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NECHAKO RIVER COURT ACTION

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GEOMORPHOLOGY

(1) THE EFFECTS OF REGULATION OF FLOW IN THE NECHAKO RIVER ON CHANNEL MORPHOLOGY, SEDIMENT TRANSPORT AND DEPOSITION AND FLUSHING FLOWS

- KENNETH M. ROOD, MSc.

(2) EFFECTS OF FLOW REGULATION ON CHANNEL MORPHOLOGY, SEDIMENT TRANSPORT AND DEPOSITION, AND FLUSHING FLOWS

- CHARLES R. NEILL, MSc.

THE EFFECTS OF REGULATION OF FLOW IN THE NECHAKO RIVER ON CHANNEL MORPHOLOGY, SEDIMENT TRANSPORT AND DEPOSITION AND FLUSHING FLOWS

Expert Report for the Nechako River Court Action

Prepared for the Department of Fisheries and Oceans

by:

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1.0 INTRODUCTION

Positions:

Hydrologist with Reid Crowther & Partners Ltd. (North Vancouver) since 1983. Previously, private consultant during 1982 and 1983 and research assistant at the University of British Columbia (Dr. M. Church) during 1981.

Experience:

Six years of applying hydrology and geomorphology to environmental issues in British Columbia. Several years experience on the Nechako River system.

Degrees and Distinctions: B.A. (1976) and M.Sc. (1980): Simon Fraser University.

2.0 STATEMENT OF TOPIC

This report discusses the effect of regulation on the morphology of the Nechako River, as expressed in:

- reduced channel width through vegetation encroachment;
- reduced channel width through abandonment of backchannels;
- sedimentation due to altered sediment transport and deposition; and
- the effect of "flushing" flows on the morphology of the Nechako River.

The opinions quoted in this report are based on studies of changes between 1953 and 1986. Opinions on the merits of the Alcan or the Department of Fisheries and Oceans flow regimes are based on the results of these studies and on supplementing these studies with other evidence.

My analysis of the geomorphology of the Nechako River focussed primarily on the river between Cheslatta Falls and Vanderhoof and specifically on three reaches; between Irvines and Greer Ck., between Diamond Island and Fort Fraser and near Vanderhoof. My opinions are based on measurement and observations in these reaches, plus a general overview of the river.

3.0 DEVELOPMENT OF OPINION

- Review of pleadings of Department of Fisheries and Oceans (para. 6 and 7) and the Aluminum Company of Canada (para. 19 and 20).

- Review of scientific literature on river morphology and "flushing" flows (see Appendix A to this report) and relevant sections (Vol. 2, Section B.1 and B.3 and Vol. 21, Section B2.2) of "Aluminum Company of Canada Ltd. Kemano Completion Hydroelectric Development: Environmental Studies" prepared by Envirocon and dated January, 1984.

- Conducted studies concerning the Nechako River and prepared the following reports:

  - Nechako Hydrology Study (December, 1982) prepared for the Nechako Steering Committee by K.M. Rood.

  - A Hydrologic Study of Some Aspects of the Kemano Completion Project (March 1985) prepared for Department of Fisheries and Oceans by K.M. Rood of Reid Crowther and Partners Ltd.

  - Some Aspects of the Geomorphology of the Nechako River (January 1987A) prepared for Department of Fisheries and Oceans by K.M. Rood of Reid Crowther and Partners Ltd and C. Neill of Northwest Hydraulics Consultants Ltd.

  - Physical Habitat Simulation Measurements on the Nechako River (January 1987B) prepared for Department of Fisheries and Oceans by K.M. Rood of Reid Crowther and Partners Ltd.

- Site visits to the Nechako River: Nov. 18, 1983; July 17 and 18, 1984; July 6-9, 1986; August 16-21, 1986; Sept. 29 - Oct. 4, 1986; and October 25-28, 1986.

- Consultation with Mr. C. Neill of Northwest Hydraulics Consultants Ltd. prior to and during field work for geomorphology studies and during report preparation. Consultation with the following staff of Department of Fisheries and Oceans: S. Blachut, G. Ennis, M. Fretwell, R. Hamilton, L. Jaremovic and C. Shirvell. As well, Dr. E.J. Hickin of Simon Fraser University and Ms. M. North of the University of British Columbia were consulted concerning vegetation succession.

4.0 SUMMARY OF OPINION EVIDENCE

It is my opinion that the Alcan flow regime would affect the morphology of the Nechako River through potentially reduced flood or dominant discharges and through reduced discharges in May and June.

It is my opinion that the following changes would be the potential outcome of their pleadings on flow regime:

- reduction of the width of the channel of the Nechako River through vegetation encroachment along the margins of a further 10-15 percent;

- further abandonment of backchannels through vegetation encroachment and sedimentation;

- reduction of the length and water surface area of flowing backchannels in May and June in all years and reduced length of continually flooded backchannels in July and August in most years compared to the DFO pleadings flow regime;

- continued accumulation of fine sediments in backchannels, along the margins and at selected locations in the main channel at the expense of gravel bed.

As well, <u>it is my opinion that</u> the following flows are required for flushing fine sediments from the Nechako River:

- A flow of 500-700 m^3/s in the upper Nechako is required to stir up the armour layer and flush fine sediments stored in the interstices of the sub-armour layer sediments.

- A flow of 150-200 m^3/s is sufficient to remove fine sediments that are stored on the armour layer.

- Further study is required to define the flow necessary to halt the accumulation of sand and fine sediments at specific locations in the Nechako River.

5.0 RATIONALE OF OPINION

a) Encroachment of Vegetation

<u>It is my opinion that</u> vegetation has continued to encroach onto previously unvegetated portions of the Nechako as a result of lowered "flood" or "dominant" discharges since 1952. Further, the reduction in channel width observed to 1986 is slightly greater than that predicted by accepted relationships between dominant discharge and channel width.

It is generally accepted that the cross-section of an alluvial river channel is controlled by the magnitude of flood flows which pass through the channel (Bray 1981, Charlton <u>et al</u> 1978, Hey and Thorne 1986, Kellerhals 1967, Lacey 1930, Leopold and Wolman 1957). A decrease in the magnitude of annual peak flows as has occurred as a result of regulation on the Nechako River will, in the long term, cause shrinkage of the channel through deposition of sediments, abandonment of backchannels and encroachment of vegetation.

