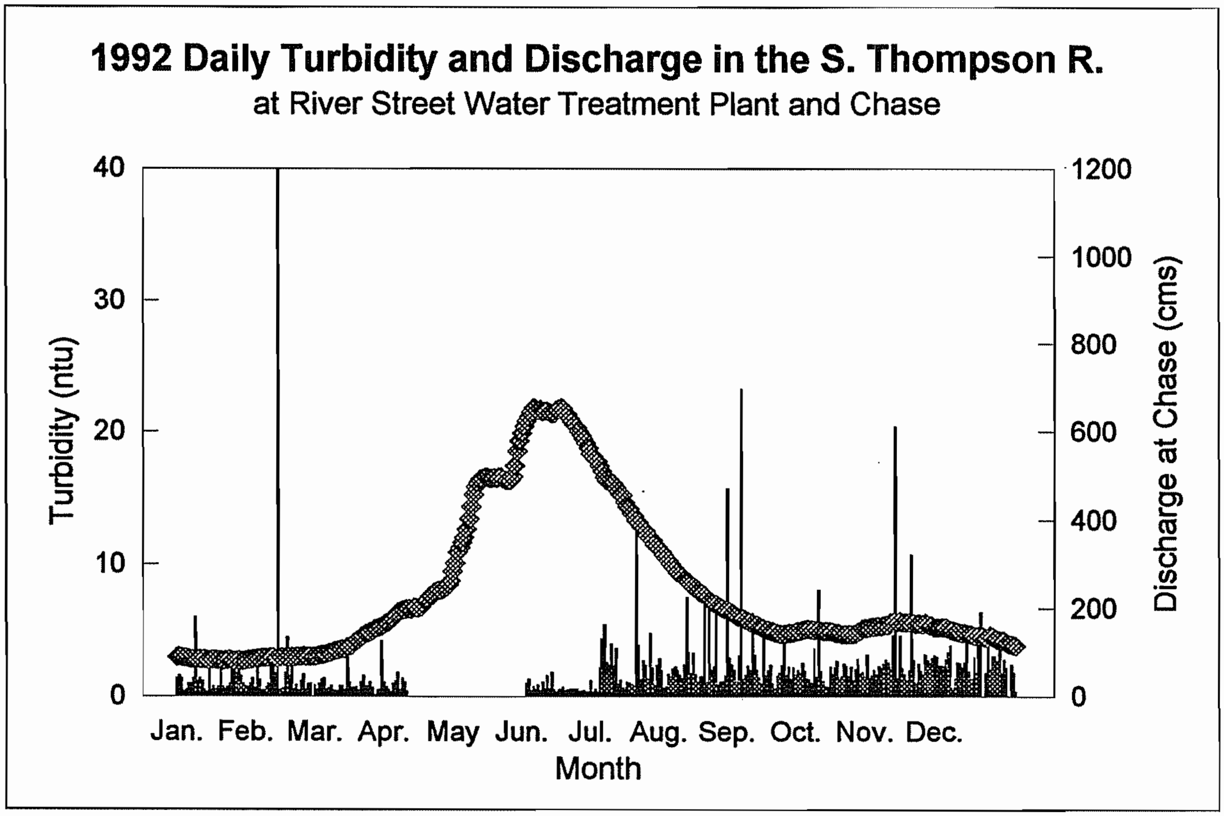

1987 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
0
10
20
30
40
Discharge at Chase (cms)
0
200
400
600
800
1000
1200
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


1988 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
Discharge at Chase (cms)
40
30
20
10
0
1200
1000
800
600
400
200
0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


1989 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
Discharge at Chase (cms)
40
30
20
10
0
1200
1000
800
600
400
200
0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


1990 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
Discharge at Chase (cms)
0
10
20
30
40
0
200
400
600
800
1000
1200
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month


1991 Daily Turbidity and Discharge in the S. Thompson R.
at River Street Water Treatment Plant and Chase
Turbidity (ntu)
Discharge at Chase (cms)
0
10
20
30
40
0
200
400
600
800
1000
1200
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month



