LGL LIMITED
environmental research associates
Tel: (250) 758-1264
Fax: (250) 758-1298

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS
201 - 1290 Broad Street
Victoria, B.C.
V8W 2A5
250-595-4223 P
250-383-2978 F
www.kwl.bc.ca

April 19,2005

Ms. Pat Stephenson
BC Conservation Foundation
3 - 1200 Princess Royal Avenue
Nanaimo, BC
V9S 3Z7

Dear Ms. Stephenson:

Re: Preliminary Sediment Management Review – Stoltz Slide and Block 51

The following is our report on the project titled 'Cowichan Sediment Source Inventory and Restoration Prescriptions' under BCCF Contract No. N111531-4. This report was prepared by LGL Limited environmental consultants and Kerr Wood Leidal Associates Ltd., consulting engineers. The purpose of the project was to evaluate critical erosion sites on the Cowichan River, to review and comment on previous conceptual restoration designs that were developed for Stoltz Slide, to recommend an action plan for quantifying the relative contributions of sediment from each of the significant sources, and to recommend a potential stabilization strategy for the Stoltz Slide including a preliminary implementation budget. The work program for this project included office reviews and assessments of previous reports and aerial photographs, field reviews of three main sediment source areas (two at Block 51 and Stoltz Slide), and development of a rehabilitation design concept for Stoltz Slide.

Project Summary

The Block 51 and Stoltz Slide sites are located about 22 and 15 km, respectively west of Duncan, BC (Figure 1). Land on both sides of the river at these two sites is under Crown ownership, either Provincial Crown or Provincial Park. Also, the river corridor between these two sites is mostly under Provincial Park ownership.

Following the office and field assessments that were conducted during the summer of 2004, a memo outlining preliminary findings for the Stoltz Slide was prepared by Kerr Wood Leidal and sent to Craig Wightman of the BC Ministry of Water, Land and Air Protection (MWLAP) on October 4, 2004 (Appendix 1). The memo provided a brief review of the status of the investigation on the possible stabilization of Stoltz Slide. It identified the need to quantify the relative contribution of sediment from Stoltz Slide in order to know how effective slide stabilization would be at reducing overall suspended sediment loads in the river. A preliminary strategy for stabilization for Stoltz Slide was also presented that included: 1) in-river structures, 2) gully stabilization treatments, and 3) bioengineering measures. A preliminary budget (Class D level) for the implementation of the sediment monitoring and three stabilization components ranged from $895,000 to $1.35M.

An overview memorandum on the findings of the aerial photograph analysis, office review and field investigations for the Stoltz and Block 51 sites was prepared by Kerr Wood Leidal on March 16, 2005 (Appendix 2). The memo provided detailed comments / recommendations on the remedial options submitted by nhc (1996) and Newbury (1996). In summary, it was concluded that the options identified by nhc and Newbury together contain elements that would be partially successful in stabilizing the slide. However, none of the recommendations are a stand-alone solution. One of the key issues is to reduce the amount of flow against the toe of the Stoltz Slide. Without a diversion of some of the flow and the establishment of a terrace at the base of the cutbank, it would be extremely difficult to stabilize the base of the cutbank and thus minimize fine sediment inputs.

A proposed strategy for stabilization of Stoltz Slide, which included a number of elements previously proposed by nhc and Newbury, was presented. The strategy as developed would be implemented in phases, as follows:

Phase 1: Fine sediment source tracking to determine the relative contribution from Stoltz and other significant erosion sites to the overall suspended sediment load in the river.

Phase 2: River based measures that include excavating or enlarging a channel on the inside of the meander bend, constructing a partial weir in the mainstem, and constructing a terrace with bank protection at the toe of the eroding cutbank.

Phase 3: Gully stabilization options that include placing an inverted filter of sand and gravel over the face of the silt, constructing horizontal drains on the face of the slope, and flattening the overall slope by bulldozing sand and gravel down from the crest of the slope.

Phase 4: Bioengineering treatments, to be used in conjunction with other measures, include: gully check dams, live staking and willow wattles, willow brush layers, and anchored large woody debris.

The preliminary budget (Class D level) for the implementation of the fine sediment source tracking assessment and three stabilization phases for Stoltz Slide remained at $895,000 to $1.35M.

A brief investigation of erosion problems in the Block 51 area found that the site represents a less suitable stabilization project in comparison to Stoltz Slide. The relative contribution of fine sediments to the river from this site are believed to be significantly smaller than the Stoltz site for most river flows and the channel remains highly susceptible to lateral instability. Further work on the fine sediment source tracking project in 2005, under Cowichan Treaty and Pacific Salmon Commission funding, will determine definitively what the sediment contribution is from Block 51. If the sediment analysis indicates that stabilizing the cutbanks in Block 51 is feasible, then a phased approach that includes river based measures and bioengineering treatments is also recommended.

Based on our preliminary review of the Stoltz Slide and Block 51 areas, we have provided a strategy to move forward on this long-standing sediment management issue. Tables 1 and 2 describe the work program and schedule of tasks for the Cowichan River Sediment Management Project. The sediment source analysis described in Phase 1 has been funded by Cowichan Tribes and Pacific Salmon Commission for 2005. Further assessments and field work will establish the feasibility for stabilization measures at the Stoltz Slide and Block 51 areas, with initial rehabilitation designs likely proceeding in Summer 2005.

If you require additional information or clarification, please contact either Marc Gaboury at 250-758-1264 or Dave Murray at 250-595-4223.

Yours truly,

Marc Gaboury , MSc.
Senior Fisheries Biologist

Dave Murray, P.Eng.
Senior Water Resources Engineer

Table 1. Proposed work program for Cowichan River sediment management project.

Task		Description
Phase 1 Preliminary Investigations and Pre-design of Erosion Protection Works		
1.1	Project Initiation ***1.1 Meeting 1***	▪ Obtain and review available background information, including: o digital base map information; o topographic data and maps, available aerial photography; and survey control. ▪ Conduct project initiation meeting to: o review proposed work program and budget estimate; o refine work program (if required); o establish communication protocol for project; o discuss historic activities; o obtain stakeholder contact information; and o execute consulting contract document. (Attended by Project Manager and Fisheries Biologist)
1.2	Photogrammetry and Mapping	▪ Review mapping data and: o Compile/examine existing survey data including photogrammetric data and cross-section data to determine its suitability for analysis. o Determine which years of aerial photos are most appropriate for use. o Identify further photogrammetric work that is required and coordinate the work to be completed by others. o Determine additional survey requirements.
1.3	Field Investigation of Block 51 and Stoltz Reaches	▪ Using preliminary basemapping, photogrammetric digital elevation data and survey data, conduct field investigation to: o Identify and assess and quantify sediment sources, map and prepare an inventory of available bed and overbank sediments in Block 51 and Stoltz reaches. o Identify and investigate river alignments/stabilization schemes that would divert the river away from the Stoltz Slide. o Identify stabilization scheme for Block 51 reach. o Conduct an environmental assessment of possible river realignments and stabilization schemes, quantify impacts and prepare environmental letter report. o Identify locations for required detailed field survey and critical cross-sections in order to prepare detailed design of stabilization works.