Average channel width - the width of channel between the margins of established vegetation and including backchannels - is easily measured from air photographs. Table 7.4 of Reid Crowther 1987A) gives average channel widths in 1953, 1974, 1980 and 1986 for three alluvial or nearly-alluvial reaches of the river. There has been a 34, 40 and 29 percent decline in width from 1953 in the 3 study reaches. Over this same period, the reduction in dominant discharge - assumed to be the mean annual flood - has been close to 50%.

For alluvial gravel rivers, the channel width is proportional to the square root of the dominant discharge (Hey and Thorne 1986, Bray 1981). For a 50% reduction in these flows a corresponding decline of 30% would be expected in channel width.

It is my further opinion that reduced flows in May and June of each year since 1980 have increased vegetation encroachment and that pioneer species are establishing to the elevation of the May and June water surface. This encroachment has and will continue to provide a substrate of terrestrial vegetation and associated "trapped" fine sediments along the wetted margins of the channel during temperature control releases in July and August of each year.

Encroachment of vegetation to the elevation of May and June flows is based on field observation (see Section 4.2.2, Reid Crowther, 1987A) in 1986, review of 1986 air photographs and the measurement and prediction of channel width changes discussed above.

Consultation with experts in the field of riparian vegetation succession suggests that pioneer species (northern black cottonwood, willows, sedges, grasses, etc.) establishing in May and June can tolerate 4 to 5 weeks of inundation during temperature control flows between July 20 and August 15. Vegetation succession may continue, leading in the long term, to alienation of this portion of the channel.

The relative merits of the Alcan and DFO pleadings on flow regime: The DFO flow regime recommends a flow of 56.6 m^3/s in May and June, the same as occurs under the injunction flows, and a constant flow of 226 m^3/s during the cooling water release period.

The Alcan flow regime recommends 28 m^3/s and 30 m^3/s during May and June and unspecified temperature control releases between July 20 and August 15 ranging from a minimum flow of 30 m^3/s to a maximum of 283 m^3/s. Flow releases may never exceed 30 m^3/s under some circumstances under the Alcan pleadings flow regime.

It is my opinion that the reduction of flows in May and June, under the Alcan regime will cause further encroachment of vegetation into the channel of the Nechako River narrowing it up to a further 10 to 15 percent.

It is my opinion that the "dominant" flow of 226 m^3/s proposed by DFO may cause a further small reduction in channel width, however the present average channel widths are only a few meters larger than the average water surface width for discharge 56.6 m^3/s (see Table 6.1; Reid Crowther, January 1987A) recommended for May and June.

It is also my opinion that the effective dominant discharge under the Alcan flow regime has not been specified. Minimum flow releases in July and August would also contribute to reduction of the channel width under the Alcan pleadings flow regime.

b) Abandonment of Backchannels

It is my opinion that the number and length of backchannels along the Nechako River, particularly of the large Type 1 channels, have continued to decline due to abandonment since 1952. Further, the backchannels are abandoned through a combination of vegetation encroachment and sedimentation at their entrances and along their length.

It is also my opinion that there is a relationship between the number and length of backchannels of different types with flowing water and observed total discharge in the Nechako River.

In my opinion there is no theory or body of scientific literature relating abandonment of backchannels to alteration of the hydrologic regime by regulation. There are also relatively few case studies in British Columbia. The Peace River (Church and Rood 1982) is one example. The measurements made to describe such changes on the Nechako River form the basis of my opinion.

Reid Crowther (1987A; Figure 6.2) categorized backchannels into three types: Type I channels are separated from the main river by permanent islands, treed with mature conifers or cottonwoods. Type 2 channels are separated from the main channel by an emergent floodplain that was experiencing primary succession under the natural flow regime. Type 3 channels are separated from the main channel by gravel bars that were unvegetated under the natural flow regime. Measurements of backchannel lengths in 1953, 1974, 1980 and 1986 are reported in Table 7.6 of Reid Crowther (1987A). The length of Type 1 channels declined 80% and 50% in two reaches between 1953 and 1986; the length of Type 2 channels declined 45% and 90%. No Type 3 channels appear to have been abandoned. Similar changes were observed on the Peace River as a consequence of regulation by Church and Rood (1982).

The number, length and water surface area of backchannels of different types on the Nechako River were measured at discharges of 12, 35, 60 and 163 m^3/s from 1980 aerial photography. The relationship between the length of different channels with flowing water and the total flow in the Nechako River is shown on Figure 6.3 and Table 6.1 of Reid Crowther's (1987A) report.

In my opinion the abandonment of backchannels is controlled primarily by the encroachment of vegetation and secondarily by sedimentation. This opinion is based on field visits to the river to examine backchannel entrances, examination of aerial photographs from 1953, 1964, 1974, 1980 and 1986 and surveys of selected backchannels (see Reid Crowther, 1987B).

Backchannel abandonment is controlled, in large part, by the factors controlling vegetation encroachment discussed in an earlier section and is one part of the discussed decrease in width. As well, slow sedimentation and growth of aquatic vegetation are changing some of the channels.

It is my opinion that the DFO pleadings flow regime would cause only minor further abandonment of backchannels through vegetation encroachment. Some unknown loss may occur through sedimentation over time. Further monitoring would be required to quantitatively define this effect.

By way of comparison it is my further opinion that the Alcan pleadings flow regime would cause the abandonment of some additional backchannels through the establishment of terrestrial vegetation. This may amount to a 15 to 30% further loss of backchannel water surface area (see Table 6.3; Reid Crowther 1987A).

It is my opinion that the Alcan flow regime would provide less length and water surface area of flowing backchannels in May and June than the DFO flow regime. Between July 20 and August 15, the Alcan pleading would provide slightly more length and water surface area in those years when temperature control releases exceeded the DFO release of 226 m^3/s but were less than the maximum of 283 m^3/s. The increase may only occur over a short portion of the July 20 to August 15 period or might never occur under the Alcan pleading flow regime.