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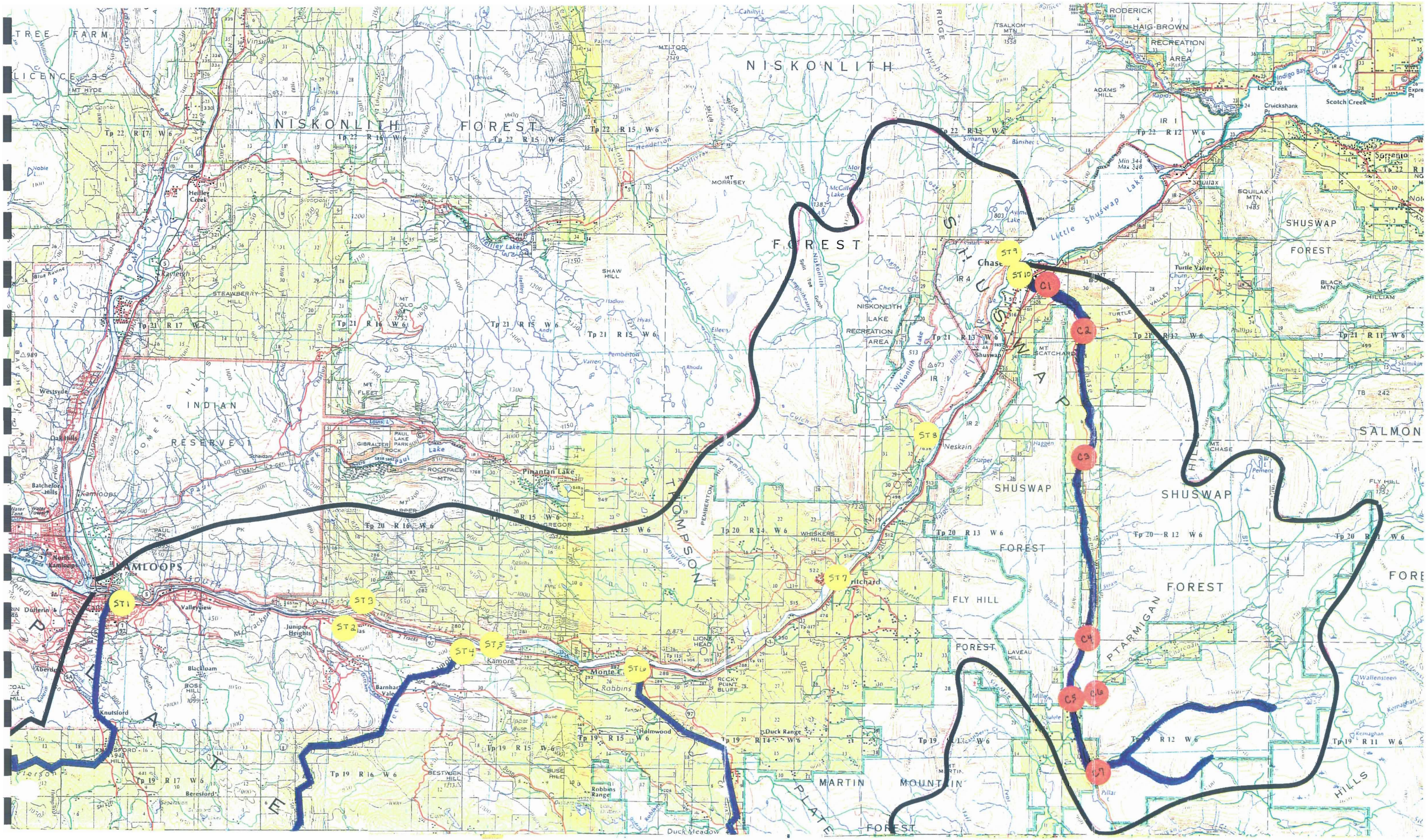
APPENDIX 'C'



TREE FARM
LICENCE 35
NISKONLITH
NISKONLITH FOREST
FOREST
SHUSWAP
SHUSWAP
SHUSWAP
SHUSWAP FOREST
FOREST
FOREST
INDIAN RESERVE 1
THOMPSON
KAMLOOPS
Kamloops
North Kamloops
Chase
Little Shuswap Lake
Sorrento
Squilax
Scotch Creek
Lee Creek
RODERICK HAIG-BROWN RECREATION AREA
NISKONLITH LAKE RECREATION AREA
Heffley Creek
Heffley Lake
Paul Lake
Pinantan Lake
Westsyde
Valleyview
Juniper Heights
Kamore
Monte Creek
Robbins
Pritchard
Neskain
Knutsford
Aberdeen
Holmwood
Duck Range
Duck Meadow
FLY HILL
FLY HILL
LAVEAU HILL
PTARMIGAN
FOREST
MARTIN MOUNTAIN
PLATEAU
PLATE
FOREST
HILLS
SALMON
SHAW HILL
STRAWBERRY HILL
MT LOLO
MT FLEET
MT MORRISEY
MT SCATCHARD
MT CHASE
ROCKFACE MTN
GIBRALTER ROCK
BOSE HILL
ROCKY POINT BLUFF
LIONS HEAD
WHISKERS HILL
ADAMS HILL
SQUILAX MTN
BLACK MTN
MT HILLIAM
TURTLE VALLEY
ST1
ST2
ST3
ST4
ST5
ST6
ST7
ST8
ST9
ST10
C1
C2
C3
C4
C5
C6
C7

Check
River St. figures
?