	Task	Description
1.4	Field Survey and Sediment Analysis	▪ Conduct a topographic survey of priority erosion areas (Stoltz and Block 51). ▪ Using photogrammetric data and new survey data, complete a quantitative analysis of sediment in the Block 51 and Stoltz reaches ▪ Compare cross-section data and identify sediment trends. ▪ Prepare a reach sediment budget and assess effectiveness of stabilization design options based on sediment analysis results.
1.5	Final Design Concept Review and Meeting *Meeting 2*	▪ Using data from field survey, field investigation and sediment analysis, assess suitability of stabilization/realignment options. ▪ Review options, environmental constraints and costs with client and stakeholders. ▪ Select final design concept.
1.6	Geotechnical Investigation	▪ Conduct geotechnical investigation of the Stoltz area including test pits, hand auger and visual inspection. ▪ Perform slope stability analyses and determine design criteria for selected stabilization scheme. ▪ Provide geotechnical input into design as required.
1.7	Pre-design *Meeting 3*	▪ Prepare base plans (assume 3 sheets) for selected design concept. ▪ Plot cross-section survey drawings (assume 2 sheets). ▪ Undertake limited hydraulic analysis to evaluate bank protection design works, impact on river velocity and flood level. ▪ Provide environmental input on site sensitivity, preferred design concept, and approach to construction. ▪ Determine design criteria. ▪ Prepare preliminary design brief outlining the basis for design. ▪ Research unit costs; prepare Class C construction cost estimate. ▪ Conduct pre-design review meeting: o discuss design and how concept fits into the long-term river management vision; o obtain feedback and direction; o confirm approach to design and construction of 2006 project with respect to budget and environmental constraints; and o confirm scope and schedule for 2006 project.

Phase 2 Detailed Design		
2.1	Design Drawings *Meeting 4*	▪ Produce draft detailed design drawings (assume total of 8 sheets) including: (title sheet, plan and profile(s), cross-sections, bank protection and gully stabilization and bioengineering details. ▪ Design review by KWL and LGL. ▪ Submit design drawings client. ▪ Conduct a detailed design review meeting. ▪ Obtain review comments and direction.
2.2	Stakeholder Consultation *Meeting 5*	▪ Consult with client regarding form, location and timing of consultation. ▪ Arrange meeting and notification. ▪ Attend meeting and provide drawings for discussion. ▪ Document issues identified.
2.3	Environmental Approvals	▪ Issue design drawings for environmental approvals. ▪ Finalize environmental input to design drawings. ▪ Incorporate bioengineering measures. ▪ Document environmental work tasks. ▪ Liaise with environmental agencies to pre-screen approval application. ▪ Submit approval documents and follow up with agencies.
2.4	Finalize Design	▪ Update design drawings to reflect feedback from meeting and environmental agencies. ▪ Submit complete drawings to for final review. ▪ Obtain feedback and finalize drawings. ▪ Issue drawings for construction.
2.5	Construction Documents and Tendering of Work *Meeting 6*	▪ Prepare contract documents and technical specifications. ▪ Prepare Class A construction cost estimate. ▪ Prepare and submit draft tender documents. ▪ Receive comments and finalize tender documents. ▪ Tender project on client’s behalf. ▪ Attend contractor information site meeting. ▪ Respond to tender inquires. ▪ Attend tender opening, evaluate tenders and make recommendation for award.

Phase 3 Construction of Works		
3.1	Construction Services	▪ Liaise with client during construction. ▪ Attend pre-construction meeting. ▪ Provide site inspection services. ▪ Provided environmental monitoring during construction. ▪ Provide survey layout of stabilization works. ▪ Provide bi-weekly project status meetings and monthly status reports. ▪ Monthly progress draw reviews and recommendation for payment. ▪ Respond to technical inquires during construction. ▪ Deficiency list preparation and follow-up inspections (assume 2 per project). ▪ Prepare substantial completion documentation. Assumptions: It is assumed that the site inspector will be required on-site 4 hours per working day for basic inspection services for 6 weeks. It is assumed that the environmental monitor will be required on-site full time during construction of creek in-stream works.
3.2	Reporting	▪ Prepare and submit record drawings (information for record drawings to be provided by the contractor). ▪ Receive comments and finalize record drawings. ▪ Prepare environmental monitoring report.

Table 2. Schedule of implementation for Cowichan River sediment management project.

	FUNDING PERIOD	2005/2006												2006/2007												2007/2008																				
	TASK	2005 MONTH									2006 MONTH												2007 MONTH												2008 MONTH											
		A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	Phase 1 Prelim. Investigation and Pre-design																																													
1.1	Project Initiation	●																																												
1.2	Photogrammetry and Mapping	■	■	■																																										
1.3	Field Investigation of Block 51 and Stoltz Reaches etc.				■	■	■																																							
1.4	Field Survey and Sediment Analysis					■	■																																							
1.5	Preliminary Sediment Management Strategy						■	●																																						
1.6	Priority Project - Final Design Concept								●																																					
1.7	Pre-design Stoltz									●																																				
1.8	Geotechnical Investigation- Stoltz										■																																			
	Phase 2 Detailed Design Stoltz																																													
2.1	Design Drawings										■	●																																		
2.2	Stakeholder Consultation											●																																		
2.3	Environmental Approvals											■																																		
2.4	Finalize Design											■	■																																	
2.5	Construction Documents and Tendering of Work												■																																	
	Phase 3 Construction of Works- Over 2 construction years																																													
3.1	Construction Services														1	1	1											2	2	2																
3.2	Reporting																	1													2															
3.3	Post Construction Monitoring																														1	1										2	2			
	Phase 4 River Sediment Management Plan																																													
4.1	Project Initiation																	●																												
4.2	Comprehensive Sediment Management Plan																		●	■	●	■	■	●																						
4.3	Consultation																								●	■																				
4.4	Final Report and Implementation																										●	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Phase 5 Block 51 Design - If Priority																																													
5.1	Block 51 Stabilization Design																											■	■	■																
5.2	Block 51 Construction Management																																								■	■	■			

