Sediment Sources and Movement in Lesser Slave Lake

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1.0 Introduction

Sediment is an integral part of the river and lake system as much as water is. Rivers carry sediment and deposit it along their bed and banks, in bars and on the floodplain. Sediment sizes range from clay sized particles less than 4 microns (0.004 mm) in diameter to boulders larger than 4 m. The bed material size plays a major role in defining the characteristics of the river channel. For example, gravel-bed rivers are typically wider and shallower than sand bed rivers conveying the same discharge.

As a river flows downstream, its ability to carry the larger sediment sizes usually decreases and the larger sized material drops out. The river sorts the material based on its ability to transport it. Thus the bed material sediment size typically decreases in the downstream direction. Finally the river reaches a lake or ocean where only the finest material remains in suspension and the rest is deposited temporarily or permanently in the delta. The lake can also transport sediment and deposit it on beaches and build them up, and transport the smaller material to the outlet. It is the ultimate fate of every lake to eventually be filled with sediment (geological time frame).

2.0 Natural Conditions

2.1 Sediment Sources

Sediment enters Lesser Slave Lake from many sources including rivers, creeks and air blown particles. Three major river systems drain into Lesser Slave Lake, the Swan, Driftpile and South Heart/East Prairie Rivers. These three river systems contribute the majority of the sediment entering Lesser Slave Lake. All three of these systems have formed deltas in the lake.

Sediment that is carried by the rivers is divided into two categories, the bed material load and the wash load. The bed material load is the sediment that is present in the bed of the river and has been transported there by the river (alluvial material) and is usually relatively coarse (larger than medium silt sizes). The wash load is fine material that has washed into the river from the surrounding lands (alluvial and non-alluvial material) and its sizes are not well represented in the bed and banks. Wash load particles are usually very small and can be subject not only to gravitation forces, but also to electro-chemical forces as well (Raudkivi, 1976). These very small particles are also the main carriers of nutrients and contaminants.

The transport of alluvial material is an integral part of the rivers flow regime and its presence is natural. Its appearance does not represent polluted water. The amount of wash load can vary depending on the characteristics of the drainage basin such as the soil type, vegetation cover, and degree of disturbance. The transport mode of sediment is divided into two groups, the suspended load and the bed load.

1. The suspended load is sediment that is transported without contacting the bed for appreciable distances along the river. Suspended particles would include virtually the entire wash load along with the finer particles from the bed material. Some of the finest particles such as clays may remain in suspension for days or months even in relatively quiet water.

2. The bed load is composed of the larger material that is transported by rolling or skipping along the bed. Most of the bed load would come from the bed material.

A particle can be part of the suspended load for certain flow conditions and be a part of the bed load for other flow conditions. Under normal flows, a sediment particle may be transported as part of the bed load but under flood conditions, due to the increased shear stresses and turbulence, may be transported as part of the suspended load. In a sand bed river there is virtually always some sediment movement, whereas in gravel bed rivers, there may be movement of the bed material only eight or ten days out of the year. The recorded ranges of suspended sediment concentrations for the East and West Prairie, Driftpile and Swan Rivers are shown in Table 1. All of these river systems start out as gravel-bed rivers in the Swan Hills and become sand bed rivers as they approach Lesser Slave Lake. The recorded suspended sediment concentration versus discharge plots for the Swan, Driftpile, and East and West Prairie Rivers are shown in Figures 1 to 4, respectively.

Table 1: Ranges of Suspended Sediment Concentration for the East and West Prairie, Driftpile and Swan Rivers

River Name	Minimum Conc. (mg./l)	Maximum Conc. (mg./l)	Date of Maximum Concentration	Period of Continuous Record
Swan River	1	8640	July 1, 1979	1969-75, 1979-88
Driftpile River	2	9160	June 3, 1986	1979-86
East Prairie River	13	12300	June 26, 1983	intermittent
West Prairie River	6	8600	July 28, 1982	intermittent
Lesser Slave River at Hwy 2A	3	1130	July 18, 1986	1977, 1979-88
Lesser Slave River at Slave Lake	3	472	July 20, 1996	1990-97

The Lesser Slave River is the only outlet for Lesser Slave Lake. Any sediment exiting the lake via water will take that route. The recorded ranges for suspended sediment for the Lesser Slave River at Slave Lake and Highway 2A are shown in Table 1. The discharge versus sediment concentration plots are shown in Figures 5 and 6.

In the lake itself, wave action erodes beaches and the shoreline and this material is carried into the lake. Processes that affect the rate of shoreline erosion include lake level variation, variability in sediment supply to the littoral zone, storm waves, surge overwash, deflation (transport of material from a beach inland by wind), longshore sediment transport and sorting of beach sediment.

2.2 Sediment Processes

2.2.1 Sediment Transport in Rivers

An integral part of the flow regime of a river is sediment transport. At its source (the Swan Hills for the Swan, Driftpile and East and West Prairie Rivers), the slope of the river is fairly steep. The river bed is lined with fairly large material (gravel, boulder sized material) which can resist movement most of the time, although smaller material such as sand and pebbles will also be present. The gradation of the material is a function of the parent material of the bed material as well as the river's ability to transport the various sediment sizes. As the river moves downstream, the slope decreases and the river cannot transport the larger material. The larger, heavier material drops out and is carried no further. Consequently, the bed material size in a given river usually decreases in the downstream direction.

In the river regime, sediment transport is very important. The ability of the river to transport and the availability of sediment will dictate the dimensions of the channel, channel roughness, the slope of the channel, erosion, the presence of bars and islands, and aggradation/degradation. It is very normal for sediment to be transported by the river. The interaction in the river between the sediment and water is described by Equation 1.

$$Q_s d \propto QS \qquad (1)$$

where Q = water discharge
Q_s = bed material discharge
S = slope of river
d = representative bed material size

This equation qualitatively illustrates how the bed material discharge interacts with the other components of the river regime. As the water discharge varies, so also the bed material discharge varies. During a flood when the discharge is quite large, the bed material discharge will also increase to maintain the balance (Equation 2). The slope and the bed material size will not change although the slope could change over the long term if the outgoing bed material load does not balance the incoming bed material load. The bed-material size would not change under most circumstances unless smaller material such as sand overlays larger material such as gravel. The slope is a product of the equilibrium between the water and bed material discharge and the bed material size.