CITY O. KAMLOOPS
SOUTH THOMPSON RIVER
WATER TURBIDITY (NTUs) MONITORING 1994

SAMPLING IDENTIF.	SAMPLING LOCATION:	SAMPLE COLLECTED: DATE: 04/14/94	DATE: 04/18/94	DATE: 04/20/94	DATE: 04/21/94	DATE: 04/25/94	DATE: 04/30/94	DATE: 04/30/94	DATE: 05/04/94	DATE: 05/08/94	DATE: 05/08/94	DATE: 05/16/94	DATE: 05/23/94	DATE: 05/28/94	DATE: 06/04/94	DATE: 06/12/94	DATE: 06/20/94	DATE: 06/26/94
SITE #1	RIVER, RIVERSTR. INTAKE	1.3	-	-	39.2	-	6.6	-	-	5.41	5.41	-	-	4.91	N/A	13.80	N/A	23.30
SITE #2	RIVER, S.E.S. INTAKE	1.5	-	-	6.3	-	5.5	-	-	4.88	4.88	3.14	3.78	2.04	2.78	58.50	28.00	7.09
SITE #3	STOBART HARPER CEEK, AT MOUTH	1.2	-	-	>1000	-	>1000	-	>1000	>1000	>1000	>1000	>1000	>1000	>1000	301	632	>1000
SITE #4	CAMPELL CREEK AT HWY #1	6.8	-	-	4.0	-	6.6	-	23.5	13.70	13.70	18.30	11.50	12.80	6.00	24.90	48.60	15.20
SITE #5	RIVER AT LA FARGE BRIDGE	2.9	-	-	6.0	-	7.2	-	-	9.30	9.30	4.25	2.72	N/A	2.10	127	8.24	7.58
SITE #6	MONTE CREEK AT CAMPGROUND	7.4	-	-	77.0	-	18.6	-	11.4	31.50	31.50	25.20	12.40	N/A	2.24	6.87	457	162
SITE #7	RIVER, PRITCHARD BRIDGE	3.3	-	-	18.0	-	2.8	-	-	10.60	10.60	47.40	1.29	N/A	1.08	31.90	51.90	244
SITE #8	NESCONLITH CREEK AT MOUTH	4.2	-	-	N/A	-	N/A	-	1.5	2.45	2.45	1.78	1.25	2.76	7.59	148	755	348
SITE #9	RIVER, LITTLE SHUSWAP OUTLET	2.2	-	-	4.0	-	8.8	-	-	6.58	6.58	30.50	9.33	1.39	52.30	106	6.23	110
SITE #10	CHASE CREEK AT MOUTH	5.5	-	-	214.0	-	50.1	-	20.6	102	102	16.40	2.05	7.07	5.30	4.21	2.75	28.10
CHASE #1	CHASE CREEK, HWY #1 BRIDGE	-	4.5	165.0	-	175.0	-	49.0	-	85.80	85.80	18.80	6.98	2.48	2.32	-	-	-
CHASE #2	CHASE CREEK, TURTLE VALLEY BRIDGE	-	5.8	195.0	-	143.0	-	41.9	15.2	72.70	72.70	15.70	7.16	3.30	-	-	-	-
CHASE #3	CHASE CREEK, 3km SOUTH OF C2	-	5.4	136.0	-	102.0	-	19.4	-	42.80	42.80	15.00	5.68	5.76	-	-	-	-
CHASE #4	CHASE CREEK, 8km SOUTH OF C2	-	5.8	46.0	-	11.4	-	6.1	-	15.70	15.70	4.39	2.75	2.11	-	-	-	-
CHASE #5	CHASE CREEK, AT CHARCOAL CREEK	-	3.7	15.5	-	4.3	-	4.2	7.0	18.90	18.90	2.49	1.24	0.87	-	-	-	-
CHASE #6	CHARCOAL CREEEK AT CHASE CREEK	-	6.3	31.8	-	9.9	-	5.6	2.6	5.24	5.24	3.86	3.33	1.61	-	-	-	-
CHASE #7	CHASE CREEK, BRIDGE NEAR PILLAR LAKE	-	6.2	14.6	-	5.8	-	6.9	2.7	22.90	22.90	2.79	1.61	1.31	-	-	-	-