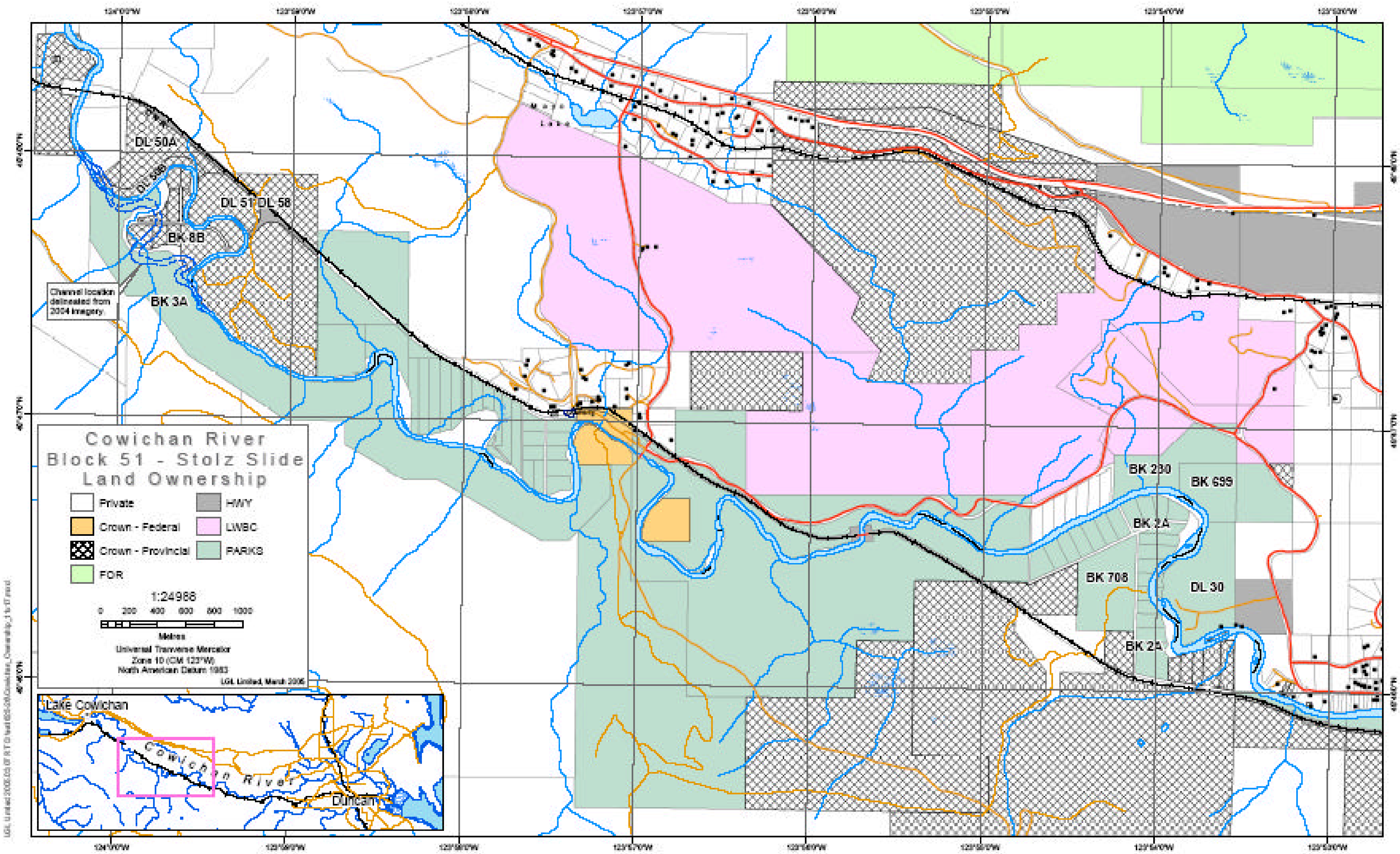

Figure 1. Map showing land ownership in the Block 51 to Stoltz Slide river corridor.

Appendix 1. Kerr Wood Leidal overview memorandum (October 4, 2004) concerning 'Cowichan River: Stoltz Slide Preliminary Findings'.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS
201 - 1290 Broad Street
Victoria, B.C.
V8W 2A5
250-595-4223 P
250-383-2978 F
www.kwl.bc.ca

Overview Memorandum

DATE: October 4, 2004

TO: Craig Wightman, Senior Fisheries Biologist
Ministry of Water, Land and Air Protection

CC: Marc Gaboury, Bob Bocking, LGL Environmental Research Associates

FROM: Dave Murray, P.Eng, Project Manager

RE: **COWICHAN RIVER**
Stoltz Slide Stabilization
Preliminary Findings
Our File 2211-001

This memorandum provides a brief review of the status our investigation of the possible stabilization of the Sloltz Slide, outlines our proposed stabilization strategy and indicates some preliminary budget figures for planning purposes.

We have reviewed past reports by other consultants, reviewed historic air photographs which shows ongoing erosion at the base of the Stoltz Slide with progressive erosion along a meander bend. We have reviewed the cutbank and preliminarily assessed it from a geomorphologic and geotechnical perspective. The air photographs indicate that the Stoltz Slide is not a slope instability at all but is a remnant of a glacial outwash deposit that is up to 40 m high. Upslope seepage runoff midway down the cutbank combined with erosion at the toe of the deposit has resulted in significant inputs of fine and coarse sediment to the Cowichan River. The cutbank appears to have gone through a cycle of activity and stabilization in the past half century.

THE NEED TO STABILIZE?

A 1997 report by Newbury references a report by Bomford of MWLAP. Bomford recommended that the cutbank erosion is natural and that it should be left alone because natural channel changes (such as meander cutoffs) and bank erosion are critical processes that maintain sediment transport and natural turnover of gravels. These processes are critical in the maintenance and creation of fish habitat. In the case of the Stoltz Cutbank, it appears that the cutbank is contributing more fine sediment than beneficial coarse sediment. However, there are channel changes occurring upstream that have recently contributed large volumes of gravel-sized sediment to downstream reaches. An example is the Block 51 area where a large meander bend was cut-off by the river.

The tributaries between Cowichan Lake and the river mouth do not appear to be significant contributors of sediment to the Cowichan River. Hence, the river relies on internal bank erosion to maintain ongoing sediment transport. The end result of stabilization of the system could be the loss of channel complexity and a significant reduction in spawning and rearing habitat.