2 $$Q\uparrow \propto \frac{Q_s\uparrow d}{S}$$

The slope can change due to human interference. For example, increasing the slope in the East and West Prairie Rivers and the Swan River (channelization and cutoff construction) has resulted in increased bed material discharge which will continue until a new equilibrium slope is reached. Referring to equation 3 it can be seen that if the river slope is increased, the bed material discharge must increase also to maintain the equilibrium. Changing the slope will not alter the discharge or the bed material size. The net result will be more sediment movement due to the increased slope and more deposition further downstream.

3 $$S\uparrow \propto \frac{Q_s\uparrow d}{Q}$$

2.2.2 Delta Processes

As the river enters the lake, the river slope is reduced along with the river's ability to carry sediment. From equation 4, it can be seen that as the river slope varies, the bed material discharge varies proportionately. As a river enters a lake, the slope is decreased and the bed material discharge is reduced. If the upstream bed material discharge is greater than the downstream, then there will be deposition of sediment in the region of the lower slope. In a river this would results in the formation of bars and islands. In a lake, this results in the formation of a delta. Conversely, if the lake level drops, the river slope will increase in the delta and there will increased sediment movement from the delta further into the lake.

4 $$Q_s\downarrow \propto \frac{QS\downarrow}{d}$$

This deposition of sediment at the confluence of the river and lake leads to aggradation of the river channel and contributes to channel shifting. In a typical delta it is not unusual for there to be several channels, along with evidence of old channels now unused. All of the deltas on Lesser Slave Lake show evidence of former channels, presently half filled with sediment or acting as oxbow lakes. Over time the delta grows out into the lake. The Swan delta has grown out roughly 10 miles into the lake. Eventually the delta will grow until Lesser Slave Lake is almost cut into two. There will be a channel connecting the two parts as long as there is flow from the west end of the lake. A similar situation exists on the Waterton Lakes where a growing delta from Blakiston Creek has created the Middle and Lower Waterton Lakes.

In the delta, a lower lake level would increase the river slope and result in down cutting in the channel and increase bed material movement. The sediment would be eroded from the delta and carried further into the lake. A higher lake level would reduce the river slope close to the lake and encourage sediment deposition further upstream. The down cutting results from the river striving towards the equilibrium slope. This would result in an increased bed material load.

2.2.3 Littoral Transport

Littoral transport is the movement of sediment in the nearshore zone of lakes by waves and currents. Littoral transport is further divided into two classes:

1. Longshore transport, the movement of sediment parallel to the shore; and

2. Onshore-offshore transport, the movement of sediment perpendicular to the shore.

The direction of longshore transport is dictated by the wind and since the dominant wind direction is from the west and northwest, the longshore transported sediment tends to accumulate near the lake outlet to the Lesser Slave River. Most of the movement is from the northwest and westerly directions. Since the wind does not blow from the south and east very often, there is little transport in the other direction. This is why Lesser Slave Lake has an extensive beach on the east shore.

The on-shore-off shore transport is controlled by wave action. Depending on lake and sediment conditions, this may result in erosion or expansion of the beaches.

2.2.4 Beach Processes

Beaches, as discussed previously, are formed by sediment deposition by littoral transport. The beaches are made up of sediments carried into the lake by the rivers flowing into it. The size the sediment on the beach is a function of the material available and the forces acting on the beach, similar to the bed material in a river. As in the case of rivers, the sediment is a constant state of flux. A stable beach is one where the incoming sediment load is equal to that leaving. An eroding beach is one where the incoming sediment is less than that leaving. And an accreting beach is one where the incoming sediment load is in excess of that leaving. A beach may alternate between these two conditions throughout the year and there may be a cycle that spans several years. Depending on the location, as the winds change direction, a beach may change from an accreting beach to an eroding beach and back to an accreting beach over time. A storm on the lake may cause severe erosion of the beach and it may take several years before it has accreted back to its original position.

Winds blowing from the lake transport sand landward from the beach to form natural protective dunes. Vegetation will establish itself in the dunes, which helps to stabilize them. The dunes can act as a natural levee to protect against wave attack. They also provide a reservoir of sand for the beach.
As a wave approaches the beach, it encounters the long sloping nearshore bottom of the lake.

Depending on the lake elevation, the wave will break away before it hits the beach. Generally speaking the wave will break when the water depth is about 1.3 time the height of the wave. The breaking of the wave dissipates some of the energy of the wave and so protects the beach. If the lake elevation increases, then the waves will break closer to the beach and can erode it.

2.2.6 Transport of Contaminants and Nutrients

Small sediment particles, especially in the clay sizes, can carry additional molecules that are attached to them by electrochemical attraction. Ion exchange between solutes and sediments can result in the transport and storage of pesticide residue, adsorbed phosphorous, nitrogen and other organic compounds, heavy metals and pathogenic bacteria and viruses. The sediment sizes of interest would be in the wash load size range and are carried into the river by bank erosion, soil erosion, and runoff. The amount of wash load in the river can be influenced by human activities such as agriculture, forestry, mining, urbanization and industrial effluent.

3.0 Effects of Human Activities

In spite of the fact that some sediment transport is very natural, human activities can play a major role in affecting the availability of sediment for transport. Channelization of rivers, land clearing, construction and other activities can increase the sediment load significantly if proper management procedures are not followed.

The Universal Soil Loss equation (Wischmeier, 1976) is shown below. Although this equation was developed for calculating runoff erosion from agricultural fields, reviewing it can indicate how certain factors can play a role in general soil loss from land.

$$E = R\,K\,L\,S\,C\,P$$

where
- E = average annual soil loss in tonnes per hectare
- R = factor expressing the erosion potential of average annual rainfall in the locality (function of the kinetic energy of the rain and the duration of the rainfall)
- K = soil erodibility factor (0.0001 to 0.21 t/ha/unit of rainfall factor R), (Chinnamani et al, 1982)
- S = $(0.43+0.3G+0.043G^2)/6.613$; for $G < 9\%$; $S=(G/9)^{1/3}$ for $G > 9\%$; G = slope measured as %,
- L = length of slope = $(L/22\ m)^{1/2}$
- C = cropping management factor, the ratio of soil eroded from a parcel of land compared to that from an identical parcel clean tilled; 0.001 (dense forest) C < 1.0 (bare, continuously tilled soil) (van Vuuren, 1982)
- P = supporting conservation practice factor; for straight row farming, P = 1.0

The R, K, S and L factors are generally dictated by the environment. Only the cropping management factor (C) and the Supporting Conservation Practice Factor (P) can be influenced by human activity. Using this equation can give a qualitative feel for the amount of erosion that could occur on a piece of land under different management practices.