In other years, when temperature releases are not required or are small the DFO flow regime will in my opinion provide greater backchannel water surface area and length (Figure 6.3; Reid Crowther 1987A).

c) Sedimentation in the Nechako River

It is my opinion that one of the effects of regulation on the Nechako River has been to reduce the capacity of the river to transport sediments, both in calibre and quantity through changes in flow regime (Raudkivi 1967, Vanoni 1975). Further, it is my opinion that sediment supply to the river, from the valley wall and bank erosion and from tributaries is unchanged by regulation. Erosion of the Cheslatta River (Kellerhals, Church and Davies 1979) has increased sediment supply to the Nechako. Theory and observation both suggest that Cheslatta and Murray Lakes are very efficient sediment traps and that only a small amount of finer sediments pass into the Nechako River (Reid Crowther, January 1987A). Erosion by the Cheslatta River near Cheslatta Falls also increased sediment supply by adding several hundred thousand tonnes of sands and gravels to the upper Nechako.

The result of reduced transport capacity and undiminished or increased sediment supply has been the accumulation of sediments in the channel of the Nechako River. Coarse sediments - gravels and cobbles - have accumulated at the mouths of some tributaries. Sand and finer material has accumulated at certain locations along the river and these zones of finer materials are expanding and covering over coarser parts of the channel.

Finer materials - silts and fine sands - are accumulating with the pioneer vegetation along the margins of the channel between the elevation of the May and June flows and the elevation of typical high water (Reid Crowther, 1987A; Section 4.3) and also in some backchannels and other sheltered areas.

The accumulation of sediments in specific locations of the river since regulation is documented from analysis of air photographs (Table 7.2: Reid Crowther 1987A), site visits and from the personal observations of residents familiar with the river before and since regulation.

It is my opinion that most sediment movement would result from the temperature control releases in July and August. Further, since the Alcan pleadings do not specify flows for this period and also because of the complex relationship between discharge and sediment movement in the Nechako River, it is not possible to evaluate the merits of the respective flow regimes. However, reduction of flows to 30 m^3/s during July and August would greatly further reduce transport capacity.

It is my further opinion that both flow regimes have significantly reduced "flood" discharges compared to the natural or pre-regulation regime and consequently reduced capacities to transport sediments. Sedimentation would continue under both of these regimes.

d) Flushing Flows

My familiarity with "flushing flows" is through a review of Reiser et al. (1985) and discussion with Department of Fisheries and Oceans staff. I am not familiar with this term otherwise.

My understanding is that flushing flows are released on regulated rivers to simulate natural high run-off events. The flows are released to maintain or enhance fisheries habitat, primarily by removing fine sediments deposited within the channel. They may also maintain channel morphology by slowing the rate of vegetation encroachment on the main channel or by removing accumulated sediments and aquatic vegetation from backchannels. This is discussed in more detail in Reid Crowther 1987A; Section 8.0).

It is my opinion that at least two types of "flushing flows" may be applicable to the Nechako River. Large releases may be required to mobilize the armour layer in the channel, stir up the bed material and carry away fine sediments. Other, smaller releases may be required to "flush" fine sediments which are sitting on top of the bed material (Beschta and Jackson 1979, O'Brien 1984).

These flushing flows could be estimated from equations describing the initiation of sediment motion or describing sediment transport (Vanoni 1975, for a summary). Unfortunately, the detailed information necessary for calculations at various locations along the river is not available. Consequently, my opinion is based on calculations of a very approximate nature at a few sites (Reid Crowther; January 1987; Section 8.0).

It is my opinion that:

- In the main channel of the Nechako River, bed material may start to move at discharges between 500 and 700 m^3/s. This opinion is based on the approximate calculation of an "initiation of motion" flow as described in Reid Crowther (1987A). The calculations were only done for three specific sites and may not apply even approximately, in other areas of the river. The duration of flow required to satisfactorily remove fines from the subsurface gravels underlying the armour layer is not known.

- The need for flushing of fine sediments from subsurface gravels would require monitoring and measurement of gravel quality.

- In the main channel fine sediments which are collected on the armour layer may be moved by discharges of 150-200 m^3/s in many areas. This opinion, is based on observations of the Nechako River prior to and following temperature control releases in 1986 and the relationships between velocity, depth and flow summarized in Figure 8.1 (Reid Crowther 1987A) for a selection of IPSFC cross sections in the upper Nechako. It may only be correct for selected portions of the river.

- Monitoring and assessment would be required to define the magnitude and duration of flows required to stop sand and other fine sediments from expanding over gravel bedded parts of the channel in areas near Greer Creek and Fort Fraser.

- The flows required to reduce vegetation encroachment were discussed in an earlier section.

- monitoring and assessment would be required at specific backchannels to determine the flow required for flushing.

It is my further opinion that neither the Alcan nor DFO flow regime would provide discharges adequate to mobilize gravels on the channel bed except perhaps in a few, very unusual locations. Without further description of the pattern of flows in July and August under the Alcan pleading, it is not possible to evaluate the relative merits of these flows with respect to movement of fine sediments stored on top of the channel bed.

APPENDIX A

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Reiser, D.W., Ramey, M.P. and Lambert, J.R. 1985. Review of flushing flow requirements in regulated streams. Pacific Gas and Electric Company Research and Development Report. 97 p and Appendices.

Vanoni, V.A., (ed) 1975. Sedimentation Engineering. ASCE Manuals and Reports on Engineering Practice No 54, New York. 745 p.

APPENDIX B

Curriculum Vitae

Education

B.A. (1976) Simon Fraser University

M.Sc. (1980) Simon Fraser University (Department of Geography)

General Experience

Mr. Rood was trained as a geomorphogist and hydrologist during his university career. Since 1980, Mr. Rood has worked as a geomorphologist or hydrologist, primarily on consulting assignments. In 1981, he worked as a research assistant to Dr. M. Church at the University of British Columbia. During 1982 and 1983 he worked as a private consultant on several projects. In 1983, Mr. Rood joined Reid Crowther and Partners Ltd., working primarily on the environmental impacts of development projects on rivers.

Publications

1987 The relation between site conditions and the number and volume of landslides in forested and clearcut terrain, Queen Charlotte Islands, B.C. B.C. Ministry of Forest Land Management Report. In preparation.