SOUTH THOMPSON RIVER - CHASE CREEK
WATER TURBIDITY MONITORING (NTUs) 1995

ID	LOCATION	DATE 02/06/95	DATE 02/13/95	DATE 02/20/95	DATE 02/27/95	DATE 03/06/95	DATE 03/13/95	DATE 03/20/95	DATE 03/27/95	DATE 04/03/95	DATE 04/10/95	DATE 04/18/95
S #1	R.S. INTAKE	8.37	4.54	8.89	4.87	FROZEN	4.24	5.85	2.82	3.45	6.24	5.45
S #2	S.E. INTAKE	18.30	2.11	6.59	5.28	FROZEN	5.00	4.15	2.95	22.10	3.06	4.19
S #3	~~HARPER~~ CR. STOBBART	4300.00	385.00	3610.00	356.00	185.00	690.00	1859.00	192.00	863.00	99.20	28.00
S #4	CAMPBELL CR.	13.00	N/A	8.37	7.23	3.91	4.11	9.48	5.66	5.04	5.74	3.01
S #5	LAFARGE BRIDGE	6.70	2.37	3.80	1.97	1.47	3.05	3.54	1.72	2.37	2.44	2.28
S #6	MONTE CR.	76.00	1.93	25.70	239.00	3.11	19.70	8.11	5.37	3.14	4.04	4.28
S #7	PRITCHARD BRIDGE	N/A	1.30	1.23	0.98	0.92	2.16	1.11	1.13	1.54	2.13	1.72
S #8	NESCONLITH CR.	DRY	DRY	DRY	0.85	FROZEN	DRY	DRY	DRY	DRY	0.92	0.72
S #9	RIVER AT SHUSWAP OUTLET	0.83	0.47	3.76	0.68	0.58	3.04	6.31	1.53	1.10	1.14	0.72
S #10	CHASE CR. AT MOUTH	3.27	1.97	1.30	3.23	1.09	15.70	1.91	3.41	5.09	5.51	2.00
S #11	DOWN FROM HARPER CR.	14.80										
S #12	UP FROM HARPER CR.	7.99										
S #13	JUNIPER CR. AT S.E INTAKE	34600.00										
C #1	HWY #1 AT BRIDGE	1.87	1.03	1.21	2.02	1.01	9.84	4.30	1.93	5.09	4.80	3.10
C #2	TURTLE VALLEY BRIDGE	FROZEN	FROZEN	FROZEN	FROZEN	FROZEN	4.79	11.30	2.38	3.87	4.22	1.89
C #3	BRIDGE 6.8km FROM C2	0.67	0.46	1.34	0.69	1.00	7.04	1.31	1.44	3.58	3.78	1.41
C #4	SITE N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C #5	CHASE CR AT CHARCOAL CR	0.32	0.20	0.93	0.48	0.37	0.85	0.67	0.38	1.13	1.54	0.71
C #6	CHARCOAL CR AT CHASE CR	0.42	0.41	2.53	1.81	1.01	2.72	2.89	2.51	6.26	5.80	2.79
C #7	BRIDGE AT MOSER RD.	FROZEN	FROZEN	FROZEN	1.17	FROZEN	2.85	4.89	2.88	4.91	4.33	2.65

ID	LOCATION	DATE 04/24/95	DATE 05/01/95	DATE 05/08/95	DATE 05/15/95	DATE 05/23/95	DATE 05/29/95	DATE 06/05/95	DATE 06/12/95	DATE 06/19/95	DATE 06/26/95	DATE 07/04/95	DATE 07/10/95	DATE 07/17/95
S #1	R.S. INTAKE	6.18	4.49	3.66	5.11	6.64	4.27	3.67	2.79	4.01	2.39	2.21	1.66	1.37
S #2	S.E. INTAKE	10.30	3.81	5.76	10.40	5.39	3.55	2.91	2.83	3.11	2.40	2.09	1.83	2.31
S #3	~~HARPER~~ CR. STOBBART	[illegible]81.00	46.20	42.30	275.00	10.90	169.00	339.00	216.00	56.90	57.10	155.00	1[illegible]8.00	108.00
S #4	CAMPBELL CR.	2.79	2.21	3.79	34.70	9.10	7.38	9.88	7.22	5.98	10.60	13.50	10.30	6.52
S #5	LAFARGE BRIDGE	2.88	2.51	3.97	3.82	3.90	2.07	2.59	1.92	1.74	2.10	1.49	1.66	1.79
S #6	MONTE CR.	10.40	32.10	37.00	69.30	13.60	6.57	1.74	5.96	4.38	2.78	1.62	3.44	1.57
S #7	PRITCHARD BRIDGE	1.10	2.67	2.41	4.11	2.48	1.64	1.95	1.73	1.25	1.19	1.10	0.99	1.09
S #8	NESCONLITH CR.	2.05	1.74	1.20	1.62	1.30	0.98	1.19	1.14	1.86	2.09	1.78	1.73	1.59
S #9	RIVER AT SHUSWAP OUTLET	0.93	0.76	0.57	1.03	2.13	0.92	1.49	0.96	0.90	1.26	0.91	1.91	1.09
S #10	CHASE CR. AT MOUTH	4.95	17.20	116.00	135.00	26.10	11.90	15.80	5.21	3.96	3.44	1.27	2.25	0.97
S #11	DOWN FROM HARPER CR.													
S #12	UP FROM HARPER CR.													
S #13	JUNIPER CR. AT S.E INTAKE													
C #1	HWY #1 AT BRIDGE	4.36	13.20	117.00	134.00	25.30	11.10	15.60	5.30	6.16	3.61	1.61	2.78	0.95
C #2	TURTLE VALLEY BRIDGE	4.97	10.20	96.60	105.00	15.50	7.91	14.10	4.25	3.85	3.63	1.83	2.08	1.03
C #3	BRIDGE 6.8km FROM C2	4.45	9.37	103.00	65.60	9.85	5.40	12.80	3.63	2.81	4.12	1.10	2.36	1.16
C #4	SITE N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C #5	CHASE CR AT CHARCOAL CR	1.45	3.64	6.10	13.70	2.84	2.14	2.91	1.27	1.28	1.45	0.83	2.36	0.60
C #6	CHARCOAL CR AT CHASE CR	5.03	6.11	7.35	8.25	3.62	2.66	4.70	2.48	2.67	2.20	1.50	1.00	0.83
C #7	BRIDGE AT MOSER RD.	4.23	4.50	6.65	12.50	3.16	2.36	2.03	1.36	2.22	2.01	1.23	1.48	0.78