FINE SEDIMENT SOURCE TRACKING

Prior to stabilization of the Stoltz area it is critical that we determine how effective stabilization would be. If the Stoltz area was stabilized (at substantial cost) and then it is found that fine sediment is still an issue for downstream users then the time and expense would be wasted. The percentage of suspended sediment (sand-sized and smaller) in the Cowichan River that is supplied by the Stoltz cutbank needs to be determined. To determine this percentage would require measurement of suspended sediment concentrations above the Stoltz area and at a couple of locations downstream. This work would need to be completed over a range of discharges to come up with a suitable rating curve. The key would be finding appropriate locations to make the measurements. Another approach is to look at the Bomford (1996) report to determine the amount of area eroded at the Stoltz cutbank between 1975 and 1993. That area could be converted to a volume by multiplying by the average height of the cutbank. The percent of fine sediment can then be estimated by a visual estimate of the cutbank deposits.

GEOTECHNICAL REVIEW

Our brief geotechnical review has determined that the "slide" may not be a slide but rather a large eroding cutbank. Based on field observations, there is probably no large-size instability extending back into the forest from the crest of the slope but rather the process is a gradual retreat of an erosional scar as a result of slope face erosion and toe undercutting by the river. The 2 main processes occurring are:

- Undercutting of the toe of the slope at river level carrying awaycolluvial material; and
- Seepage erosion (shallow to deep seated) of the silt by groundwater emerging from the slope halfway up, forming a talus cone of soft silt from 3 major gullies extending all the way to river level.

The silt material on the slope face is gradually piping through to the base of the slope. It should be clearly recognized that surficial treatments such as bioengineering may only cause minor reductions in the rate of surface erosion as is evidenced by the bioengineering measures that have been buried by sediments along the lower part of the slope. Since the seepage erosion is mainly groundwater related and no evidence of surface erosion from above was observed, we see little advantage of diverting flows away at the top of the cutbank.

PRELIMINARY STRATEGY FOR STABILIZATION

Several options for bank stabilization have been presented by NHC (1996) and Newbury (1997). These options focused on reducing the amount of flow against the toe of the Stoltz Slide by various means. Without a diversion of some of the flow and the establishment of a terrace at the base of the cutbank, it would be extremely difficult to stabilize the base of the cutbank and thus minimize fine sediment inputs. Based on our assessment of the existing situation and a review of previous options identified, the following approach is recommended:

PHASE 1 - RIVER BASED MEASURES

1. **Excavated Channel:** Excavate a new channel on the inside of the meander bend or enlarge existing backchannels. While the backchannels have been identified as high quality habitat, less flows must be reduced against the cutbank and increasing the inlet end capacity of the sidechannels could be completed with only minor effects.

2. **Partial Weir:** At the entrance to the excavated channel, a partial weir should be built across the channel to direct a certain portion of the flow into the excavated channel Without the diversion, the channel is likely to aggrade quickly on its own given that the near bed velocity vectors are not directed into the backchannels.

3. **Constructed Terrace with Bank Protection:** With a portion of the flow directed into the backchannel, the toe of the main cutbank area (about a 250 m length) is more easily stabilized. We recommend widening the channel in this location and that the excavated gravels and cobbles be placed at the toe of the cutbank to create a 2.5 m high terrace. The terrace could then be planted with willows to promote stability. The terrace could be 15 to 25 m wide and could be protected with riprap and large woody debris.

All these measures would required heavy equipment and instream work.

PHASE 2 - GULLY STABILIZATION MEASURES: Stabilize the silt gully areas of the cutbank by a combination of:

1. **Inverted Filter**: An inverted filter over the face of the silt where it is exposed in the gully. By placing a layer of well-graded sand and gravel over the face of the silt to weight it down, while still allowing seepage to emerge without carrying away silt particles. The filter has to be coarse enough the permit the free outflow of seepage water, yet fine enough to prevent the escape of soil particles through their voids.

2. **Horizontal Drains:** Another possible remedy would be to install horizontal drains in the slope to pull the phreatic surface back from the face thus preventing erosion. This is worth consideration as a possible solution but would be costly due to the intensive labour involved and access issues.

3. **Slope Flattening:** Another measure would be to flatten the overall slope by bulldozing dozing down sand and gravel from the crest of the slope, protecting the silt with filter cloth.

All three of these measures would require heavy equipment access to the top of bank.

PHASE 3 – BIOENGINEERING MEASURES

Previous attempts to stabilize the cutbank with bioengineering have yielded mixed results. There is some question about the potential effectiveness of such work. Since the silt piping is the main erosion mechanism and is fairly deep seated in certain zones, then bioengineering should only be used in conjunction with other measures that reduce the piping of silt through the slope.

1. **Gully Check Dams:** Installation of gully check dams (logs) could be effective in combination with other measures such as the inverted filter technique but test pits would be required to determine if the check dams or willow wattle fences could be founded sufficiently to prevent failure by piping silts.

2. **Live Staking and Willow Wattles:** Live staking could be done on top of the proposed terraced berm. Willow wattles have been used as an attempt to stabilize the cutback in the past. Wattles could be used in conjunction with geotechnical gully stabilization methods in transition areas between the gullys and the terraced toe berm.

3. **Willow Brush Layers:** Willow brush layers could be used along the outer slope of the terraced berm to provide stability and overhanging vegetation. If successful they would provide excellent cover, however, if high flows damage them prior to establishment then the self revealing riprap buried in the terrace would act as a second line of defence.

4. **Anchored Large Woody Debris:** LWD could be anchored in the terraced berm to provide increased habitat and roughness. If this material is undermined or shifts during high flows then the self-revealing riprap would provide secondary protection.

PRELIMINARY CAPITAL PLANNING

The stabilization of the Stoltz cutbank is a major undertaking. Should sediment analysis deem it feasible to stabilize this slope then a phased approach is recommended. Table 1 below presents preliminary cost ranges for each project phase to assist you in capital planning. We must stress that these costs are Class D level as detailed surveys and geotechnical investigations are not within our scope at this time.

Table 1 Stoltz Cutbank Preliminary Capital Costs

Phase /Years	Item	Cost Range ($)		
2004	Sediment Monitoring	$25,000	to	$40,000
1 2005-2006	Channel excavation, terraced toe berm and partial weir	$380,000	to	$570,000
2 2006-2007	Gulley Stabilization	$370,000	to	$560,000
3 2007-2008	Bioengineering treatments	$120,000	to	$180,000
Totals		**$895,000**	**to**	**$1,350,000**

Dave Murray, P.Eng., A.Sc.T.,CPESC
Project Manager

Appendix 2. Kerr Wood Leidal overview memorandum (March 16, 2005) concerning 'Cowichan River: Preliminary Sediment Management Review – Stoltz Slide and Block 51'.