1984 (Roberts M.C. and Rood K.) The role of the ice contributing area in the morphology of transverse fjords, British Columbia. Geographiska Annaler 66A: 381-393

1984 An aerial photograph inventory of the frequency and yield of mass wasting on the Queen Charlotte Islands, B.C. B.C. Ministry of Forest Land Management Report 34. 55 pp.

1982 (Church M. and Rood K.) Peace River Surveys - 1979 and 1981. University of British Columbia Department of Geography Report. 55 pp and figures.

Selected Consulting Projects

1986 Geomorphology of the Nechako River for Department of Fisheries and Oceans.

1983 - 1986 Investigation of the physical effects of the CN twin tracking project on the North Thompson and Thompson Rivers for CN Rail.

1984 - 1986 Examination of the effect of the Annacis sand islands on near-bank velocities in the Fraser River for Ministry of Transport and Highways.

1985 Investigation of bank erosion and stability along the Yukon River near Whitehorse for the City of Whitehorse.

1985 Investigation of the sediment balance of the Lower Fraser River for an economic study of Fraser River Training works for Public Works Canada.

1983 Investigation of the effects of regulation of Atlin Lake on downstream hydrology and morphology for Northern Canada Power Commission.

TABLE 6.1: The variation of total water surface area and water surface width with discharge for Reaches 2 and 4. Reach divisions are described on Figures 5.4 and 5.5

REACH 2

Subreach	Thalweg Length	WATER SURFACE AREA (1000 m^2)				AVERAGE WATER SURFACE WIDTH (m)			
		June 28 1980	August 3 1980	August 29 1980	August 19 1980	June 28 1980	August 3 1980	August 29 1980	August 19 1980
	(m)	(12 m^3/s)	(35 m^3/s)	(60 m^3/s)	(163 m^3/s)	(12 m^3/s)	(35 m^3/s)	(60 m^3/s)	(163 m^3/s)
1	2780	210.4	299.3	(358)[2]	416.7	76	108	(129)	150
2	2490	197.7	237.0	283.1	379.3	79	95	114	152
3	2770	228.1	285.6	343.9	419.6	82	103	124	151
4	3020	217.4	257.2	293.8	376.2	72	85	97	125
5	2600	195.3	23.8	258.8	331.0	75	90	100	121
6	3710	(254.9)[1]	293.8	318.6	397.3	(69)	79	86	107
7	2930	(258)[2]	309.0	337.9	395.4	(88)	105	115	135
8	3600	236.5	308.9	358.5	508.1	66	85	100	141
9	3460	223.7	286.5	304.5	408.6	65	82	88	118
Total Reach	27360	2021.6	2511.1	2857.1	3632.2	74	92	104	133

REACH 4

Subreach	Thalweg Length (m)	June 28 1980 (12 m^3/s)	August 3 1980 (35 m^3/s)	August 29 1980 (60 m^3/s)	August 19 1980 (163 m^3/s)	June 28 1980 (12 m^3/s)	August 3 1980 (35 m^3/s)	August 29 1980 (60 m^3/s)	August 19 1980 (163 m^3/s)
1	2600	162.9	194.8	228.1		63	75	88	
2	2930	215.3	241.0	271.7		73	82	93	
3	2140	(193.6)[1]	205.3	248.4		(90)	96	116	
4	3110	213.8	260.4	–		69	84	–	
5	3220	205.4	304.8	–		64	95	–	
6	3640	289.4	326.0	374.8		79	90	103	
7	3310	342.5	405.6	475.4		103	123	144	
Total Reach	20950	1623.2	1937.9	–		77	93	–	

1 estimated from nearly-complete coverage
2 estimated from regression

Table 6.3: The variation of secondary channel water surface area with discharge for Reaches 2 and 4.

	Backchannel Surface Area (1000 m^2)			
	June 28 1980 (12m^3/s)	August 3 1980 (35 m^3/s)	August 29 1980 (60 m^3/s)	August 19 1980 (163m^3/s)
Reach 2				
Flowing	116.4	230.1	270.0	431.6
non-flowing	50.7	13.7	12.4	49.0
Reach 4 Subreaches 1-3				
Flowing	23.6	149.3	224.4	m[1]
non-flowing	49.8	7.1	0	m
Reach 4: all subreaches				
Flowing	88.2	225	-	m
non-flowing	54.1	16.2	-	m

TABLE 7.2: Net changes in bar surface area over time in Reaches 2, 4 and 6 of the Nechako River

REACH 2		Net Change in Bar Surface Area (1000 m^2) 1953-1974	1974-1980	1980-1986	1953-1986
Subreach	1	0	0	0	0
	2	0	0	0	0
	3	-23	0	0	-23
	4	-40	0	0	-40
	5	0[1]	0	0	0
	6	0	0[2]	0	0
	7	+26	-26	+24	+24
	8	+29	-29	+20	+20
	9	+34	-34	+19	+19
Total		+26	-89	+63	0
Rate (1000 m^2/yr)		(1)	(-15)	(10)	(0)

1 increase of Swanston Creek an: erosion of opposite bar
2 deposition at Targe Creek; erosion of opposite bar. Net change is zero

REACH 4		Net Change in Bar Surface Area (1000 m^2) 1953-1973	1973-1980	1980-1986	1953-1986
Subreach	1	+21	0	0	+21
	2	0	0	0	0
	3	0	0	0	0
	4	0	0	0	0
	5	+55	0	0	+55
	6	+47	+54	-25	+76
	7	+96	+42	+18	+156
Total		+219	+96	-7	+308
Rate (1000 m^2/yr)		(11)	(14)	(-1)	(9)

REACH 7		Net Change in Bar Surface Area (1000 m^2) 1953-1973	1973-1980	1980-1986	1953-1986
Subreach	1	0	0	0	0
	2	+36	0	-21	0
Total		+33	0	-21	+12
Rate (1000 m^2/yr)		(2)	(0)	(4)	(1)

TABLE 7.4: The change in channel width over time for Reaches 2, 4 and 7.