CITY OF KAMLOOPS
SOUTH THOMPSON RIVER - CHASE CREEK
WATER TURBIDITY MONITORING (NTUs) 1995

ID	LOCATION	DATE 02/06/95	DATE 02/13/95	DATE 02/20/95	DATE 02/27/95	DATE 03/06/95	DATE 03/13/95	DATE 03/20/95	DATE 03/27/95	DATE 04/03/95	DATE 04/10/95	DATE 04/18/95	DATE 04/24/95
S #1	R.S. INTAKE	8.37	4.54	8.89	4.87	FROZEN	4.24	5.85	2.82	3.45	6.24	5.45	6.18
S #2	S.E. INTAKE	18.30	2.11	6.59	5.28	FROZEN	5.00	4.15	2.95	22.10	3.06	4.19	10.30
S #3	~~HARPER~~ CR.- STOBBART	4300.00	385.00	3610.00	356.00	185.00	690.00	1859.00	192.00	863.00	99.20	28.00	181.00
S #4	CAMPBELL CR.	13.00	N/A	8.37	7.23	3.91	4.11	9.48	5.66	5.04	5.74	3.01	2.79
S #5	LAFARGE BRIDGE	6.70	2.37	3.80	1.97	1.47	3.05	3.54	1.72	2.37	2.44	2.28	2.88
S #6	MONTE CR.	76.00	1.93	25.70	239.00	3.11	19.70	8.11	5.37	3.14	4.04	4.28	10.40
S #7	PRITCHARD BRIDGE	N/A	1.30	1.23	0.98	0.92	2.16	1.11	1.13	1.54	2.13	1.72	1.10
S #8	NESCONLITH CR.	DRY	DRY	DRY	0.85	FROZEN	DRY	DRY	DRY	DRY	0.92	0.72	2.05
S #9	RIVER AT SHUSWAP OUTLET	0.83	0.47	3.76	0.68	0.58	3.04	6.31	1.53	1.10	1.14	0.72	0.93
S #10	CHASE CR. AT MOUTH	3.27	1.97	1.30	3.23	1.09	15.70	1.91	3.41	5.09	5.51	2.00	4.95
S #11	DOWN FROM HARPER CR.	14.80											
S #12	UP FROM HARPER CR.	7.99											
S #13	JUNIPER CR. AT S.E INTAKE	34600.00											
C #1	HWY #1 AT BRIDGE	1.87	1.03	1.21	2.02	1.01	9.84	4.30	1.93	5.09	4.80	3.10	4.36
C #2	TURTLE VALLEY BRIDGE	FROZEN	FROZEN	FROZEN	FROZEN	FROZEN	4.79	11.30	2.38	3.87	4.22	1.89	4.97
C #3	BRIDGE 6.8km FROM C2	0.67	0.46	1.34	0.69	1.00	7.04	1.31	1.44	3.58	3.78	1.41	4.45
C #4	SITE N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C #5	CHASE CR AT CHARCOAL CR	0.32	0.20	0.93	0.48	0.37	0.85	0.67	0.38	1.13	1.54	0.71	1.45
C #6	CHARCOAL CR AT CHASE CR	0.42	0.41	2.53	1.81	1.01	2.72	2.89	2.51	6.26	5.80	2.79	5.03
C #7	BRIDGE AT MOSER RD.	FROZEN	FROZEN	FROZEN	1.17	FROZEN	2.85	4.89	2.88	4.91	4.33	2.65	4.23