Examining Table 2, one can get a feel for the relative contribution of various activities in the drainage basin to the sediment load.

Table 2: Relative Potential for Sediment Production for Individual Activities (Falletti, 1976)

Activity	Relative Erosion Potential
Vegetation manipulation by mechanical means	High
Roads and trails	High
Fire	High
Grazing	Medium
Timber Harvest	Medium
Recreation	Low

Stephens et al. (1977) examined the soil loss from several land use categories. The results are summarized in Table 3. The actual amounts of sediment produced are not as important as the relative amounts as this basin has different characteristics from the Lesser Slave Lake basin. Timber harvested land is not included in this comparison.

Chang et al (1982) studied the effects of land clearing of forested land on soil loss in Texas. The treatments he used were as follows:

1. undisturbed forest,
2. thinned forest, approximately 50% of original crown density,
3. clearcut, all saleable timber removed, no site preparation,
4. clear cut and roller chopped,
5. clear cut, sheared, root raked and slash piled in windrows, and
6. clear cut, clear tilled, continuous fallow, cultivated up and down hill.

The soil loss ranged from 10.7 to 3432.4 kg/ha over the 9 month test period with treatment one having the least soil loss and treatment six having the most soil loss. There was no significant different difference between the means of the undisturbed and thinned treatments. The calculated C (cropping management factor) values are listed in Table 4. One would expect with proper site preparation that the C factor for timber harvested land treatment would be in between treatment 2 and 3.

Table 3: Gross Erosion and Sediment Yield for Deer Creek Watershed, Maryland (Stephens et al, 1976)

Sediment Source	Soil Loss (tonnes/ha/yr.)	%greater than woodland
Cropland	18.67	1851
Idle	3.50	347
Pasture	4.33	429
Woodland	1.01	n/a
Urbanized	2.87	284
Road shoulder	28.2 tonnes/km	n/a
Streambank	39.4 tonnes/km	n/a

The C_c values presented in Table 4 are not directly comparable with other values presented in this paper (Table 5). However, the variation in C_c values between land uses is still very relevant although these studies have not considered variation in the soil erodibility.

Table 4: C_c Values Calculated from six Different Treatments of Forested Land (Chang et al, 1982)

Treatment Number	Calculated C_c Value	% Greater then Treatment 1
1	0.00014	n/a
2	0.0019	1357
3	0.0017	1178
4	0.0033	2321
5	0.0242	17,857
6	0.097	69,285

Dramatic variation can exist in soil erodibility especially when examining at a drainage basin scale. Martz (1978) found that most of the sediment yield in the Spring Creek Watershed originated from a relatively small portion of the total basin (about 1% of the drainage basin) over a short period of time over the year. The parcel in question contributed approximately 90% of the sediment over an average of 18 days per year. In a case such as this, the natural sediment load from a small parcel of land could easily mask any effect that human activity has had in other parts of the basin. Avoiding activities that could enhance erosion at sites with a high erodibility factor (K) would greatly reduce the potential erosion impact of a given activity.

3.1 Forestry

Timber harvest, like many other human activities, removes the vegetation from the land and this can allow increased runoff and soil erosion (Table 2). This can result in an increase in the wash load that is the main carrier for pollutants and nutrients. Although logging would only clear the land once every generation or less, the fact that logging often occurs on steeper slopes than agriculture and can result in greater land erosion.

Based on studies on Cabin Creek, Rothwell (1977) reports that the water quality of creeks could be protected in logging areas if precautions were taken. His recommendations were as follows:

1. Avoid excessive soil disturbance by carefully planning roads and logging. The locations of roads and cut blocks should be away from stream channels, steep road grades should be avoided, minimize the number of road crossings of streams, and construct the roads and do the logging at a time of year when the runoff, soil moisture and rainfall are at a minimum.

2. Trained supervisors should be on site to ensure that road and logging directives are followed. This will also reinforce to the field crews the importance of good logging and construction practices.

The 1994 Alberta Timber Harvest Planning and Operating Ground Rules requires that buffer strips be designated along watercourses. The width of the buffer strip varies from 20 m on small streams to 100 m around lakes larger than 16 ha. Normally harvesting is not permitted on slopes steeper than 45 per cent (Alberta Environmental Protection, 1994).

In 1965 the Tri-Creeks Experimental watershed was established by the provincial forestry department to determine, among other objectives, the effectiveness of forest harvesting ground rules on protecting the water resource. Three creek basins, Wampus, Deerlick and Eunice, were monitored for several years in their virgin state. Then Deerlick and Wampus creek basins were logged and Eunice Creek was maintained as a control. The forest harvesting on Wampus Creek followed the established ground rules. The forest harvesting on the Deerlick Creek basin followed the ground rules but did not have buffer strips. Approximately 37% of the two basin areas were harvested.

A review of the data showed that the sediment production from the Wampus Creek basin increased by 132.6% compared to the control stream (Eunice Creek). Deerlick Creek sediment production increased 210.3% compared to the control. These increases are based on sediment samples collected at the outlet of each basin. When point sources were examined, poorly constructed, maintained and reclaimed stream crossings and access roads through ephemeral draws, tributaries and source areas were identified as the primary sources of sediment. Jablonski (1986) concluded that good forestry management practices, rather than buffer strips, was the main determinant in minimizing the amount of sediment entering the stream.

3.2 Agriculture

The Universal Soil Loss equation described in section 3.0 was originally designed to predict soil loss due to agricultural activities. Table 5 lists typical values for C used for various crop management practices (Note: the C values are not directly comparable to the C_c values in Table 4).