	Average Channel Width (m)			
	1953	1974	1980	1986
REACH 2				
Subreach 1	170	161	156	108
2	172	166	159	101
3	161	157	154	121
4	142	139	130	90
5	140	137	135	97
6	122	158	112	92
7	172	158	148	110
8	191	179	159	119
9	138	137	131	91
Average	157	152	144	104
% Decline from 1953	0	3	8	34
REACH 4				
Subreach 1	217	196	189	114
2	143	138	115	85
3	261	223	184	117
4	190	179	148	98
5	155	149	143	110
6	137	127	115	101
7	211	209	150	138
Average	183	171	146	109
% Decline from 1953	0	7	20	40
REACH 7				
Subreach 1	222	203	190	174
2	305	248	217	205
Average	263	225	202	188
% Decline from 1953	0	14	23	29

Table 7.6: Total length of backchannels of different types in 1953, 1973/74, 1980 and 1986.

	Length of Backchannel (km)			
	1953	1973/74	1980	1986
Reach 2				
Type 1	10.0	6.8	4.4	2.1
Type 2	5.4	5.0	4.0	3.0
Type 3	none are abandoned			
Reach 4				
Type 1	13.0	8.4	7.2	6.2
Type 2	3.3	2.1	1.2	0.3
Type 3	none are abandoned			

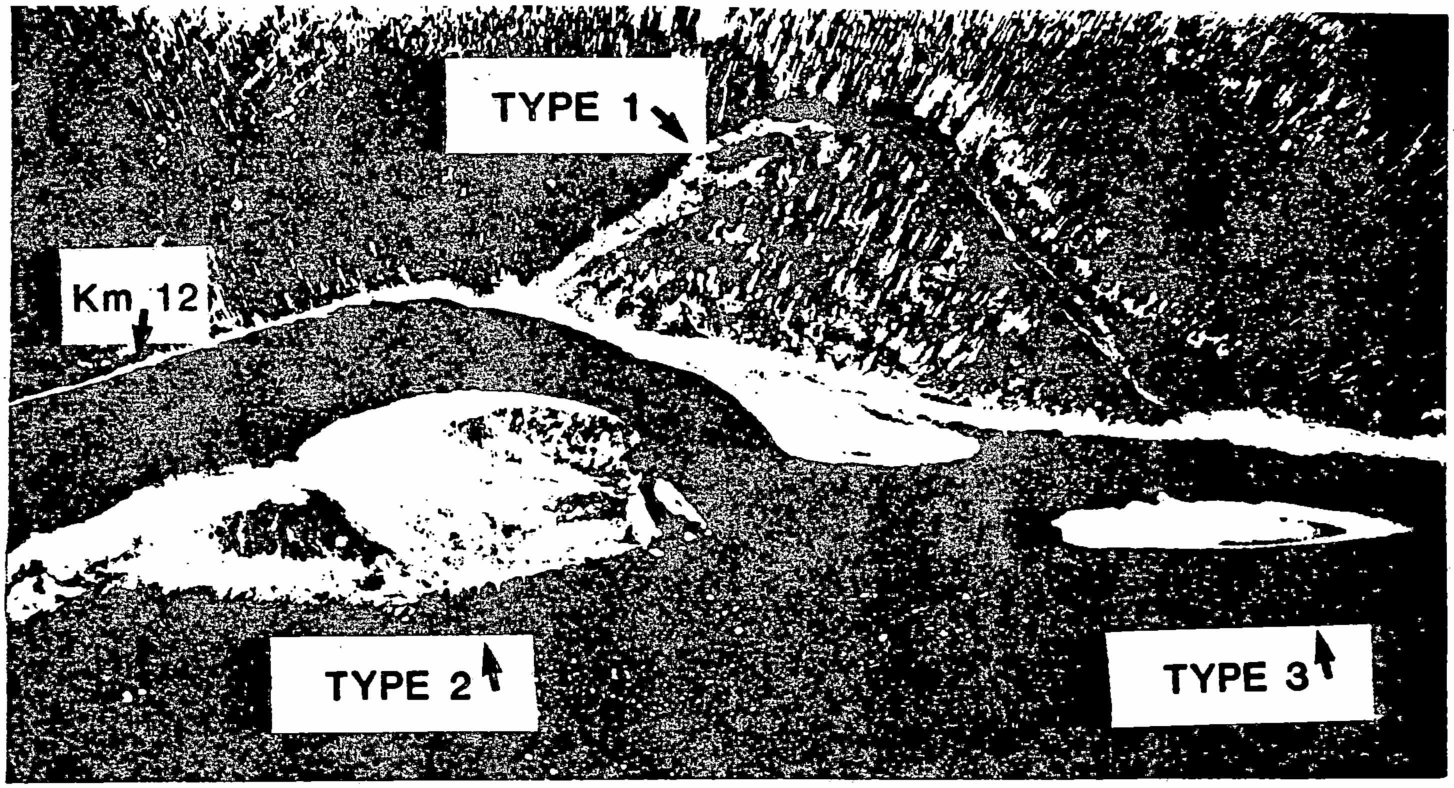
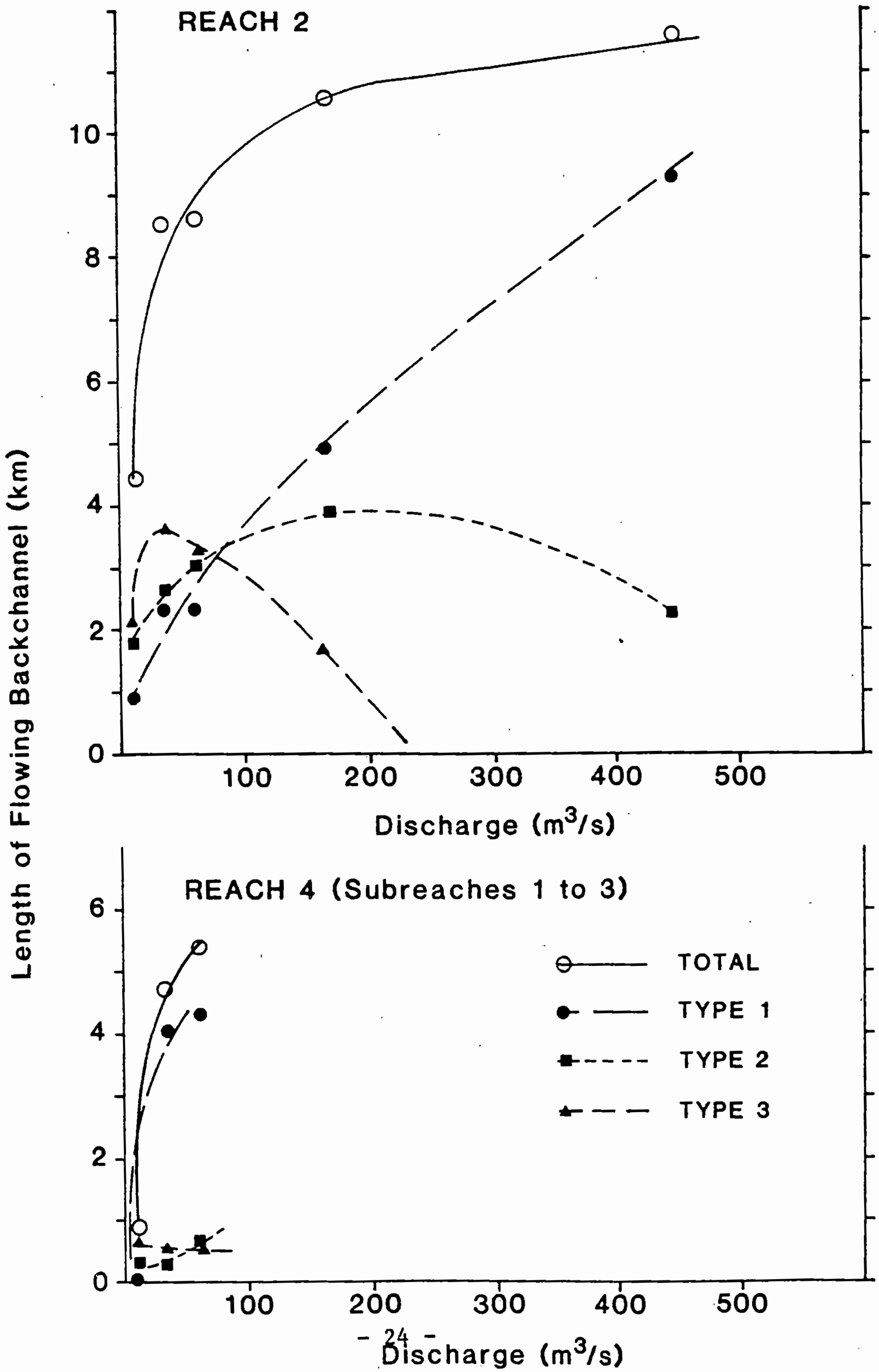


