Potential Impact on Sediment Volume due to Berm Construction

Introduction

Recently there has been an increased interest in suspended sediment concentration impacts of bridge construction activities, particularly construction of berms to access pier locations. There appears to be a perception by some regulatory authorities that sedimentation can have negative impacts on the fisheries resource. As a result, berm construction practices have been modified to attempt to minimize the addition of sediment to the stream during construction. These include measurement of turbidity (used as an indicator of sediment concentration) and construction of berm isolation techniques on top of isolation techniques. Some of these modifications have resulted in significant additional expense and delays to bridge construction.

Observations of rivers in flood suggest that they have the capacity to transport very large volumes of sediment. Published sediment transport measurements corroborate these observations. However, bridge construction access berms have a finite volume of material, and the loss of a relatively small quantity would be readily noticeable to those on site. In order to illustrate the relative magnitude of sediment transport in a river and the potential for sediment that could be added during berm construction, a comparison is performed for a selected site.

Methodology

Environment Canada operates the Water Survey of Canada (WSC) Gauge 05DF001 on the North Saskatchewan River at Edmonton. This gauge has a long flow record (> 90 years) with several known large runoff events. The published sediment concentration data includes over 120 measurements (Table 1). This river would require significant berms to access pier construction locations, as has been the case on several recent projects (Hwy 11A near Rocky Mountain House, Anthony Henday Drive SW at Edmonton) as well as some proposed projects (Hwy 22 near Drayton Valley, Anthony Henday Drive NE at Edmonton). Due to the available data and the relevance of this river to berm construction activities, the WSC Gauge 05DF001 site has been selected for the comparison study.

The first step in the analysis approach was to develop a relationship between sediment concentration ‘C’ and flow rate ‘Q’ for the available data. This relationship was then used to calculate sediment volumes transported for any given day based on the continuous mean daily flow record. These results have been presented in a variety of forms, including plots of sediment volume by day of year and by each year in the record. Sediment volumes have also been presented by flows that represent the range of flows experienced with an indicator of the frequency of these events. Finally, the potential for sediment to be added from access berms during bridge construction has been estimated and compared to the volumes naturally transported by the river.

Analysis

The relationship between 'C' and 'Q' for this site can be seen in Figure 1. Note that the 'C' values are plotted on a log scale. Significant scatter in the data is visible. However, a straight line does appear to visually fit the trend in the data quite well. Statistical regression can be biased by the un-even distribution of data points. A good visual fit results in the equation:

$$C = 0.00012Q^{2.4}$$

The form of this equation is consistent with those observed in a recent unpublished Alberta Transportation study of all WSC gauging stations with sediment concentration data in Alberta.

Table 2 shows the magnitude of suspended sediment in terms of cubic meters per day that are transported by the North Saskatchewan River at this site over a range of flows. A brief description of the flow and the amount of time it is exceeded during the summer months is shown. The exponential relationship between sediment load and flow is readily apparent. Over 1000m^3 of sediment is transported past any given cross section on an average summer day (Q = 300cms). At the peak of the mean annual flood (Q = 1000cms), the volume of sediment transported increases to over 50,000m^3. Extrapolating to the largest daily flow on record (Q = 4600cms, June 1915), the volume of sediment transported increases to over 12,000,000 m^3, which is approximately 11000 times more than on the average summer day.

Table 3 and Figure 2 show the calculated annual volumes of sediment transported by the river at this site from 1912 to 2002. The high variance in yearly volumes is due to the occurrence of large runoff events in certain years. One large runoff event can greatly exceed the total annual sediment volume for non-flood years in a few days. The annual sediment transport volumes at this site range from 60,000m^3 to 20,600,000m^3, with an average of 1,600,000m^3.

Figure 3 shows the calculated average daily sediment volumes for each day of the year. Maximums and minimums are also shown. Typical transport volumes range from about 20m^3/day during the winter to more than 10000m^3/day during the summer. Volumes during relatively low flow, open water conditions that are typical of berm construction and removal are still in excess of 1000m^3/day.