DATE: March 16, 2005

TO: Craig Wightman, Senior Fisheries Biologist
Ministry of Water, Land and Air Protection

CC: Marc Gaboury, Bob Bocking
LGL Environmental Research Associates

FROM: Dave Murray, P.Eng, Project Manager
Nigel Skermer, M.Sc., P.Eng., Senior Geotechnical Engineer

RE: **COWICHAN RIVER**
Preliminary Sediment Management Review – Stoltz Slide and Block 51
Our File 2211-001

This memorandum describes the results of field investigations and a preliminary sediment management review undertaken of the Stoltz Slide and Block 51 reaches of the Cowichan River by Kerr Wood Leidal Associates (KWL) in 2004/2005. For the Stoltz Slide site we have reviewed past reports, completed a preliminary analysis of aerial photographs, and developed a potential stabilization strategy for the Stoltz Slide including a preliminary budget for planning purposes. Also included is results of our preliminary assessment of sediment management and erosion issues in the Block 51 reach of the river.

Fluvial geomorphology work has been undertaken by Hamish Weatherly, M.Sc., P.Geo. and Erica Ellis, M. Sc. Geotechnical analysis and review has been undertaken by Nigel Skermer, M.Sc., P.Eng. The river engineering and stabilization strategy was undertaken by Dave Murray, P.Eng.

Stoltz Slide

The Stoltz Slide is located on the left bank of the Cowichan River about 15 km west of Duncan, BC. The area of concern is the outside edge of a meander bend where a 30 to 40 m high deposit of glacial sediment is actively eroding. Seepage and overland runoff draining down the cutbank combined with erosion at the toe of the deposit has resulted in significant inputs of fine and coarse sediment to the Cowichan River. The cutbank appears to have gone through a cycle of activity and stabilization in the past half century. Upstream of the tight meander bend and eroding cutbank, the Cowichan River passes through Marie Canyon where it is incised into bedrock.

Figure 1
1998 air photograph of Stoltz Slide area. Flow is from left to right. The arrows point to areas of active bank erosion.

1.2 Assessment

Three sources of information were used to assess the Stoltz Slide:

- historic air photographs of the site (1957, 1962, 1975, 1980, 1984, 1993 and 1998);
- past reports by other consultants;
- a site visit on August 13, 2004 by Dave Murray (river engineer) and Nigel Skermer (geotechnical engineer); and
- site visits on March 3 and 10, 2005 by Erica Ellis and Hamish Weatherly (fluvial geomorphologists).

Geotechnical Assessment

The air photograph review and site visit results indicate that the Stoltz Slide originates in a complex sequence of glacial fluvial and glacial lacustrine materials with visible thicknesses of up to 40 m. The bank stratigraphy consists of multiple layers of glaciolacustrine sediments (fine sand, silt and clay) interbedded with layers of fine sand as well as layers of coarser outwash material (sand, or sand and gravel). The slope has an average gradient of 70 to 80%. Erosion is occurring along a 600 m long section of the river. The average channel gradient through the site is approximately 0.35%.

Figure 2. Cutbank erosion at Stoltz Slide area. Flow is from left to right. Note the person on the gravel bar for scale. July 2004.

There is probably no large-size, deep-seated instability that extends back into the forest from the crest of the slope. Rather the process is a gradual retreat of an oversteepened erosional scar, with the slope instability a result of two main factors:

- undercutting of the toe of the slope at river level carrying away colluvial material; and
- seepage erosion of the silt by groundwater emerging from the slope halfway up, or by surface water draining from the crest of the slope.

The seepage process is a primary erosion mechanism unrelated to river erosion at the toe. However, ongoing river erosion at the base of the slope can prevent sections of the cutbank from reaching a condition of permanent stability.

Groundwater seepage was clearly visible toward the end of an extended hot and dry period, as well as during the March 2005 visits. Surface drainage onto the slope observed in March 2005 originated from small ponds and swamps at the crest of the slope, as well as from one small stream draining from further upslope. It should be recognized that surficial treatments such as bioengineering may only cause minor reductions in the rate of surface erosion as is evidenced by the bioengineering measures that have been buried by sediments along the lower part of the slope.

Slope failures appear to originate in the uppermost and thickest layer of glaciolacustrine material, which comprises the majority of the top 20 m of the slope. Failures and subsequent erosion of the soil debris have resulted in amphitheatre-shaped bowls along the crest of the slope. The observed bowls may originate from slumping, possibly rotational sliding, within the lacustrine sequence. These failures could be due to high pore pressures, possibly static liquefaction or even seismic induced liquefaction within loose, saturated sand lenses in the slope. Eroded material is delivered to the base of the slope where it is entrained by the river.

Air Photograph Review

The cutbank has gone through a cycle of activity and stabilization in the past half century. Air photographs from 1957 and 1962 indicate a stable bank. By 1975, the cutbank was actively eroding. Further stabilization followed as the cutbank is observed to have largely revegetated on 1980 and 1984 air photographs. More recent air photographs from 1993 and 1998 indicate that the cutbank started to actively erode once again. The cutbank erosion appears to be natural and unrelated to any road construction or logging in the area.

Jim Bomford of MWLAP mapped the meander bend using historic air photographs from 1946, 1958, 1975, and 1993. The mapped channel planform allows for a quantitative analysis of erosion trends.

1.3 Previous Assessments

Northwest Hydraulic Consultants (NHC, 1996) and Newbury (1997) have previously presented several options for bank stabilization.

NHC (1996)

Five remedial options were identified by NHC in a report prepared for the BC Conservation Foundation[1]. Our recommendations for the five options are provided under each bulleted item.

- Construct a toe berm with riprap near the base of the cliffs to allow some storage room for eroded sediment.
  - This option was not recommended due to the limited storage area and the likelihood of the eroding material quickly overtopping the berm.

- Construct a series of short spurs (22) out of rock (or gabion baskets filled with local cobbles) to move the thalweg of the channel away from the eroding bank.
  - This option may be successful in *reducing* erosion at the toe of the cutbank, but slope failures of the glacial sediments are likely to continue. Erosion at the toe of the cutbank is also likely to continue to some degree. Gabion baskets are not generally effective on large rivers and over the long-term.

- Construct a diversion dike to completely block the existing river and force the flow into a series of existing backchannels along the inside of the bend. This option also has a short spur upstream of the dike to deflect a portion of the flow into a pre-excavated diversion channel.
  - A diversion dike might be the most effective long-term solution for a portion of the cutbank. However, some erosion would likely continue to occur at the outlet of the backchannels. Also the diversion dike represents a significant in-stream structural measure that may not be acceptable from an environmental perspective.