ID	LOCATION	DATE 05/01/95	DATE 05/08/95	DATE 05/15/95	DATE 05/23/95	DATE 05/29/95	DATE 06/05/95	DATE 06/12/95	DATE 06/19/95	DATE 06/26/95	DATE 07/04/95	DATE 07/10/95	DATE 07/17/95
S #1	R.S. INTAKE	4.49	3.66	5.11	6.64	4.27	3.67	2.79	4.01	2.39	2.21	1.66	1.37
S #2	S.E. INTAKE	3.81	5.76	10.40	5.39	3.55	2.91	2.83	3.11	2.40	2.09	1.83	2.31
S #3	~~HARPER~~ CR.- STOBBART	46.20	42.30	275.00	10.90	169.00	339.00	216.00	56.90	57.10	155.00	108.00	108.00
S #4	CAMPBELL CR.	2.21	3.79	34.70	9.10	7.38	9.88	7.22	5.98	10.60	13.50	10.30	6.52
S #5	LAFARGE BRIDGE	2.51	3.97	3.82	3.90	2.07	2.59	1.92	1.74	2.10	1.49	1.66	1.79
S #6	MONTE CR.	32.10	37.00	69.30	13.60	6.57	1.74	5.96	4.38	2.78	1.62	3.44	1.57
S #7	PRITCHARD BRIDGE	2.67	2.41	4.11	2.48	1.64	1.95	1.73	1.25	1.19	1.10	0.99	1.09
S #8	NESCONLITH CR.	1.74	1.20	1.62	1.30	0.98	1.19	1.14	1.86	2.09	1.78	1.73	1.59
S #9	RIVER AT SHUSWAP OUTLET	0.76	0.57	1.03	2.13	0.92	1.49	0.96	0.90	1.26	0.91	1.91	1.09
S #10	CHASE CR. AT MOUTH	17.20	116.00	135.00	26.10	11.90	15.80	5.21	3.96	3.44	1.27	2.25	0.97
S #11	DOWN FROM HARPER CR.												
S #12	UP FROM HARPER CR.												
S #13	JUNIPER CR. AT S.E INTAKE												
C #1	HWY #1 AT BRIDGE	13.20	117.00	134.00	25.30	11.10	15.60	5.30	6.16	3.61	1.61	2.78	0.95
C #2	TURTLE VALLEY BRIDGE	10.20	96.60	105.00	15.50	7.91	14.10	4.25	3.85	3.63	1.83	2.08	1.03
C #3	BRIDGE 6.8km FROM C2	9.37	103.00	65.60	9.85	5.40	12.80	3.63	2.81	4.12	1.10	2.36	1.16
C #4	SITE N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C #5	CHASE CR AT CHARCOAL CR	3.64	6.10	13.70	2.84	2.14	2.91	1.27	1.28	1.45	0.83	2.36	0.60
C #6	CHARCOAL CR AT CHASE CR	6.11	7.35	8.25	3.62	2.66	4.70	2.48	2.67	2.20	1.50	1.00	0.83
C #7	BRIDGE AT MOSER RD.	4.50	6.65	12.50	3.16	2.36	2.03	1.36	2.22	2.01	1.23	1.48	0.78

APPENDIX 'D'

Table D1: Ranking of Stream Reaches and Gullies from Aerial Photographs

Tributary	Bank	Fan / Delta Present (y / n)	Stream Erosion Reach (#)	Stream Erosion Class (#)	Gully Erosion * Gully (#)	Gully Erosion * Class (#)	Valley Wall Class (#)	Sediment Potential	Potential to Raise Turbidity	Comments
0.65	LB	y	S1	N/A - reach is underground				LOW	NONE	fines visible in S. Thompson R.
Peterson Ck			S2	1			1			
			S3	1			1			channelized channel through mine
			T1	1			1			
			T2	1			1			
			T3	1			1			
			T4	1			1			
			T5	1			1			
2.40	LB	n	S1	1			1	LOW	NONE	
Joyce Gulch										
unnamed 7	LB	n			G1	1	1	V LOW	NONE	
4.50	LB	n	S1	1			1	LOW	MODERATE	
			S2	2			1			unstable banks
			S3	1			1			
			T1	1			1			
5.25	RB	n	S1	1			1	V LOW	NONE	no channel visible on floodplain
					G1	1	1			
5.70	RB	y	S1	1			1	V LOW	NONE	very small fan on floodplain; not into S. Thompson
					G1	1	1			
5.95	LB	n	S1	1			1	V LOW	MODERATE	
6.55	RB	y	S1	1			1	MODERATE	NONE	large old fan extending to S. Thompson
					G1	2	1			
					G2	1	1			
7.60	RB	y	S1	1			1	LOW	NONE	old fan extending to S. Thompson
					G1	1	1			
					G2	1	1			
					G3	1	1			
8.05	RB	n	S1	1			2	MODERATE	NONE	unstable wall sections
					G1	1	1			
					G2	1	1			
8.40	LB	n	S1	1			1	V LOW	MODERATE	
9.25	RB	y	S1	1			1	LOW	V LOW	
					G1	1	1			
9.65	LB	n	S1	1			1	V LOW	MODERATE	
10.10	LB	n	S1	1			1	V LOW	MODERATE	
unnamed 1	RB	n	S1	2			4	MODERATE	V LOW	unstable banks; valley walls very unstable
					G1	2	4			- no flow reaches S. Thompson R.
unnamed 2	RB	n	S1	2			3	LOW	V LOW	fewer wall failures reach channel than unnamed 1
					G1	2	3			see photo 30BCC92007 #142
11.40	RB	n	S1	1			1	LOW	LOW	
					G1	1	1			
11.40	LB	n	S1	1			2	MODERATE	HIGH	
Juniper Ck			S2	2			1			
			S3	1			1			
11.85	RB	n	S1	1			1	MODERATE	LOW	
					G1	1	2			
unnamed 3	RB	n	S1	2			3	HIGH	LOW	
					G1	1	3			
unnamed 4	RB	n	S1	1			2	MODERATE	LOW	
13.95	RB	y	S1	3			1	HIGH	MODERATE	small delta present; sed. from banks not walls
Stobart Ck			S2	2			1			bank erosion present
			S3	1			1			see photo 30BCC92007 #144
					G1	4	1			
					G2	1	2			
18.60	RB	n	S1	1			1	MODERATE	MODERATE	
McGregor Ck			S2	2			1			unstable banks
19.00	LB	y	S1	1			1	LOW	HIGH	very stable low gradient meanders; little or no +
Campbell Ck			T1	1			1			bank erosion through whole reach; +
			T2	1			1			no valley wall failures to channel.
unnamed 5	RB	n	S1	1			1	LOW	LOW	no sediment inputs from open pit mine evident
25.30	LB	n	S1	1			1	LOW	LOW	
25.55	LB	n	S1	1			1	LOW	LOW	
25.80	RB	n	S1	1			1	LOW	LOW	
26.00	LB	n	S1	1			1	LOW	LOW	