Comparison with Potential Sediment from Bridge Construction Activities

The estimated total volume in a pier construction access berm on this river would likely be in the 5000m^3 range. Current construction techniques ensure that the upstream flank of such berms is sheltered during installation, and that the portions of berms adjacent to higher velocities at the flow constriction are protected from erosion. In addition, the timing of pier access berm use is generally limited to periods of low flow, reducing the likelihood of loss to high runoff events. The loss of significant portions of berm while following these techniques is unlikely. If some material was lost, the loss of volumes as low as $10m^3$ would become readily apparent to construction crews as they may make the worksite unsafe.

Some addition of sediment to the river flow is inevitable during berm construction and removal. However, the volumes of material that could potentially be introduced to a river during construction and use of pier access berms are much smaller than the daily sediment transport occurring in the river at low flow conditions (~ 1%). It is also clear that even the total loss of a pier access berm under flood conditions would result in a very small increase to the amount of sediment being carried by the river (~ 1% at Q = 2000cms).

Conclusion

The North Saskatchewan River at Edmonton has been used as an example site to compare the relative magnitude of natural sediment transport volume and the potential for sediment volume added due to construction access berms. Calculations suggest that even if loss of berm material were to occur, the impact on the sediment volume transported in the channel would only be in the range of 1%.

Loss of berm material is undesirable from both potential negative fisheries impact and construction efficiency and safety perspectives. Therefore, it appears reasonable to put effort into application of cost-effective measures that minimize the potential for loss of berm material, such as deflector walls and protection along surfaces exposed to constricted flows. Regular visual inspection of the berms and adjacent water for signs of loss of material is also warranted. However, the low potential for impact on natural sedimentation in the stream calls into question the cost effectiveness of other recent practices, such as regular turbidity measurements and secondary isolation techniques.

Table 1: Sediment Concentration Data
WSC Gauge 05DF001 – North Saskatchewan River at Edmonton

Year	Month	Day	Time	Q (cms)	Qs (mg/L)
1974	7	13	1200E	753	1580
1974	7	14	1200E	617	749
1974	7	15	1200E	436	335
1974	7	16	1200E	374	220
1975	5	2	1200E	343	93
1975	5	16	1200E	185	97
1975	7	2	1200E	189	42
1975	8	7	1200E	127	7
1975	8	19	1200E	110	11
1975	8	20	1200E	112	6
1975	9	23	1200E	98.8	3
1976	4	9	1200E	218	143
1976	4	27	1200E	120	88
1976	6	21	1200E	183	48
1976	7	22	1200E	172	34
1977	5	12	1200E	264	126
1977	5	30	1550	903	2460
1977	5	31	940	920	1510
1977	6	3	1200E	637	555
1977	6	6	1200E	388	279
1977	6	7	1200E	391	245
1977	6	9	1200E	320	134
1977	6	23	1200E	317	78
1977	7	28	1200E	219	37
1977	9	29	1200E	245	25
1978	4	25	1200E	168	102
1978	4	28	1200E	188	274
1978	5	19	1200E	289	113
1978	6	8	1200E	680	777
1978	6	9	1200E	617	543
1978	6	30	1200E	447	129
1978	7	14	1200E	827	738
1978	8	31	1200E	175	7
1978	9	15	1200E	459	137
1978	9	28	1200E	218	29
1978	11	2	1200E	188	16
1979	4	27	1200E	347	400
1979	5	10	1200E	252	173
1979	6	1	1200E	188	74
1979	6	28	1200E	233	39
1979	7	26	1200E	173	22
1979	8	23	1200E	149	7
1979	9	27	1200E	110	8
1979	11	1	1200E	98.3	8
1980	6	2	1200E	297	142
1980	7	14	1200E	284	65
1980	8	14	1200E	270	32
1980	9	26	1200E	246	28
1981	5	7	1200E	229	64
1981	5	28	1200	565	267
1981	6	25	1200E	175	102
1982	5	27	1200E	174	44
1982	6	23	1200E	293	77
1982	7	7	1600	1730	1980
1982	8	10	1200E	83	11
1982	9	8	1200E	201	16
1982	10	4	1200E	206	24
1983	4	28	1200E	432	396
1983	6	1	1200E	242	74
1983	6	29	1200E	251	133
1983	7	19	1200E	328	147
1983	8	31	1200E	130	8
1983	9	29	1200E	117	30
1983	11	3	1200E	147	10