- Construct a partial diversion dike that would be overtopped by flows having a 3-year return period. Some bank erosion would continue. The entrances to the backchannels would be widened, and logs would be removed in order to allow flows to enter the backchannel.
  - Bank erosion would continue due to undercutting during a large event and the ongoing slope failures. However, this is a recommended component of future stabilization efforts.

- Excavate a new channel on the inside bend where there is sufficient room between the two most north backchannels. This option would avoid disturbance of existing backchannels.
  - Without a diversion in the main channel, the excavated channel is likely to aggrade quickly on its own given that the near bed velocity vectors are not directed into the backchannels. Ongoing channel maintenance would be required.

Newbury (1997)

About one year later Newbury[2] presented a report to BC Fisheries that outlined six recommendations for stabilization of the Stoltz Slide. These recommendations included:

---

[1] Northwest Hydraulic Consultants Ltd. July 1996. Cowichan River Stoltz Slide. Report prepared for BC Conservation Foundation.
[2] Newbury Hydraulics. March 1, 1997. Letter report to Craig Wightman of BC Fisheries, Ministry of Environment, Lands and Parks

- Redirect upland drainage away from the slide to decrease saturation levels.
  - Because the slope failures are mainly groundwater related, there appears to be little advantage of diverting flows away at the top of the cutbank. It would also be conceptually difficult to divert the surface water, particularly where swamps and ponds have developed in low-lying areas.

- Construct rock, log and straw bale cribs across the lower end of the gullies on the slide. As the area behind the first cribs infill they may be replanted. Additional cribs should be added above the infills until the headcutting is stopped.
  - This is a recommended element of future stabilization efforts.

- Restore the bankfull channel width to 60 m by widening the inside of the meander bend.
  - Gravel-bed rivers tend toward an equilibrium width based on sediment inputs and annual flows. The existing channel is mostly likely at equilibrium with current stream conditions. Attempts to widen the channel will therefore be a temporary measure, as the channel will revert to a narrower channel.

- Riprap the toe of the slide with a 1 m high rock berm.
  - A 1 m high rock berm is not high enough and would likely be overtopped with peak flows, resulting in erosion behind the berm.

- Clear two abandoned floodplain channels on the inside of the bend. Increasing the capacity of these channels will decrease flood depths and erosion at the toe of the cutbank.
  - Without a diversion in the main channel, the excavated channel is likely to aggrade quickly on its own given that the near bed velocity vectors are not directed into the backchannels. Ongoing channel maintenance would be required.

- Add three low rock riffles to control local stream gradients.
  - It is assumed that the function of the gradient control riffles would be to prevent channel scour adjacent to the cutbank. It is not known how effective the riffles would be at reducing the overall level of erosion at the toe of the cutbank but they could be combined with bendway weirs to improve effectiveness.

Summary

The options identified by NHC and Newbury together contain elements that would be partially successful in stabilizing the slide. However, none of the recommendations are a stand-alone solution. One of the key issues is to reduce the amount of flow against the toe of the Stoltz Slide. Without a diversion of some of the flow and the establishment of a terrace at the base of the cutbank, it would be extremely difficult to stabilize the base of the cutbank and thus minimize fine sediment inputs. The following section provides a proposed strategy for stabilization of the cutbank, which includes a number of elements previously proposed.

1.4 Preliminary Strategy for Stabilization

The tributaries between Cowichan Lake and the river mouth do not appear to be significant contributors of sediment to the Cowichan River. Hence, the river relies on internal bank erosion to maintain ongoing sediment transport. Natural channel changes such as meander cutoffs can be essential processes that maintain sediment transport and natural turnover of gravels critical in the maintenance and creation of fish habitat.

In the case of the Stoltz Slide, it appears that the cutbank is contributing more fine sediment than beneficial coarse sediment. Currently, a work program is underway to define contributions of significant volumes of fine sediment, and quantify the distribution and size of sediment inputs into the river from monitoring and field data.

Based on our assessment of the existing situation and a review of previous options identified, the following approach is recommended:

Phase 1 - Fine Sediment Source Tracking

Prior to stabilization of the Stoltz Slide it is critical to determine how effective such works would be. If the Stoltz Slide was stabilized (at substantial cost) and then it is found that fine sediment is still an issue for downstream users then the time and expense would be wasted. The percentage of suspended sediment (sand-sized and smaller) in the Cowichan River that is supplied by the Stoltz Slide and Block 51 area needs to be determined. The relative contributions of both sources can be analyzed by two methods.

Suspended Sediment Sampling

The first method would require measurements of suspended sediment concentrations at a number of locations along the river. This work would need to be completed over a range of discharges to come up with a suitable rating curve. A key component of this work would be to find appropriate locations to make the measurements that can be easily accessed and that capture the longitudinal variation in sediment sources.

Fortunately, DFO has been measuring total suspended solids (TSS) and turbidity at ten locations along the Cowichan River for the past several months. Five of the locations are located above Stoltz and five below. The objective of the sampling is to quantify the relative contributions of the Stoltz Slide and Block 51 to suspended sediment concentrations. It is further hoped that the turbidity readings can be correlated to the TSS analyses, which are much more expensive and labour intensive than turbidity readings. By the end of February 2005, DFO had completed sampling on at least ten occasions, including a moderate peak flow event that was captured on the rising and falling limb (although the peak was missed).

Volumetric Analysis

Another approach is to look at the volume eroded at the Stoltz cutbank between 1993 and 2004. The period after 1993 is well suited for analysis, as the cutbank has been actively eroding the last decade. Aerial photography from 1993, 1998 and 2004 can be used to derive spot elevations at the cutbank using photogrammetric methods. The resulting elevations can be used to develop a digital elevation model (DEM) for each of the years. The DEM's can then be overlain in a GIS environment to calculate volumetric changes between dates.

The contribution of each of the size classes (gravel, sand, silt and clay) can be further defined by representative grain size sampling of the Stoltz Slide. The fine sediment volumes could also potentially be related to the Cowichan River flow record to estimate suspended sediment concentrations during high flow periods.

Work Program

While this memorandum focuses primarily on work completed in 2004, a sediment source work program is currently underway to further quantify sediment sources and channel changes in the Cowichan River to determine the viability of stabilization of the Stoltz Slide area. This work program which is funded by the Cowichan Tribes Treaty Office is summarized on Table 1 below.