Table 5 : Estimated C Values for Cropping Management Strategies in California (Evans and Kalkanis, 1976)

Soil Management Practice	Estimated C Value	% Greater than Continuous Perennial Grass
Continuous clean tilled fallow	1.00	33300
Continuous tilled fallow, 1000 lb. straw/ac	0.50	16600
Continuous bare soil, untilled	0.50	16600
Continuous grain, conventional tillage	0.36	12000
Continuous grain, minimum tillage	0.24	8000
Orchard cover crop, spring disced	0.25	8300
Orchard cover crop, untold, mowed	0.10	3300
Continuous annual grass or hay	0.10	3300
Continuous perennial grass	0.003	n/a

As mentioned previously, continuous crops often disturb the soil annually through tillage. Reviewing the C values in Table 5, it can be seen that having a vegetation cover and reducing tillage can significantly reduce the amount of sediment that runs off a given field.

The timing of the vegetative cover can also be an issue. Erosion due to rainfall only occurs during rainfall events or during snowmelt. A vegetative cover is especially important at those times.

3.3 Road Construction

As an activity, road construction is perhaps the largest contributor to disturbed soil erosion. Because it is associated with other activities such as forestry, and oil and gas exploration, these activities are sometimes blamed for any increased sediment loading. As mentioned previously in Section 3.1, road crossings contribute the lion's share to the increased sediment load attributed to logging activities. Most of the sediment is derived from roads with steep gradients, deep cut and fill sections, poor drainage, erodible soils and road stream crossings. The maximum damage is done in situations where no attempt is used to reduce erosion either by avoiding sites which have high erosion potential or not taking mitigative measures after construction (e.g. appropriate revegetation). Roads also cross streams and thus the potential source of sediment is right on the channel whereas sediment from other sources may have travel overland for a significant distance, increasing the chance that it is intercepted by vegetation and stabilized.

The Public Lands Operational Handbook advises that road construction is a major contributor to erosion and sedimentation and notes that vegetation is the only true, long-term, flexible and self-perpetuating erosion control method (Alberta Sustainable Resource Development, 2003). It also advises to minimize the number of creek crossings, and to ensure that when crossings are necessary that they are properly planned, designed, installed, maintained and reclaimed

3.4 Urbanization

Under urbanization much of the land surface becomes covered with asphalt (roads, parking lots etc.) and buildings and there can be one to two thirds less surface area available for rainfall infiltration. Also, urban areas have drainage systems (ditches, storm sewers etc.) that convey the water faster to the receiving water body. The water quality of urban runoff is usually quite poor and cities are starting to construct retention ponds to slow the flow of the runoff into the sewers. Retention ponds also provide an opportunity for an improvement in water quality. Water in the retention ponds will drop out most of the sediment, and nutrients and heavy metals will also drop out and the water quality of the water leaving the retention pond is markedly higher. Without the retention ponds any sediment or other deleterious material would travel to the receiving water body fairly directly because of the improved drainage.

Mitchell (1994) reported that the range of Total Suspended Solids from Edmonton storm sewers during the period 1987 to 1991 was from 10 to 2240 mg/l (compare to Table 1). She reported that other authors found that total suspended solids ranged from 2 to 7340 mg/l for Ontario, North Carolina and various other US sources. During the September 7-8, 1991 storm, it was estimated that the Edmonton Storm sewers contributed 61per cent of the Total Suspended Solids load in the North Saskatchewan River during that event. While the concentrations from urban sources are comparable to those in Table 1, they are generated from a much smaller drainage area. Urban drainage into Lesser Slave Lake at present is very small, but will increase as the land around the lake is developed.

3.5 Construction

Construction activity would create sediment rates similar to C values listed in Tables 2 and 4 for bare ground constantly being reworked. Soil in this condition is ripe for erosion and very high soil losses can be expected. Guy (1965) showed an increase of at least 6000 per cent for a 58 acre (23.5 ha.) parcel over a five year transition from rural to urban cycle. At the end of the construction, the sediment dropped again to values much closer to the pre-construction values.

3.6 Weir and Cutoffs on Lesser Slave River

In the early 1980's, eight cutoffs and a weir were constructed at the outlet of Lesser Slave Lake and along the upstream end of the Lesser Slave River. The purpose of these works was to control the lake level in a narrower range. The cutoffs degrade over time resulting in additional sediment load, but in this case that additional sediment would be carried down the Lesser Slave River and would not affect Lesser Slave Lake. One concern that has arisen, is the deposition of sediment in the Lesser Slave River channel upstream of the weir. Cross sections surveyed in 1982 and 1993 have confirmed this to be happening. The source of this sediment is the littoral transport parallel to the shoreline.

The deposition of this sediment upstream of the weir is a natural result of the imbalance between the incoming sediment and the ability of the Lesser Slave River to transport it downstream. Immediately upstream of the weir, the river velocities close to the bed would be much lower as a consequence of the weir being in place. The sediment which is transported as bed load (bed material that moves on or near the bed) is deposited immediately upstream of the weir. In the event of a high flow, much of this material would be washed away, since it is sand sized. Aggradation of the outlet channel has been documented as occurring before the weir was constructed and had caused problems for the earlier water supply intake for the Town of Slave Lake.

3.7 Town of Slave Lake Intake

The Town of Slave Lake had a new water supply intake constructed in 1983 in the outlet channel of Lesser Slave Lake, about 200 m downstream of the lake. This structure replaced an earlier structure that was located near the new site. The former structure had experienced operational problems caused by bed fluctuations.

In 1987, the River Engineering Branch wrote a report assessing the sedimentation problems at the intake and concluded that the lake regulation works probably made no significant contribution to the problem. It was recommended that the ports be altered with risers to withdraw water from a higher elevation in the channel that would contain less fine sediment (Drury and Vincic, 1987).

3.8 Buffalo Bay - Horse Lakes Cutoffs and Works

Starting in the early 1950's and culminating in 1974, the East and West Prairie and South Heart Rivers were extensively channelized. The resulting increase in river slope boosted the sediment transport in those rivers dramatically. Since the water from these rivers flowed first through Buffalo Bay before entering Lesser Slave Lake, much of the increased sediment was deposited in the Buffalo Bay - Horse Lakes complex. The increased sediment transport into Buffalo Bay has raised concerns about the fish fry that feed in there during the early part of the year. If Buffalo Bay becomes too shallow, the water temperature could rise sufficiently in some years to reduce the viability of the fishery.