Year	Month	Day	Time	Q (cms)	Qs (mg/L)
1984	4	25	1130	191	41
1984	4	25	1131	191	37
1984	5	24	1000	120	17
1984	5	24	1001	120	17
1984	6	13	1129	296	251
1984	6	13	1130	296	238
1984	7	5	959	272	61
1984	7	5	1000	272	58
1984	8	1	859	157	14
1984	8	1	900	157	9
1984	8	30	959	181	7
1984	8	30	1000	181	8
1984	10	3	1529	171	6
1984	10	3	1530	171	6
1985	4	7	1100	267	214
1985	5	1	1300	217	88
1985	5	21	1300	147	22
1985	8	6	1115	149	11
1985	8	27	1200	182	23
1985	9	23	1310	212	38
1986	4	1	945	225	65
1986	4	15	905	282	254
1986	5	13	930	318	126
1986	6	10	900	354	122
1986	7	8	930	413	111
1986	8	13	1100	257	77
1986	9	16	930	179	8
1986	10	21	915	159	12
1986	11	4	850	149	9
1987	4	13	1615	238	239
1987	4	28	940	159	64
1987	5	25	1300	168	31
1987	6	24	1525	208	38
1987	7	29	1540	234	93
1987	8	26	1635	156	12
1987	9	30	1645	164	15
1987	11	4	1615	113	8
1988	4	7	930	155	53
1988	5	5	930	116	9
1988	5	30	1240	168	21
1988	6	27	1240	186	9
1988	7	25	1600	117	10
1988	8	22	1430	224	56
1988	9	15	1100	220	13
1988	11	7	1400	124	13
1989	4	21	840	211	155
1989	5	8	1130	302	179
1989	5	31	1200	193	47
1989	7	4	1100	245	27
1989	7	31	1110	208	33
1989	8	6	920	712	610
1989	8	10	1335	319	116
1989	8	19	1015	787	634
1989	9	7	900	362	97
1989	10	2	1200	182	16
1989	11	6	1040	176	12

Table 2: Sediment Transport Summary Data (Gauge 05DF001)

Flow Description	% Exceeded	Q (cms)	C (mg/L)	Vol. m^3/day	Vol. Ratio
Average Annual Daily Flow	90	140	20	100	0.1
Average Summer Daily Flow	50	300	100	1100	1
	20	500	350	6000	6
Mean Annual Flood	2.5	1000	2000	55,000	60
	0.2	2000	10000	490,000	650
Highest Flow Recorded	0	4600	75000	12,000,000	11000

'% exceeded' = percent of all days between May and September that Q is exceeded.

'C' = C value as calculated by the graphical fit equation for this gauge.

'Vol.' = calculated volume of sediment that passes the gauge site in one day, assuming an average material density of 2500kg/m^3.

'Vol. Ratio' = ratio of the transported volume at the specified flow to the transported volume at the average summer daily flow.

Table 3: Annual Sediment Transport Volume Data (Gauge 05DF001)

Year	Vol. (Mm^3)	Year	Vol. (Mm^3)
1912	4.36	1958	1.41
1913	1.15	1959	1.03
1914	1.54	1960	0.74
1915	20.73	1961	0.52
1916	2.91	1962	0.47
1917	2.90	1963	0.65
1918	0.70	1964	1.50
1919	0.28	1965	8.02
1920	1.91	1966	1.38
1921	0.45	1967	0.79
1922	0.46	1968	0.33
1923	3.73	1969	1.72
1924	0.64	1970	0.70
1925	2.88	1971	0.92
1926	1.74	1972	4.58
1927	1.96	1973	0.25
1928	4.69	1974	0.80
1929	0.42	1975	0.06
1930	0.39	1976	0.10
1931	0.72	1977	0.28
1932	2.21	1978	0.52
1933	0.73	1979	0.08
1934	0.30	1980	1.84
1935	1.86	1981	1.00
1936	0.83	1982	1.88
1937	0.41	1983	0.15
1938	1.11	1984	0.08
1939	0.49	1985	0.12
1940	0.40	1986	8.64
1941	0.25	1987	0.09
1942	1.16	1988	0.08
1943	0.94	1989	0.41
1944	7.18	1990	3.17
1945	0.33	1991	0.66
1946	1.15	1992	0.10
1947	0.62	1993	0.15
1948	4.34	1994	0.13
1949	0.35	1995	0.66
1950	1.02	1996	0.24
1951	0.95	1997	0.17
1952	7.04	1998	0.87
1953	1.63	1999	1.38
1954	10.22	2000	0.19
1955	0.68	2001	0.12
1956	0.45	2002	0.07
1957	0.29		