Table 1: Work Program for Sediment Source Analysis

Task		Description
1.1	Project Initiation	▪ Obtain and review available background information, including: – DFO turbidity and TSS data; – Cowichan River flow data; – Norske turbidity data; – digital base map information; – topographic data; and – digital aerial photography. ▪ Conduct project meeting to: – review proposed work program and budget estimate; – obtain stakeholder contact information; and – execute consulting contract document.
1.2	Photogrammetry and Mapping	▪ Determine which years of aerial photography are most appropriate for use (probably 1993, 1998 and 2004). ▪ Identify further photogrammetric work that is required and co-ordinate the work to be completed by others. ▪ Determine additional survey requirements. ▪ Complete channel mapping at Stoltz Slide and Block 51 (1993, 1998 and 2004) to document planform changes over the last decade. – channel features to be mapped include floodplain, gravel bar and wetted channel

Task		Description
1.3	Fine Sediment Analysis	▪ Determine the relative contributions of fine sediment from the Stoltz reach and Block 51 reach based on TSS and turbidity data from DFO. ▪ Compare Norske turbidity data to DFO data. ▪ Correlate TSS data with flow record to derive suspended sediment concentrations for last several years. ▪ Use photogrammetric data to develop a digital elevation model of Stoltz Slide for three different years. ▪ Compare DEM's in GIS environment to determine volumetric changes for 1993 – 1998 period and 1998 – 2004 period. ▪ Complete grain size analyses of various deposits at Stoltz and Block 51 to relate volumetric changes to size fractions (gravel, sand, silt and clay). ▪ Identify and assess sediment sources for other significant sediment sources on the river that have been identified by aerial photography analysis.
1.4	Channel Planform Changes	▪ Analyze channel mapping at Block 51 and area downstream of Stoltz Slide. ▪ Relate channel changes to bedload transport rates at both sites. ▪ Assess lateral stability of Block 51 area with respect to suitability of bank protection works.
1.5	Refinement of Stabilization Strategy	▪ Assess relative effectiveness of stabilization design options based on sediment analysis results of overall river (note, to be ground truthed during field program). ▪ Building on the 2004 concept assessment, identify river alternative alignments/stabilization schemes that would divert the river away from the Stoltz Slide. ▪ Identify locations for required detailed field survey and critical cross-sections in order to design stabilization works. ▪ Produce mapping that document the sediment analysis, identifies key sediment source zones and identifies sites to investigate in the field. ▪ Assess potential impacts of stabilization on downstream channel changes. Calculate whether the substrate will continue to be mobilized following stabilization (use Shield's equation to estimate).
1.6	Preliminary Sediment Management Strategy	▪ Confirm the importance of the Stoltz and Block 51 areas and justification for moving forward on a stabilization scheme. ▪ Identify steps to develop a sediment management plan and sediment budget for the river. ▪ Prepare an outline for a future Cowichan River Sediment Management Plan.

Phase 2 - River Based Measures

The proposed river based measures do not include a diversion dike that would completely block the existing river and force the flow into a series of existing backchannels along the inside of the bend. A diversion dike of this size would represent a significant in-stream structural measure that would likely not be acceptable to downstream users (such as BC Parks) or fisheries managers. Instead the proposed measures consist of:

1. **Excavated Channel:** Excavate a new channel on the inside of the meander bend or enlarge existing backchannels. While the backchannels have been identified as high quality habitat, flows must be reduced against the cutbank and increasing the inlet end capacity of the side channels could be completed with only minor effects.

2. **Partial Weir:** At the entrance to the excavated channel, a partial weir should be built across the channel to direct a certain portion of the flow into the excavated channel. Without the diversion, the channel is likely to aggrade quickly on its own given that the near bed velocity vectors are not directed into the backchannels.

3. **Constructed Terrace with Bank Protection:** With a portion of the flow directed into the backchannel, the toe of the main cutbank area (about a 250 m length) is more easily stabilized. We recommend widening the channel in this location and that the excavated gravels and cobbles be placed at the toe of the cutbank to create a 2 to 3 m high terrace. The terrace could then be planted with willows to promote stability. The terrace could be 15 to 25 m wide and protected with riprap and large woody debris. The riprap could be buried with native sediment to provide self-revealing bank protection.

These measures would require heavy equipment and instream work. The river-based measures will have the highest likelihood of success if considered as complementary elements of one another. If the measures are considered as stand-alone elements, the likelihood of success will be low. Additional field investigations and a detailed survey are recommended before a conclusive recommendation is made, which would be followed by a detailed design.

Phase 3 - Gully Stabilization Measures

STABILIZE THE SILT GULLY AREAS OF THE CUTBANK AND THE POTENTIAL OF LANDSLIDING BY A COMBINATION OF:

1. **Inverted Filter**: An inverted filter over the face of the silt where it is exposed in the gully. By placing a layer of well-graded sand and gravel over the face of the silt to weight it down, while still allowing seepage to emerge without carrying away silt particles. The filter has to be coarse enough to permit the free outflow of seepage water, yet fine enough to prevent the escape of soil particles through their voids. This measure, however, will not prevent slope failures.

2. **Horizontal Drains:** Another possible remedy would be to install horizontal drains in the slope to pull the phreatic surface back from the face thus preventing erosion. This option is worth consideration but would be costly due to the intensive labour involved and access issues. It would also have to be preceded by a detailed slope stability analysis and possibly the installation of piezometers to determine the number, depth, and location of horizontal drains necessary to decrease the factor of safety of the slope to a level that would effectively minimize the possibility of further movements.

3. **Slope Flattening:** Another measure would be to flatten the overall slope by bulldozing down sand and gravel from the crest of the slope, protecting the silt with filter cloth. Slope regrading would require an enormous amount of soil to be moved, which may turn out to be cost-prohibitive.

Stabililzation works that aim to reduce future landslides should be preceded by a geotechnical analysis in order to understand failure mechanisms and to optimize the use of geotechnical stabilization equipment and effort. To complete this task, vertical holes could be drilled along the crest of the slope and standpipe piezometers installed at variable depths and a slope stability analysis undertaken. There is no clear consensus at this time whether the above measures are best considered in isolation or a combination thereof.

Phase 4 – Bioengineering Measures

Previous attempts to stabilize the cutbank with bioengineering have yielded mixed results and there is some question about the potential effectiveness of such work. Bioengineering is generally a surficial treatment that is used to reduce shallow erosion rates. Therefore, bioengineering should only be used in conjunction with other measures that reduce the potential for slope failures.

1. **Gully Check Dams:** Installation of gully check dams (logs) could be effective in combination with other measures such as the inverted filter technique but test pits would be required to determine if the check dams or willow wattle fences could be founded sufficiently to prevent failure by piping silts.