In the mid 1980's, several floods occurred which plugged up the East Prairie channel with debris and in 1988 a diversion channel was excavated which allowed the East Prairie to flow east. It connected with some existing channels, and then flowed into Lesser Slave Lake, entering just upstream of the

Grouard causeway, under low flow conditions. This would allow more sediment to flow directly into Lesser Slave Lake. Also, the South Heart River channel was plugged up by debris and a new channel directed the flow into Horse Lakes. As a consequence of these two actions, the sediment load entering Buffalo Bay has been reduced significantly.

In 1992, the final report was submitted by the Public Advisory and the Interagency Management and the Interagency Technical Committees to the Minister of the Environment. Among the recommendations in the report were the construction of River Bed Armouring Structures which are designed to stabilize the river bed and reduce back to its natural level.

3.9 Swan River Cutoffs

In 1983-84 cutoffs and dykes were constructed along the Swan River to protect the Town of Kinuso from floods. As discussed in section 3.8, this would result in increased sediment transport as the cutoffs adjust back to a stable slope. An assessment of the changes on the river due to the cutoffs has not been done, but the rating curve for the Water Survey of Canada gauge at Highway No. 2 has degraded by about 1 m. Most of the increased sediment transport would occur during floods and a lot of this material may end up being deposited on the flooded banks. The presence of dykes would reduce this phenomenon, as the dykes would prevent the sediment-laden water from flooding over the banks. However, the net result of this would be an increased sediment load entering Lesser Slave Lake from the Swan River until the cutoffs stabilize themselves.

3.10 Dykes

Dykes, designed to prevent flooding, have been constructed along points on the Swan River, the East and West Prairie and South Heart Rivers and Sawridge Creek. Many of these dykes were constructed to protect cropland from being flooded in delta areas. Deltas, as discussed earlier, are built up by sediment deposition at the confluence of rivers and lakes. The deposited material is very fertile and thus there is an attraction to develop deltas for agriculture. Usually a delta in its natural state will be covered with fast growing vegetation that can stand being flooded once in a while. A natural part of a delta's cycle is to be flooded and sediment deposited on it, adding fertility to the system.

When dykes are constructed, this natural process of flooding is interrupted and so the sediment carried by the channel is deposited in the channel or carried into the lake. Either way, this contributes to aggradation that is raising the elevation of the channel bed. Eventually this will contribute to increased water levels for a given discharge and the need to increase the elevation of the dykes to maintain the same level of protection.

4.0 Reducing the Impacts of Human Activity

Human activities have had and will continue to impact the sediment load entering in the drainage basin of Lesser Slave Lake. As discussed, certain activities have little impact on the amount of sediment in the rivers, creeks and lake while other activities have the potential for increasing it significantly (Table 3). However, even relatively high-risk activities can be done without necessarily causing excessive sediment movement in the drainage basin.

5.0 Recommendations for Reducing Human Caused Increases in the Sediment Load

1. Identify and avoid disturbing areas where the soil has a high erodibility factor. Martz (1978), found that about 1% of the drainage area of Spring Creek contributed approximately 90% of the sediment for the season. In the Universal Soil Loss equation there is a variation by a factor of 2,000 in the soil erodibility factor.

2. Land with exposed soil will erode much faster than land with a cover (e.g. vegetative). Establishing a vegetative cover as soon as possible after a disturbance will reduce sediment production significantly. The erosion potential between clean tilled land and dense forest cover varies by a factor of 1,000.

3. Avoid disturbing steep slopes. There is a much higher potential for erosion to occur and it is difficult for vegetation to establish itself at a site with high erosion as the seed or seedling can easily be washed away. The erosion factor varies 113 times between a 1% slope and a 20% slope. While forestry plans will avoid disturbing steep slopes, road construction often will not.

4. Extreme care needs to be taken when constructing stream crossings as the potential source of sediment is right on the channel.

5. River channelization and cutoff construction are two activities that will increase the sediment load both initially and for a period of time after. The sediment load on the East and West Prairie Rivers has increased over the past 20 years and will continue to be higher until the rivers have degraded back to their stable slope. The cumulative impact of such works needs to be assessed as part of the review process.

6. When considering dyking as a flood control measure, the cumulative impact on the stream or river and area should be assessed as part of the review process. Dyking disturbs the natural sediment deposition pattern in a delta and can make flooding problems worse over the long term.

7. Most studies found that road building was one of the highest sources of sediment due to human activity. Much of the increased sediment load attributed to forestry, gas exploration etc. is directly related to road construction. Drainage patterns should not focus runoff water directly towards a stream but use an indirect route so there is a greater opportunity for the runoff to be intercepted by vegetation and settle out. Also, exposed soil, especially on slopes should be revegetated as soon as possible after being disturbed.

8. An assessment of the relative contribution of various human activities (e.g. agriculture, forestry and road building) to the total sediment load should be conducted. The purpose would be to determine the relative contribution of each activity to the total sediment load. Historically, only the total load passing Highway 2 has been documented for the rivers where sediment data was collected.

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Fig 1: Sediment Rating Curve for the Swan River Near Kinuso, 1969 - 1996.