Table D1: Ranking of Stream Reaches and Gullies from Aerial Photographs

Tributary	Bank	Fan / Delta Present (y / n)	Stream Erosion Reach (#)	Stream Erosion Class (#)	Gully Erosion Gully (#)	Gully Erosion Class (#)	Valley Wall Class (#)	Sediment Potential	Potential to Raise Turbidity	Comments
26.40	LB	n	S1	1			1	LOW	LOW	
27.65	LB	y	S1	2			2	MODERATE	HIGH	no fines seen entering S. Thompson
Monte Creek			S2	2			1			portions have point bars in this steeper reach
			S3	1			1			stable meander bends on floodplain and ditch
			S4	2			1			point bars present in channel
			S5	1			1			steep reach with isolated pt. bars and valley wall slumps
			T1	1			1			see photo 30BCC92003 #102 for Monte Ck.
			T2-1	1			1			
			T2-2	2			2			
			T2-3	1			1			
			T4	1			1			
			T5	1			1			
			T6	1			1			unconnected slough slope with lots of colluvium (92010-100)
28.95	RB	n	S1	1			1	LOW	LOW	
Swain Ck										
30.30	LB	n	S1	1			1			
32.05	RB	n	S1	2			1	MODERATE	LOW	fines visible entering S. Thompson R.
			S2	1			1			
					G1	1	1			
					G2	1	1			
32.60	LB	n	S1	1			2	MODERATE	V LOW	no flow seen in creek
33.60	LB	n	S1	1			1	MODERATE	V LOW	
					G1	1	2			
unnamed 6	RB	n	S1	2			4	HIGH	V LOW	undercut bank making valley wall fail; some fines seen entering S. Thompson R.
			S2	1			1			
					G1	1	1			
34.00	LB	n	S1	1			1	HIGH	V LOW	
			S2	1			3			
			S3	1			1			
34.65	LB	n	S1	2			1	MODERATE	MODERATE	
Dry Creek			S2	1			1			
34.85	RB	y	S1	2			2	MODERATE	MODERATE	no fines seen in S. Thompson; unstable banks is sections
Moulton Ck			S2	1			1			
35.55	RB	n	S1	1			2	MODERATE	V LOW	a few slides entering channel from road
35.80	RB	y	S1	3			2	HIGH	LOW	lots of fines in S. Thompson R.; unstalbe banks and pt. bars
			S2	1			1			see photos 30BCC92004 #208 +#209
36.30	RB	y	S1	3			3	HIGH	V LOW	undercut banks failing throughout reach and affecting walls
			S2	1			1			see photos 30BCC92004 #208 +#209
36.50	LB	y	S1	2			1	MODERATE	MODERATE	sediment inputs from unvegetated banks
Neds Creek			S2	1			1			
			T1	1			1			
37.65	RB	y	S1	1			1	HIGH	LOW	some fines in S. Thompson R.
			S2	2			3			undercut banks de-stabilizing walls
			S3	1			1			see photos 30BCC92007 #158 +#159
38.40	RB	y	S1	2			2	MODERATE	MODERATE	little flow seen; little fines seen in S. Thom.; failures from road
Pemberton Ck			S2	1			1			see photos 30BCC92007 #158 +#159
39.70	RB	y	S1	2			1	V LOW	LOW	
Gore Creek			S2	1			1			
41.00	LB	y	S1	1			1	LOW	MODERATE	no fines in S. Thompson
Martin Creek			S2	2			1			some bank erosion
			S3	1			1			
			T1	1			1			
43.90	LB	n	S1	1			1	LOW	MODERATE	
Harper Creek										
47.15	RB	n	S1	1			1	V LOW	MODERATE	may join Niskonlith Ck.; no flow entering S. Thompson
Gulch Creek										
47.85	RB	y	S1	1			1	V LOW	HIGH	may be reworking S. Thompson bank material
Niskonlith Ck										