Figure 6.2: Secondary channel typing near km 12, Nechako River.

Figure 6.3: The Relationship of Backchannel Length to Discharge for Reach 2 and the Upper Part of Reach 4.



EFFECTS OF FLOW REGULATION ON CHANNEL MORPHOLOGY, SEDIMENT TRANSPORT AND DEPOSITION, AND FLUSHING FLOWS

Expert report for Nechako River court action

by Charles R. Neill

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1. QUALIFICATIONS

Principal and specialist engineer with Northwest Hydraulic Consultants, Edmonton and Vancouver, since 1975. Previously research engineer with Alberta Research Council 1961-73 and associate professor at Memorial University of Newfoundland 1973-75. 25 years experience in engineering and environmental problems related to river behaviour, hydrology, hydraulics, erosion and sedimentation, in Canada and various other countries.

Degrees and distinctions: B.Sc., M.Sc.: Member Can.Soc. for Civil Engineering, Amer. Soc. of Civ.Engrs. Institution of Civ.Engrs. (U.K.), International Assoc. for Hydraulic Research, Can. Water Resources Assoc. Numerous publications in field of river mechanics and hydraulic engineering. Several awards for technical publications. 13 years on editorial board of Can.Soc. for Civ. Engineering.

C.V. and list of publications attached.

2. TOPICS COVERED

(a) changes in size and form of Nechako River channel resulting from past and projected future regulation of flows.

(b) changes in pattern of sediment transport and deposition resulting from regulation.

(c) flushing flows.

My opinions on these topics are based on (i) my familiarity with relevant technical literature; (ii) my personal experience of river behaviour in a variety of environments; (iii) discussions with Mr. K.L. Rood of Reid Crowther and Partners prior to and after the latter's field investigations; (iv) review of Mr. Rood's draft report of January 1987 to DFO and preparation of contributions and amendments thereto; and (v) participation in meetings with DFO personnel in connection with the Reid Crowther report.

3. Summary of Opinion Evidence

(1) Past regulation of the Nechako River has resulted in significant reduction in the average channel width and in the elimination of significant areas of backchannels. In my opinion, the proposed Alcan flow regime is likely to lead to further reduction in average width and further elimination of secondary and back-channel areas. The main factor in these changes is encroachment of vegetation aided by deposition of fine sediment.

(2) In my opinion, the main effect of past regulation on the sediment regime has been to reduce the capacity of the Nechako River to transport sediment supplied to it by tributary inflows and bank erosion with the result that the area of bed covered by fine sediment has increased. Under the proposed Alcan flow regime, I would expect a further reduction in transport capacity and an extension of areas covered by fine sediment.

(3) In my opinion, flows in the range 500 to 700 m^3/s (17,657 to 24,720 ft^3/s) would be required to flush out fine sediments that have accumulated within the gravel in gravel-bed reaches of the river. Flows in the range of 150 to 200 m^3/s (5,297 to 7,063 ft^3/s) should be sufficient to disturb surface layers of fine sediment, but not to prevent a gradual extension of areas normally covered with fine sediment.

4. <u>OPINIONS</u>

(a) <u>Changes in size and form of channel</u>

It is generally recognized that the width and cross-section of a river channel are determined by the magnitude of flows, particularly flood flows, that the river channel has to carry (Ackers 1971, Blench

1957, Bray 1973, Charlton et al. 1978, Hey 1982, Kellerhals 1967, Neill 1964, Nixon 1959). If flows are increased, as in the case of the Cheslatta River, the channel enlarges by erosion. If flows are reduced, as in the case of the Nechako River, the channel tends to shrink, usually by a combination of sediment deposition and vegetational encroachment (Kellerhals 1982, Kellerhals et al. 1979). These responses are usually particularly noticeable with respect to channel widths, changes in which can be detected fairly easily by comparison of aerial photographs of different dates.