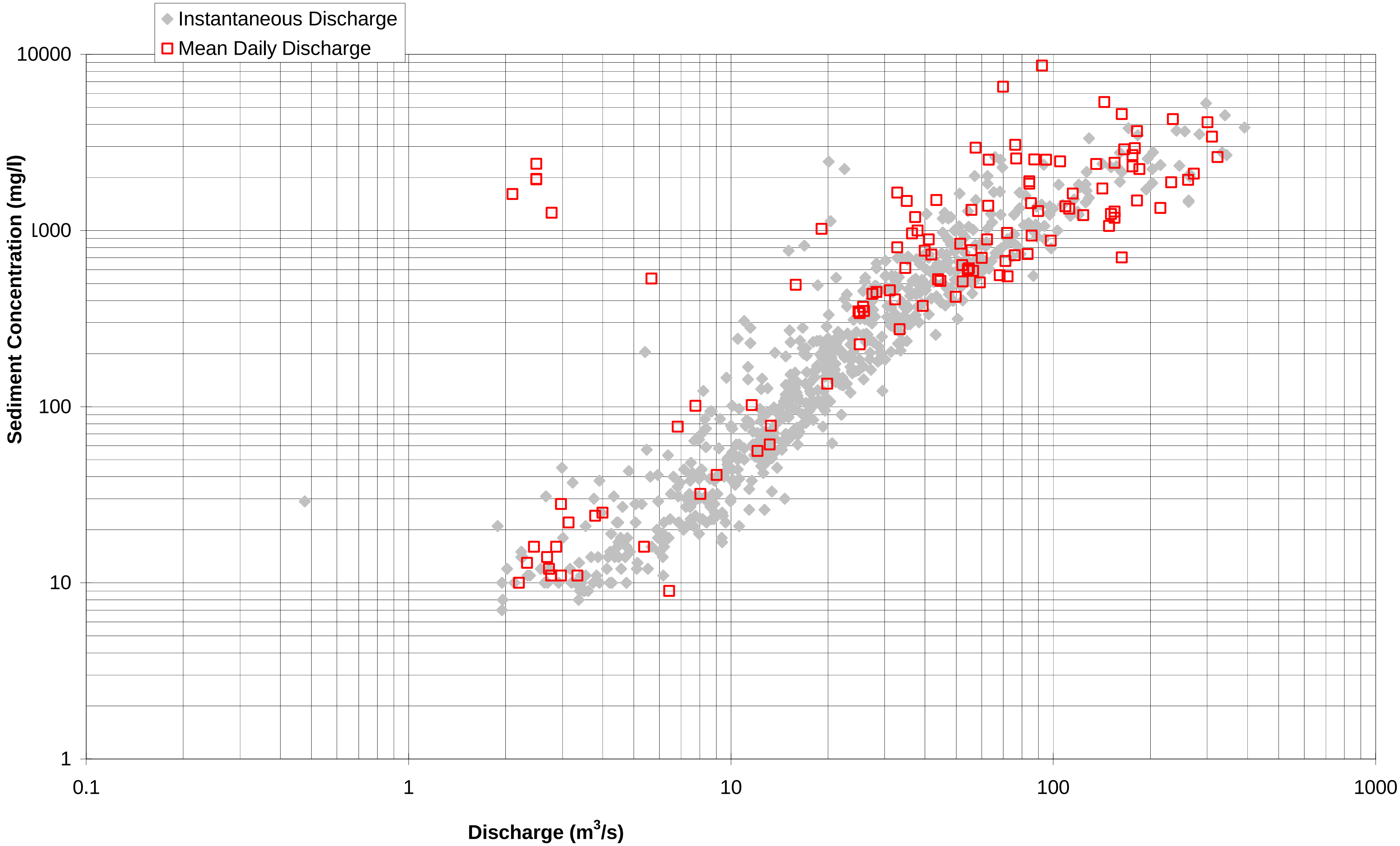

Fig 2: Sediment Rating Curve for the Driftpile River at Driftpile, 1977 - 1986.

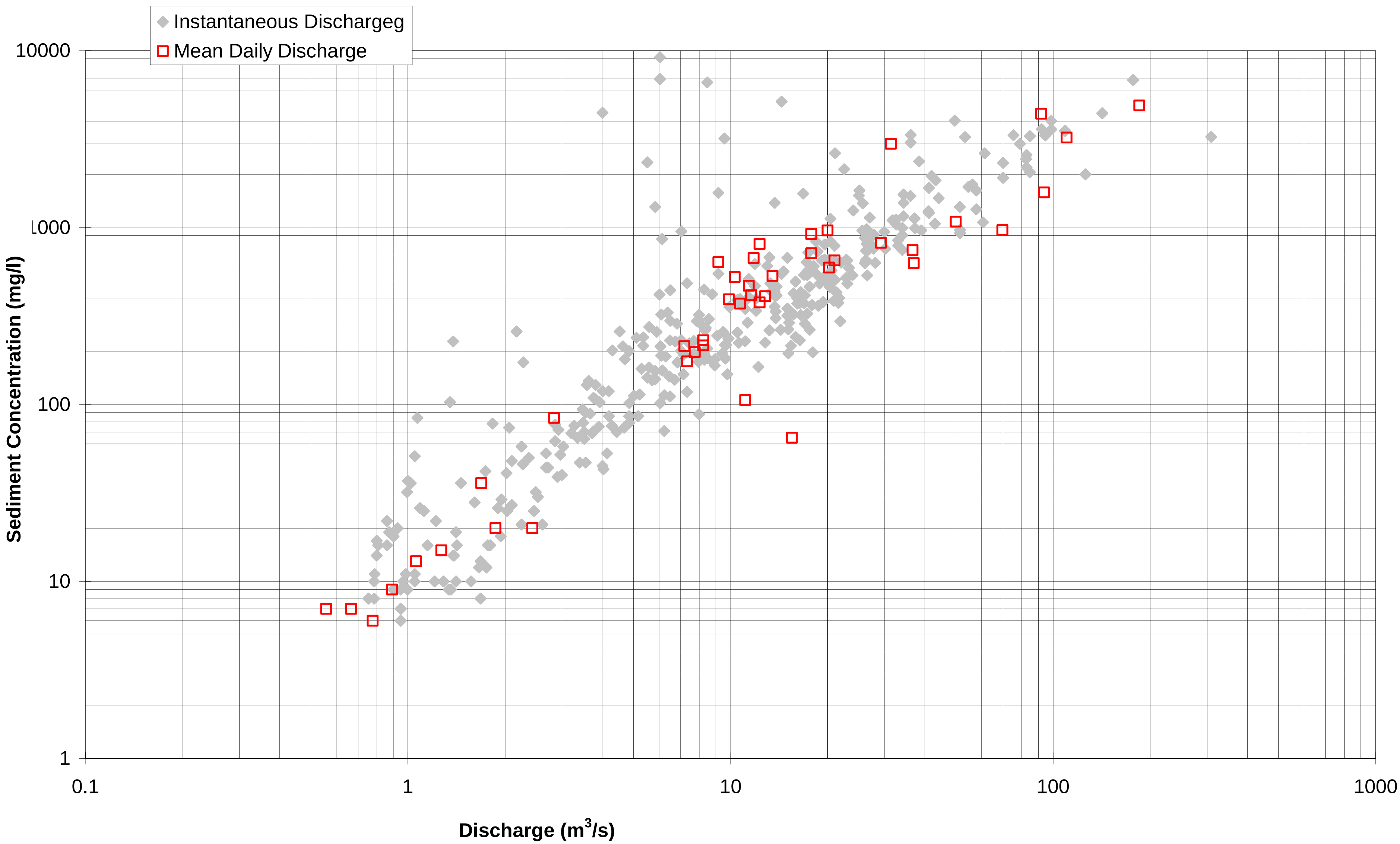

Fig 3: Sediment Rating Curve for the East Prairie River near Enilda, 1973 - 1996.