Figure 1 – C vs Q Relationship – North Saskatchewan River at Edmonton

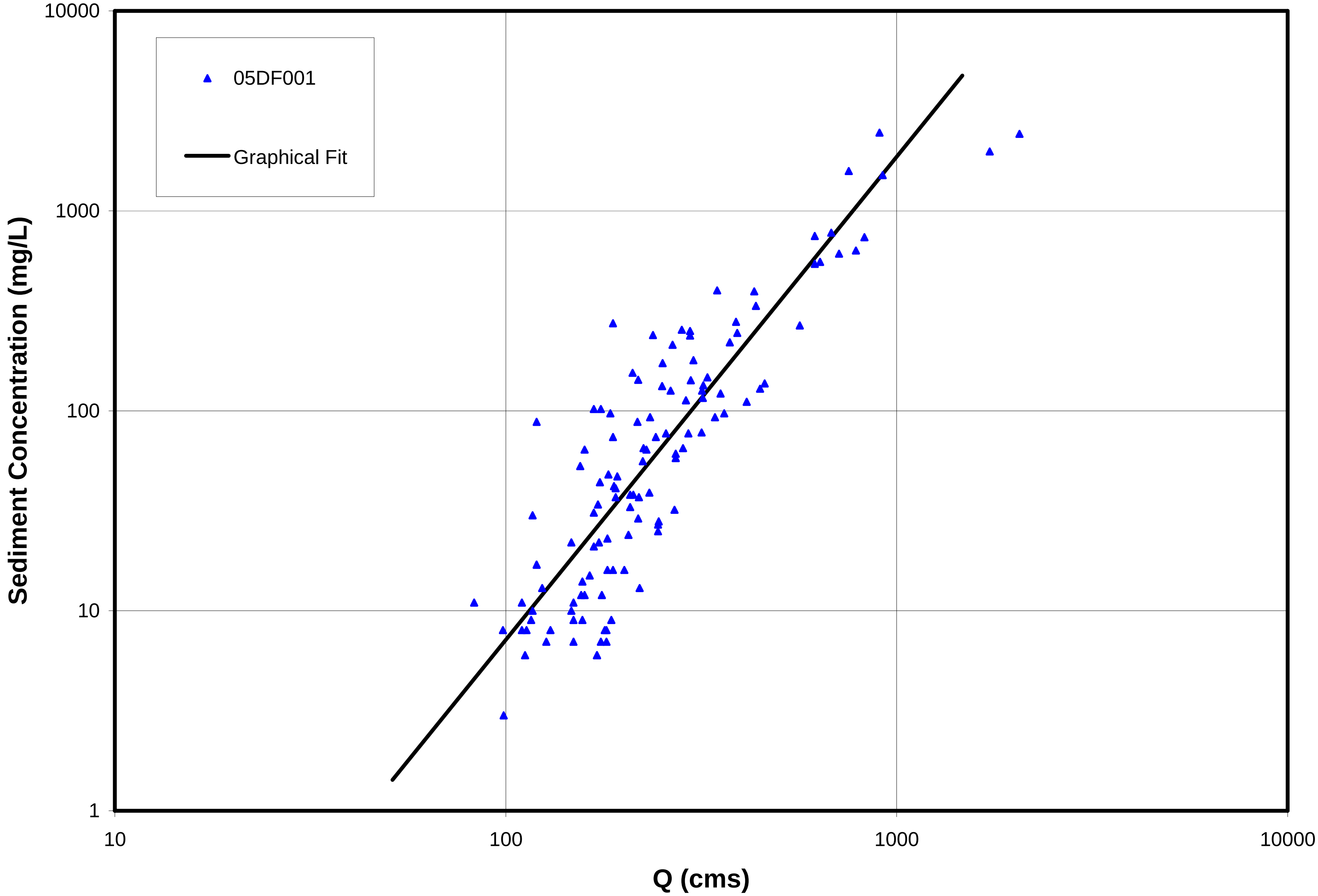

Figure 2 – Annual Sediment Transport Volume – North Saskatchewan River at Edmonton