Table 7.4 of the January 1987 Reid Crowther report details average channel widths for 3 reaches of the Nechako, as determined by examination of aerial photographs for 1953, 1974, 1980 and 1986. It is my understanding that the tabulated widths represent net widths between the margins of established vegetation.

It appears that by 1980, the overall average width of the Nechako River had been reduced by about 15% of the 1953 value, and that by 1986 the reduction was about 30%. It is my opinion that these width reductions are quite compatible with general relationships between channel width and flood flows. I estimate on the basis of reported annual maximum flows, that between 1953 and 1980 the "dominant" discharge of the Nechako River was reduced by about 30%, and between 1953 and 1986 by about 50%. Assuming the normal square-root relationship between width and discharge, these flow reductions could be expected to result in ultimate width reductions of about 16% and 29%. It therefore appears that despite the relatively short period since 1980, the river width as defined by the margins of established vegetation has, in fact, more or less adjusted to the post-1980 regime, at least in those reaches covered by Mr. Rood's detailed studies. I should, however, point out that in view of the large fluctuations in annual maximum discharge from year to year, it is somewhat unrealistic to draw a clear distinction between the periods 1953-79 and 1980-86.

The future flow regime proposed by DFO involving an annual maximum of 226 m^3/s (8,000 ft^3/s), which would however run steadily from approximately 20 July to 15 August each year, in my opinion implies a somewhat smaller dominant discharge than the recent regime and would probably result in some further shrinkage of the channel.

The future flow regime proposed by Alcan provides for flows specified numerically only to a maximum of 30 m^3/s (1,060 ft^3/s), but with a commitment to such additional flows as may be required for temperature control. It is my understanding that this would involve a variable annual maximum of uncertain duration, but not exceeding 283 m^3/s (10,000 ft^3/s). I am uncertain as to what results this would have in terms of channel size. If a maximum of 283 m^3/s

occurred every year for a few days, perhaps widths would not further reduce. It seems to me more likely, however, that the actual effect would be to reduce the dominant discharge further and therefore lead to further reductions in width. However, without a more exact specification of the flow regime, I am unable to predict the ramifications of the Alcan flow regime with respect to channel size. I am also unsure whether the timing of the maximum flows (e.g. early versus late in the summer season) would affect the ultimate size of the channel. It does seem to me possible, however, that a reducing trend of width would be retarded if maximum flows occurred earlier in the season when vegetation is becoming established.

The changes in average channel width tabulated in the Reid Crowther report represent both reduction in the width of single-channel cross-sections and elimination of back channels in double-channel cross-sections. With reduction of flood flows, multiple-channel rivers tend to eliminate secondary channels by sediment deposition and vegetational encroachment.

(b) Changes in sediment transport and deposition

The most noticeable sediment effect of the Alcan Nechako diversion has been to increase erosional activity and sediment transport along the Cheslatta River above Cheslatta Lake. On the basis of both theory and observations, it can be said that very little of this sediment reaches the Nechako River due to the high efficiency of the Cheslatta-Murray Lake system as a sediment trap.

It is my opinion that the regulation of Nechako River flows probably has had little effect on sediment input under ordinary operating conditions. Input is now derived mainly from two sources, tributary creeks and local bank erosion. Under natural and regulated conditions these inputs are relatively small and consists mainly of sand and silt. In my opinion the main effect of regulation has been to reduce the ability of the river to transport these inputs through the system because flood or 'flushing' flows have been reduced. There is therefore a tendency for finer sediments, that previously would have been carried through the system, to accumulate in reaches and zones of lower velocity. As described in the Reid Crowther report (1987), areas of the bed that can be generally characterized as sandy appear to have been extended at the expense of areas that could be described as having a more gravelly composition. In my opinion, in marginal and back-channel areas where velocities are low, fine sand and silt have deposited to some extent, encouraging encroachment of vegetation.

One special effect of the Nechako River regulation was avulsion of the Cheslatta River above Cheslatta Falls in 1961, resulting from an abnormally large release to the Cheslatta River from Skins Lake spillway. This special event is believed to have delivered a large input of sand and gravel to the Upper Nechako river. I do not believe that it has been an important factor in reduction of channel width and back-channel areas, but it has probably been a factor in the extension of sandy areas of bed.

(c) Flushing flows

I am not familiar with the term "flushing flow" as an established concept in river mechanics and sedimentation engineering. I understand that the term is used by fishery biologists to mean a flow sufficient to remove biologically undesirable finer sediments from the bed or substrate of a river. In my opinion it is very difficult to determine such a flushing flow without extensive field investigations. Also, the duration and magnitude of such a flow might vary considerably from one reach to another along a river. Some reasons for this opinion are given below.

The flow that is required to set in motion a certain size or size range of sediment particles on the bed of a stream can be approximately calculated if sufficient information is available on the gradient and cross-sections of the river at the point of interest; or, if the gradient is unknown, on the relationship between velocity and depth over a sufficient range of flows. The flow so calculated is generally referred to in hydraulic engineering as an 'initiation-of-motion' flow (Raudkivi 1976, Vanoni 1975). For the Nechako River, information sufficient for reliable calculations is not generally available. However, if this calculation could be made reliably at a series of points of interest, it might be possible to identify a 'flushing flow' sufficient to stir up the surface (armour) layer from time to time and thereby flush out finer sediment that had deposited in the interstices of the gravel in the river bottom.

Very approximate calculations detailed in the Reid Crowther report on the basis of information from three special study sites indicate that flows in the range of 500 to 700 m^3/s (17,657 to 24,720 ft^3/s)would be required to initiate motion of the natural surficial bed material. Flows of this magnitude occurred most years under natural conditions, but in the last 12 years they have occurred only once, in 1976.