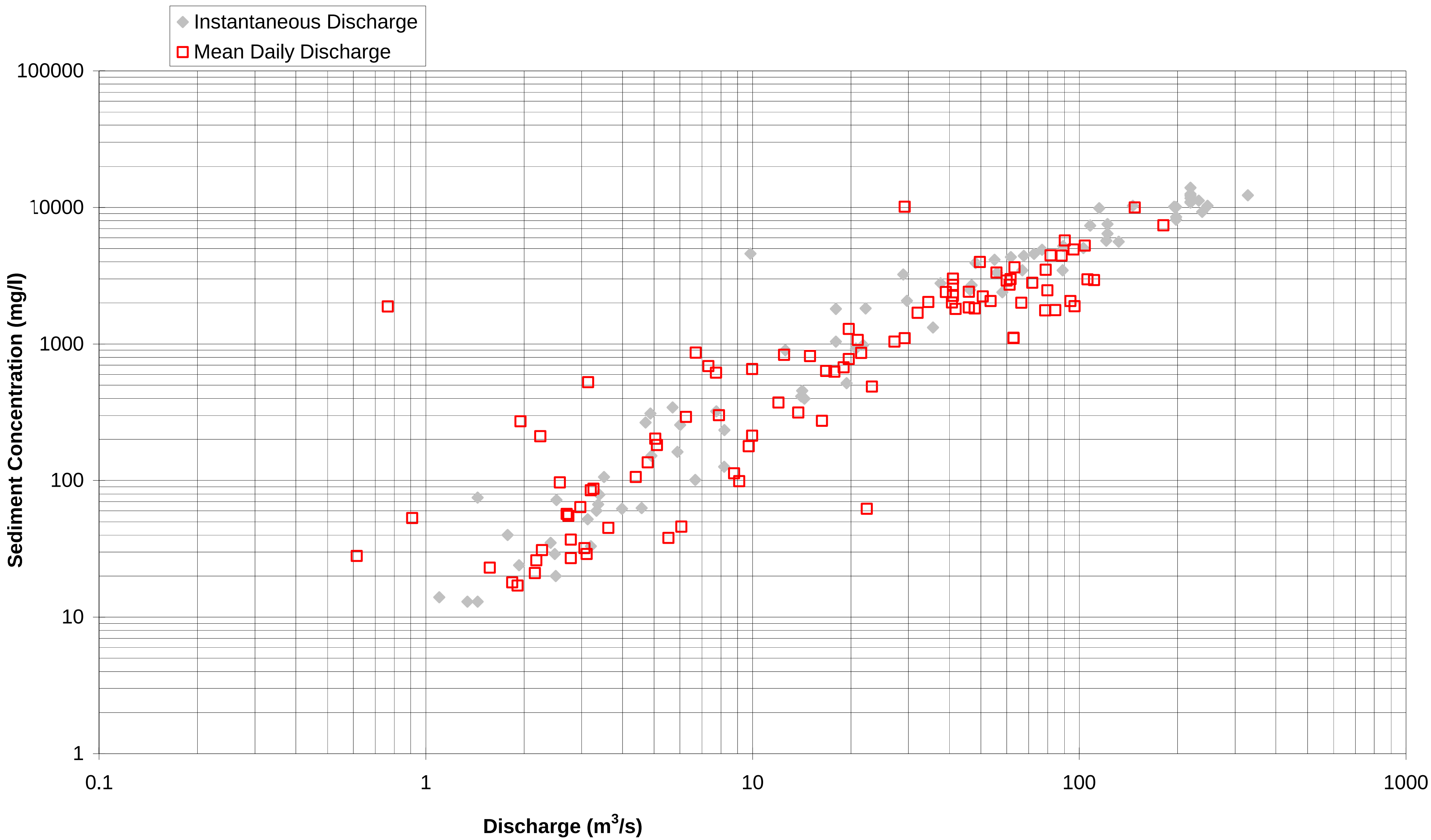

Fig 4: Sediment Rating Curve for the West Prairie River at High Prairie, 1973 - 1997.