2. **Live Staking and Willow Wattles:** Live staking could be done on top of the proposed terraced berm. Willow wattles have been used as an attempt to stabilize the cutback in the past. Wattles could be used in conjunction with geotechnical gully stabilization methods in transition areas between the gullies and the terraced toe berm.

3. **Willow Brush Layers:** Willow brush layers could be used along the outer slope of the terraced berm to provide stability and overhanging vegetation. If successful they would provide excellent cover, however, if high flows damage them prior to establishment then the self revealing riprap buried in the terrace would act as a second line of defence.

4. **Anchored Large Woody Debris:** LWD could be anchored in the terraced berm to provide increased habitat and roughness. If this material is undermined or shifts during high flows then the self-revealing riprap would provide secondary protection.

The above measures will require further field investigation, but are not mutually inclusive. One or several of the above measures could be part of the final design. It should be recognized that surficial treatments such as bioengineering may only cause minor reductions in the rate of surface erosion as is evidenced by the bioengineering measures that have been buried by sediments along the lower part of the slope.

1.5 Preliminary Capital Planning

The stabilization of the Stoltz cutbank is a major undertaking. Should sediment analysis deem it feasible to stabilize this slope then a phased approach is recommended. Table 1 below presents preliminary cost ranges for each project phase to assist you in capital planning. We must stress that these costs are Class D level as detailed surveys and geotechnical investigations are not within our scope at this time.

Table 2: Stoltz Cutbank Preliminary Capital Costs

Phase /Years	Item	Cost Range ($)		
2005	Fine sediment source tracking	$15,000	to	$30,000
1 2005-2006	Channel excavation, terraced toe berm and partial weir	$380,000	to	$570,000
3 2006-2007	Gully stabilization	$370,000	to	$560,000
4 2007-2008	Bioengineering treatments	$120,000	to	$180,000
Totals		**$885,000**	**to**	**$1,340,000**

Block 51

A second scope of work detailed in this memorandum is preliminary investigation of sediment erosion and sediment transport issues in the Block 51 area. Block 51 is located about 7 km west of the Stoltz Slide and 6 km southeast of the outlet of Cowichan Lake. The Block 51 reach is highly active and characterized by large areas of available sediment and lateral instability.

1.6 Assessment

In the early 1990s, the Cowichan River cut off two tight meander bends to flow in a more direct line toward the southeast. The old channel distance through the abandoned meanders was approximately 2 km, and has now been shortened to approximately 1.2 km. The river sinuosity (defined as along-channel distance divided by along-valley distance) has been reduced from 2.3 in its former configuration, to 1.5 (measured from 1999 air photographs). While the straightening of the river appears to be a natural event, the channel avulsion has resulted in significant channel instability. The new channel section is characterized by extensive gravel bar deposits that have been stripped of their overbank sediment and vegetation by the recent geomorphic activity. In addition, this section of the river is characterized by large deposits of woody debris that accumulate at the downstream corners of bends.

The recent channel avulsion represents measurable geomorphic change in that the Cowichan River relies on internal bank erosion to maintain sediment transport and natural turnover of gravels. However, the avulsion has also increased the input of fine sediment into the system. The river is actively eroding into remnant glacial outwash deposits at multiple locations in the vicinity of the meander cutoffs. On the right bank of the river, a number of 15 to 20 m high cutbanks are being eroded. The lengths of the cutbanks vary from about 80 to 150 m.

Figure 2. Cutbank erosion at Block 51 area. July 2004.

Cutbank soils consists of layers of sand, and sand mixed with gravel and cobble that overlie 5 to 7 m of glaciolacustrine sediment (fine sand, silt and clay). Erosion from the coarser deposits at the top of the banks provide a source of bed material to the river, and coarse material tends to accumulate along the base of the slope where it is easily entrained into the river. Although the fine sand, silt and clay materials are exposed along the length of the cut-bank, erosion is often limited to the upstream-most section of the cutbank, where back-eddies tend to form.

During a site visit on March 3, 2005, glaciolacustrine sediments were observed at multiple locations along the river bank from upstream of Block 51 to Skutz Falls. According to local observers, although these sediments are prevalent along the river, the primary fine sediment sources tend to be localized (e.g. at particular places along a cut-bank, rather than the entire bank) and also tend to vary from year to year given local channel changes (e.g. large woody debris input that alters flow patterns).

1.7 Preliminary Strategy for Stabilization

The cutbank erosion at Block 51 represents a less suitable stabilization project in comparison to the Stoltz Slide. Because the erosion area is significantly smaller, the contribution of fine sediment to the Cowichan River is probably an order of magnitude less than at Stoltz. Furthermore, the Block 51 area remains highly susceptible to lateral instability due to extensive gravel bar deposits. This lateral instability (and hence the predictability of channel form) could make it difficult to protect the cutbank areas from further erosion.

While Block 51 represents a lower magnitude stabilization problem than Stoltz Slide, the area has a significantly more complex geomorphology. If stabilization of the cutbanks at Block 51 is desired, additional field investigations will be required to formulate a detailed strategy. Possible options would be a combination of bioengineering on upper slopes with toe stabilization using large woody debris and rock footing. Bendway weirs or riffles could also be considered, however, the likelihood of the river changing alignment and moving around or away from stabilization projects is somewhat unknown.

The work program detailed in Table 1 will allow for further quantitative analysis of the Block 51 area. This work includes:

- analysis of DFO turbidity and TSS data;
- grain size analyses of the eroding cutbanks at Block 51; and
- analysis of channel planform changes, including estimates of downstream sediment transfers.

Once the relative contributions of fine sediment from Block 51 relative to the Stoltz and other areas are known then the effectiveness of stabilization of areas of Block 51 can be fully assessed.

1.8 Preliminary Capital Planning

If the sediment analysis indicates that stabilizing the cutbanks in Block 51 is feasible, then a phased approach is also recommended. After detailed investigation, banks in Block 51 could be stabilized using a pilot project approach so that success of techniques can be observed and adjustments made. Preliminary costs for a typical 4 m high bank 50 m long could be in the $50,000-75,000 range.

Closure

We trust that the above information is suitable for your present purposes. Based on our preliminary review of the Stoltz and Block 51 areas, we have provided a strategy to move forward on this long-standing sediment management issue. The sediment source analysis currently underway followed by future field work will establish the feasibility for stabilization measures at the Stoltz Slide and Block 51 areas and determine if design should proceed in Summer 2005.

If you require additional information or clarification please contact the undersigned at (250) 595-4223.

Dave Murray, P.Eng., A.Sc.T., CPESC
Project Manager

Nigel Skermer, M.Sc., P.Eng.
Senior Geotechnical Engineer