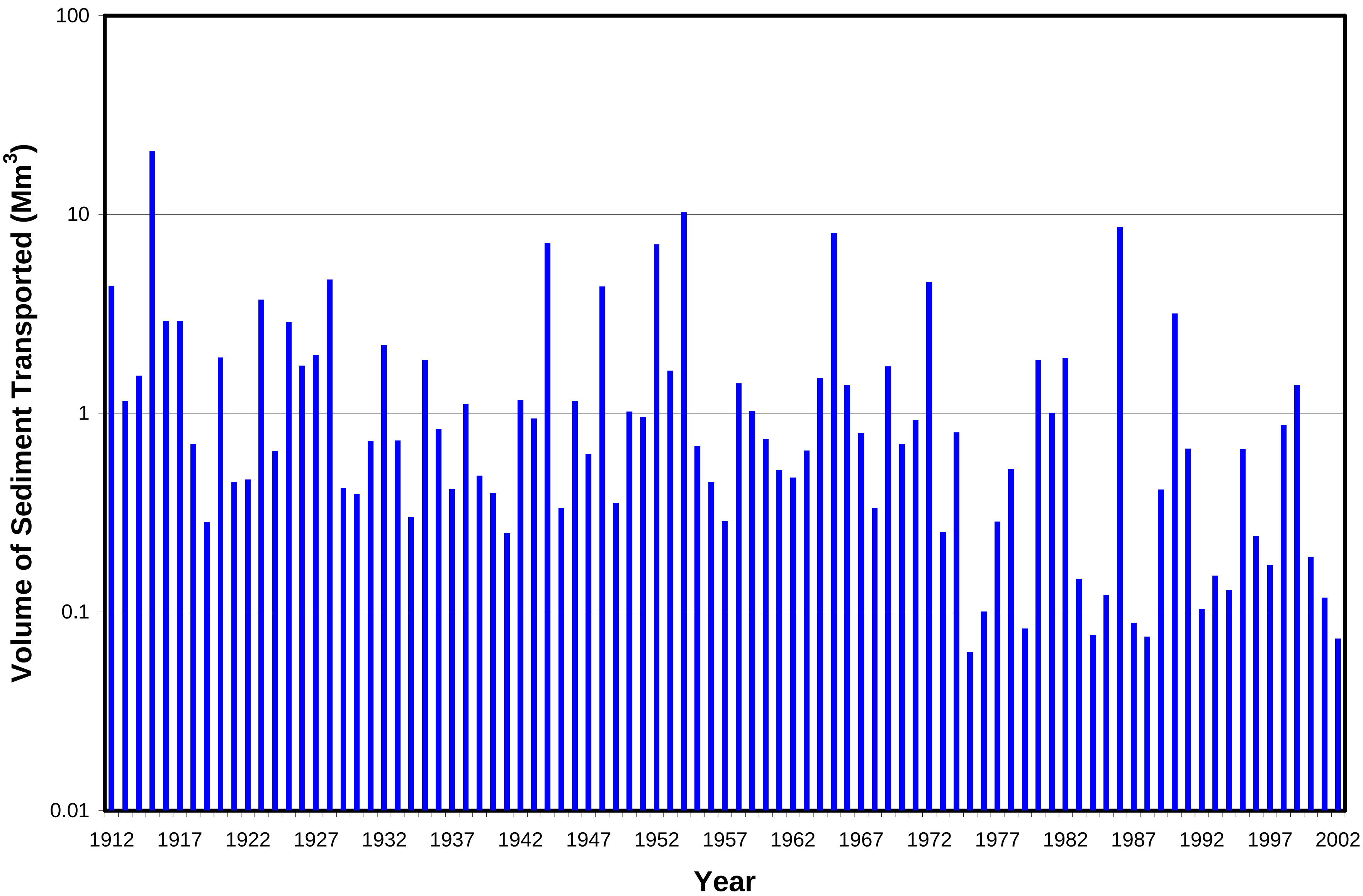

Figure 3 –Sediment Transport Volume Distribution – North Saskatchewan River at Edmonton