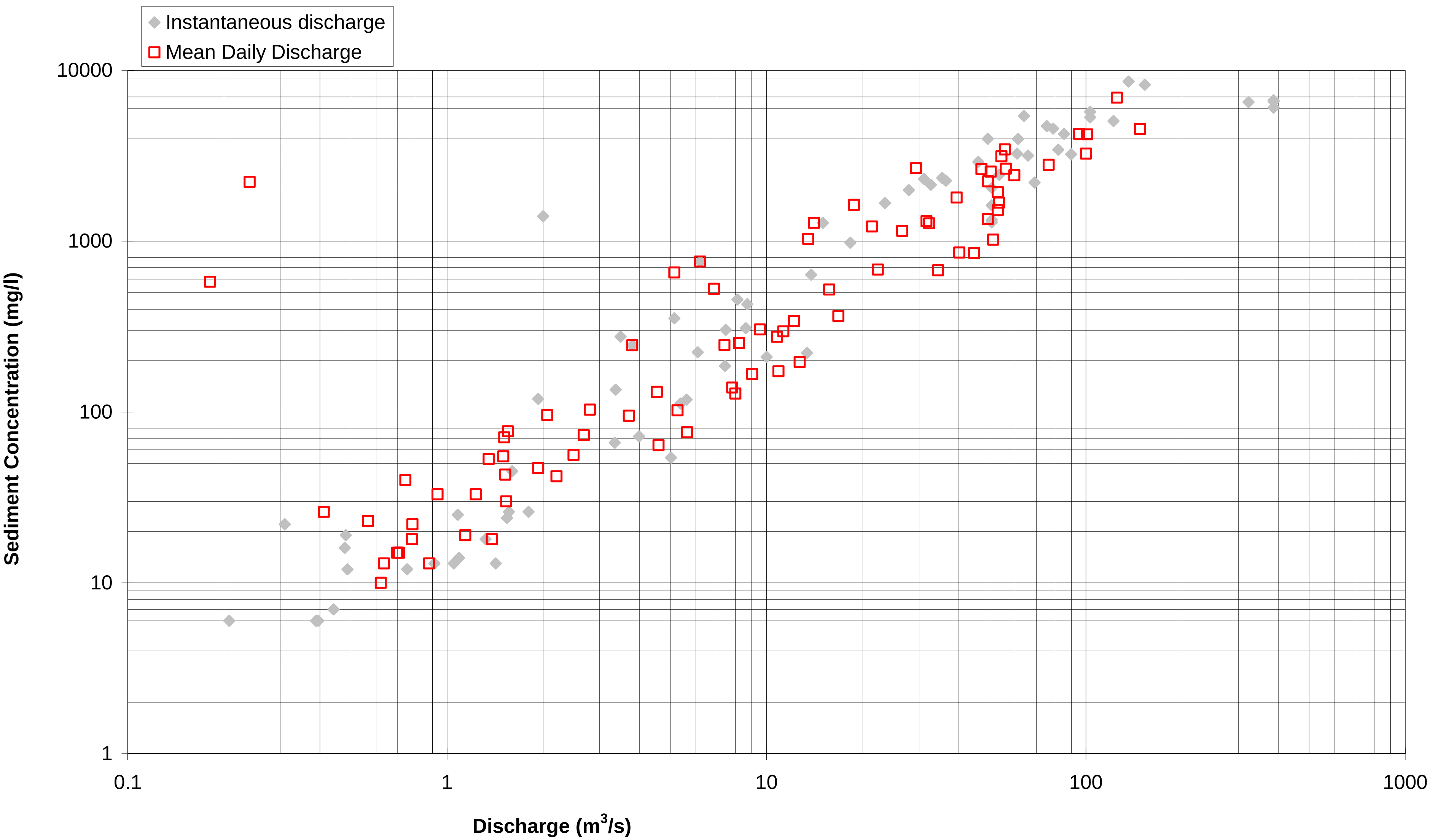

Fig 5: Sediment Rating Curve for the Lesser Slave River at Highway 2A, 1977 - 1988.

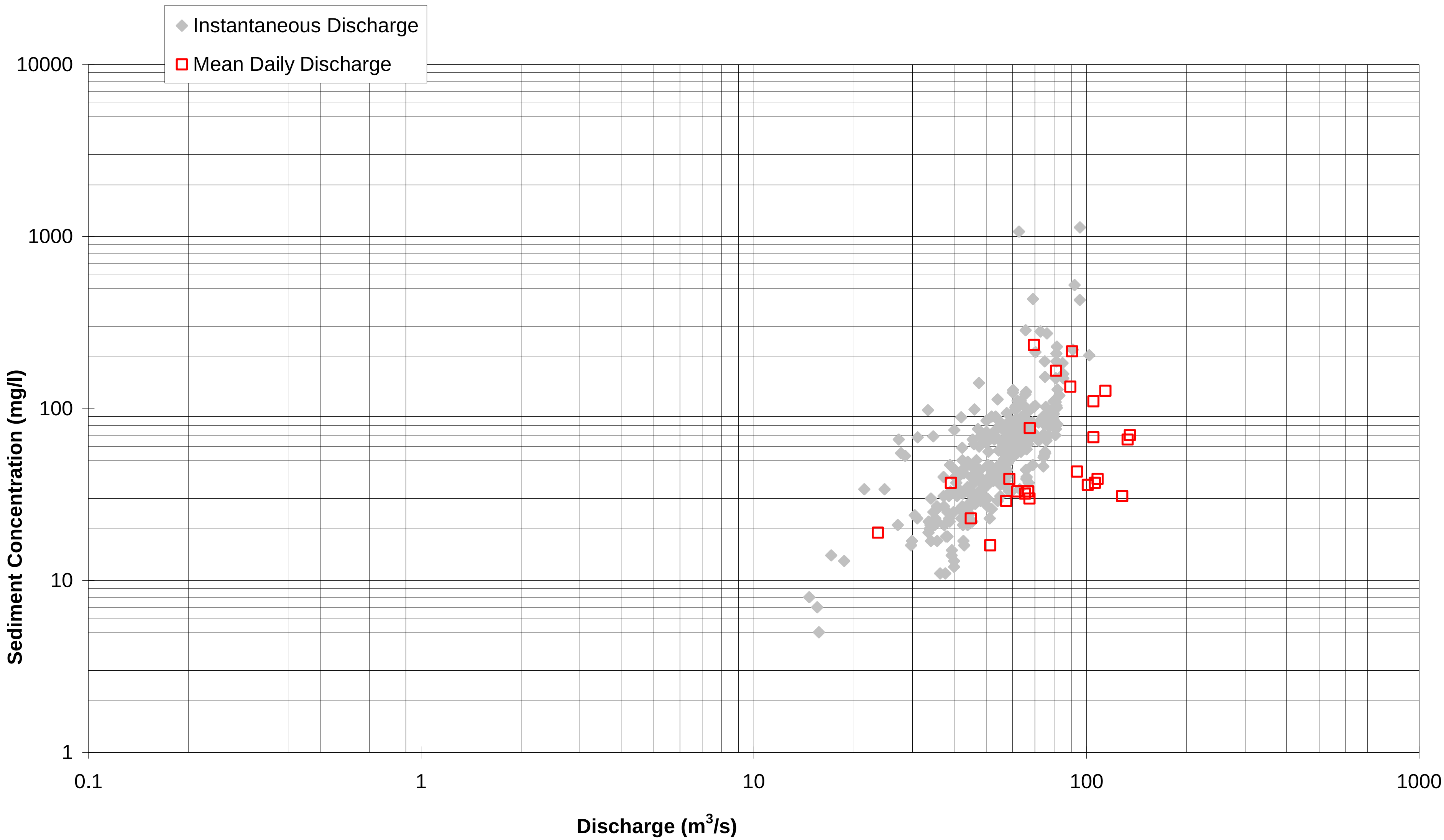

Fig 6: Sediment Rating Curve for the Lesser Slave River at Slave Lake, 1978 - 1997.