Table D1: Ranking of Stream Reaches and Gullies from Aerial Photographs

Tributary	Bank	Fan / Delta Present (y / n)	Stream Erosion		Gully Erosion *		Valley Wall Class (#)	Sediment Potential	Potential to Raise Turbidity	Comments
			Reach (#)	Class (#)	Gully (#)	Class (#)				
57.90 Chase Creek	LB	y	S1	2			N/A	MODERATE	HIGH	little fines seen entering S. Thompson
			S2	1			N/A			banks armored and channel is dyked through town
			S3	1			1			canyon reach with well vegetated slopes
			S4	2			2			1 large cut bank supplying sediment
			S5	3/4			3			reworking valley flat; bank erosion destabilizes valley walls
			S6	2			1			stable banks and confined channel
			S7	3/4			2			few valley wall inputs; dramatic change to S8
			S8	2			1			sediment moved through reach; little in storage
			S9	2			4			road heavily impacting stream; forrested slides occurring
			S10	2			3			forrested slope and road failures
			T1	1			3			
			T2	1			1			
			T3	1			1			
			T4	1			1			
			T5	1			1			
			T6	1			1			
			T7	1			1			
			T8	1			1			no sediment inputs even from logged area
			T9	2			1			fan in Chase Ck; some in channel erosion and storage now
			T10	1			1			

APPENDIX 'E'

CITY OF KAMLOOPS

SOUTH THOMPSON RIVER - CHASE CREEK

WATER TURBIDITY MONITORING (NTU's) 1996

ID	LOCATION	DATE FEB 13	DATE FEB 19	DATE FEB 26	DATE MAR 11	DATE MAR 18	DATE MAR 25	DATE APR 01	DATE APR 15	DATE APR 22
S #1	R.S. INTAKE	FROZEN	FROZEN	FROZEN	144.00	9.29	5.63	5.33	7.62	8.37
S #2	S.E. INTAKE	FROZEN	FROZEN	FROZEN	87.60	8.52	4.96	3.39	8.53	9.39
S #3	HARPER CREEK	343.00	4015.00	376.00	54700.00	5800.00	2665.00	4340.00	1405.00	2205.00
S #4	CAMPBELL CREEK	FROZEN	116.00	55.50	36.70	19.50	13.10	12.80	25.60	23.90
S #5	LAFARGE BRIDGE	FROZEN	2.26	3.10	44.50	4.12	3.16	2.57	5.92	3.94
S #6	MONTE CREEK	FROZEN	119.00	4.97	68.00	20.90	24.30	11.50	36.20	15.10
S #7	PRITCHARD BRIDGE	0.85	1.09	1.51	1.66	1.25	1.06	1.21	2.72	1.92
S #8	NESCONLITH CREEK	0.86	2.44	1.37	20.90	7.64	3.94	1.53	2.59	2.24
S #9	RIVER AT SHUSWAP OUTLET	3.12	1.14	3.12	1.10	1.08	1.75	1.31	7.54	1.64
S #10	CHASE CREEK AT MOUTH	FROZEN	FROZEN	FROZEN	18.40	19.70	6.23	3.34	27.10	11.20
S #11	DOWN FROM HARPER CR.									
S #12	UP FROM HARPER CR.									
S #13	JUNIPER CR. AT S.E. INTAKE				11700.00	3250.00	6000.00	1665.00	950.00	N/A
C #1	HWY #1 AT BRIDGE	1.99	3.10	2.31	18.50	21.10	5.65	3.31	20.10	10.40
C #2	TURTLE VALLEY BRIDGE	FROZEN	FROZEN	FROZEN	10.10	11.40	9.46	3.61	15.70	9.06
C #3	BRIDGE 6.8km FROM C2	FROZEN	FROZEN	4.24	9.50	6.19	10.40	2.63	13.10	8.08
C #4	SITE N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C #5	CHASE CR. AT CHARCOAL CR.	FROZEN	FROZEN	FROZEN	10.60	4.65	3.12	3.75	6.64	4.05
C #6	CHARCOAL CR. AT CHASE CR.	FROZEN	FROZEN	FROZEN	6.63	6.79	5.21	3.92	11.60	7.63
C #7	BRIDGE AT MOSER RD.	FROZEN	FROZEN	FROZEN	18.70	28.10	5.85	10.10	8.78	4.61

STC1 22/11/95

PHOTOGRAPHS

Photo 1

North shore of the South Thompson River.

Photo 2

Monte Creek -- left valley wall near the mouth.

Chase Creek -- lacustrine sediments downstream of Charcoal Creek.

Photo 3

Chase Creek -- bank erosion downstream of Charcoal Creek.

Photo 4

Photo 5

Upper Chase Creek -- natural landslides on the left valley wall.

Photo 6

Charcoal Creek -- erosion downstream of China Lake.