A different concept of "flushing flow" is that required to simply remove finer material that has deposited over the natural bed under regulated conditions. As discussed in some detail in the Reid Crowther report (op. cit.), it appears that flows in the range of 150 to 200 m^3/s (4,297 to 7,063 ft^3/s) are sufficient to initiate motion of finer bed sediments at most locations, but not necessarily to prevent the progressive extension of reaches that are covered with fine sediments under lower flow conditions. It is my opinion that progressive extension of areas of bed characterized by finer sediments is unlikely to be arrested unless flows in the order of 300 to 400 m^3/s (10,594 to 14,126 ft^3/s) are released every year or two.

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Northwest Hydraulic Consultatns Ltd. (Vancouver) for Department of Fisheries and Oceans.

Vanoni, V.A., editor, 1975. Sedimentation engineering. Amer. Soc. of Civil Engineers, Manual 54.

Education

B.Sc. in Civil Engineering, Glasgow, Scotland.

M.Sc. in Civil Engineering, Alberta, Canada (hydraulics)

General Experience

Mr. Neill has had a varied career in construction, consulting, research and teaching. Prior to 1960, he worked in heavy construction and municipal design. From 1961 to 1973 he was employed by the Research Council of Alberta, conducting research studies in culvert and bridge hydraulics, river hydraulics and morphology, hydrology, sedimentation and ice mechanics. From 1973 to 1975 he was associate professor with Memorial University of Newfoundland, responsible for courses in hydraulics, hydrology and ice engineering. Since 1975 he has directed and conducted a wide variety of consulting projects in the fields of river engineering, hydrology and hydraulics, in Canada, the United States and overseas.

Mr. Neill has served on numerous technical and professional committees and review boards, has written and edited a considerable number of technical publications, and has received awards for publications from several organizations.

Awards

Telford Premium, Institution of Civil Engineers, 1967.

J.D. Stevens Award, American Society of Civil Engineers, 1973.

Merit Award, Canadian National Committee for International Hydrologic Decade, 1973.

Frank Spragins Award, Association of Professional Engineers, Geologists and Geophysicists of Alberta, 1980.

Camille Dagenais Award, Canadian Society for Civil Engineering, 1981.

Advisory Appointments

Paddle River Dam Review Board - for Alberta Environment, Edmonton, 1979-83.

Tanana River Advisory Committee - for U.S. Corps of Engineers, Alaska, 1980-81.

Water System Advisory Committee, Alberta Oil Sands Environmental Research Program, 1978-79.

Liard-Mackenzie River Ice Studies, B.C. Hydro, 1980-81.

Editorial Board, Design Flood Guide for Canada, NRC Assoc. Committee for Hydrology, 1983-__.

Professional Memberships

Canadian Society for Civil Engineering

American Society of Civil Engineers

Institution of Civil Engineers (U.K.)

Canadian Water Resources Association

International Association for Hydraulic Research

Association of Professional Engineers, Geologists and Geophysicists of Alberta

Languages

French: read easily, fair verbal communication

Spanish: read easily, fair verbal communication

Selected Papers and Publications

Hydraulic Roughness of Corrugated Pipes. ASCE Hydraulic Journal, May 1962.

Riverbed Scour. A review for bridge engineers. Roads and Transportation Association of Canada, Technical Publication 23, 1964 (reprinted 1970).

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Bank Erosion vs. Bedload Transport in a Gravel River. Rivers '83, ASCE/IAHR, New Orleans, 1983.

(With D.D. Andres). Freeze-up Flood Stages Associated with Fluctuating Reservoir Releases. ASCE/CSCE Cold Regions Engin. Conference, Edmonton, 1984.

Practical slope-discharge-sediment relationships for gravel channels. C.S.C.E. conference, Saskatoon, 1985.

Sediment balance considerations linking long term transport and channel processes. International Workshop on Sediment Transport in Gravel-bed Rivers, Fort Collins, Colo., 1985.

Selected Consulting Assignments

Alberta Environment, 1977-80. Studies of effects of watershed management on runoff, and on sources of erosion and sedimentation, upper Oldman River basin.

U.S. Corps of Engineers, 1980-84. Participation in research and monitoring studies re effects of flood control works, Tanana River, Alaska.

U.S. Corps of Engineers, Washington, 1984-85. Studies and recommendations on criteria for stability of flood control channels.

Underwood McLellan and Associates, 1983-84. Assessment of sediment transport and budget for St. Mary Irrigation District canal system, southern Alberta.

Canadian International Development Agency, 1985-86. Preliminary study and assessment of flood control works for rivers in northeast Bangladesh, including sedimentation and morphologic effects.

Empresa Nacional de Electricidad, Santiago, Chile, 1983-84. Assessment of likely changes to morphology of braided gravel river following regulation by hydro project.

Euroestudios S.A., Madrid, Spain. Review of proposed flood control embankment project on shifting gravel river.

B.C. Hydro, 1980-82. Review of winter regime studies for Liard-Mackenzie River system under proposed Liard hydro project.

Constantino and Otto, lawyers, Bethel, Alaska, 1985. Advice in case against local authorities re river erosion and loss of property.

Woods, Fuller, Schultz and Smith, lawyers, Sioux Falls, S. Dakota, 1985-86. Advice in case against Corps of Engineers re river sedimentation upstream of a reservoir.

Milner Steer, lawyers, Edmonton, 1977. Advice and testimony in case re river sedimentation resulting from construction accident.

TABLE 7.4: The change in channel width over time for Reaches 2, 4 and ~~6~~ 7.

	Average Channel Width (m)			
	1953	1974	1980	1986
REACH 2				
Subreach 1	170	161	156	108
2	172	166	159	101
3	161	157	154	121
4	142	139	130	90
5	140	137	135	97
6	122	158	112	92
7	172	158	148	110
8	191	179	159	~~157~~ 117
9	138	137	131	91
Average	157	152	144	~~110~~ 104
% Decline from 1953	0	3	8	~~30~~ 34
REACH 4				
Subreach 1	217	196	189	114
2	143	138	115	85
3	261	223	184	117
4	190	179	148	98
5	155	149	143	110
6	137	127	115	101
7	211	209	150	138
Average	183	171	146	109
% Decline from 1953	0	7	20	40
REACH 7				
Subreach 1	222	203	190	174
2	305	248	217	205
Average	263	225	202	188
% Decline from 1953	~~14~~	[illegible]	23	29