Freeze Core Sampling for Sediment Intrusion from Road Stream Crossings in Alberta's Foothills

3.2.04

Project Summary
January 26, 1998

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Acknowledgements

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Contents

1. Action plan

2. Draft report written May 7, 1997

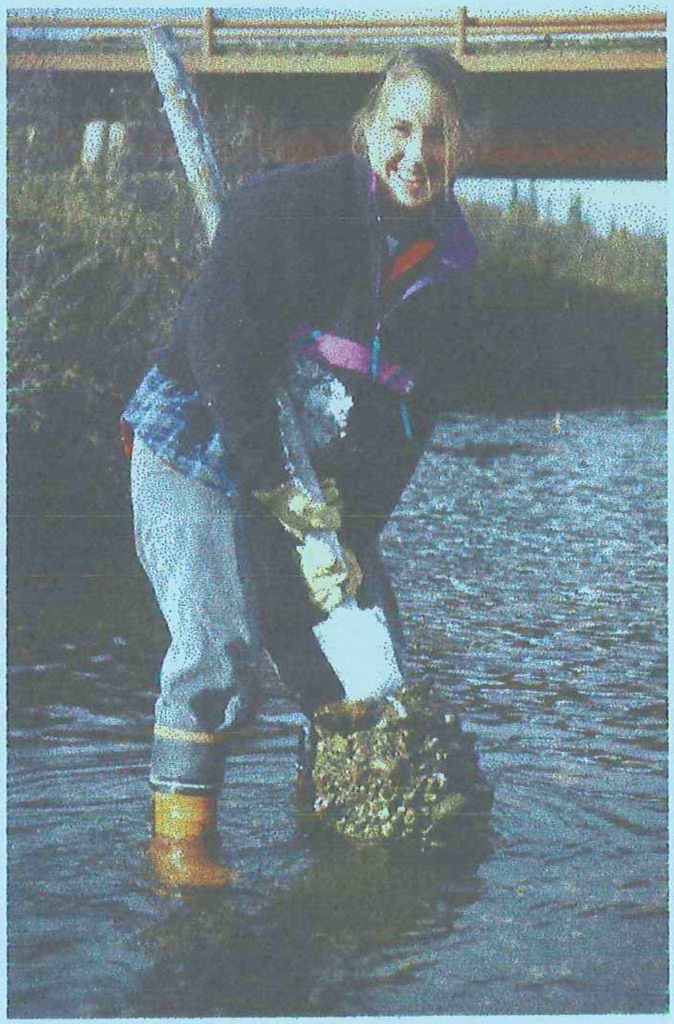
This draft contains information on the 1996 field season data.

3. Draft report written November, 1997

This draft contains information on the 1995 field season data. It was produced for the proceedings of the Forest Fish Conference and is **in press**. The text is similar in content to previous reports, but is somewhat more refined, organised and well referenced than documents produced in 1996.

Appendix 1.

Graphical data summaries for 1995 and 1996 data.



photograph by
Craig Johnson

Action Plan for Sediment Intrusion Study

Month	Number of Days	Task	Milestones
November 1997-December 1997	10 days	data manipulation, forest fish conference proceedings paper	submission of Forest Fish Conference Proceedings Paper
January 1998	4 days	package for funding sources	summary package for funding sources
February 1998-April 1998	13 days	• lab work to redo a few missing data values, • preliminary comparisons between 1995 and 1996 data, • comparisons between samples within streams for 1995 data, • comparisons between tops and bottoms of 1995 samples, • final data manipulation	missing data values filled, preliminary comparisons complete, data manipulation complete
May 1998	15 days	statistical analysis,	statistical analysis
June 1998	5 days	• send results package of statistical analysis to funding agencies, • refine methods, • update library research	results package of statistical analysis
July-October 1998	20 days (minimum)	compiling and writing report/thesis • incorporate updated library research and papers written to date, • refine Introduction, • write/refine Results and Discussion	
November 1998		submit complete thesis draft	complete thesis draft

Freeze Core Sampling for Sediment Intrusion
from
Road Crossings in Small Alberta Foothill Streams.

Introduction

Background

During and shortly following European settlement and development of Alberta's foothills, there were larger fish in greater numbers than we see today. The quality and quantity of salmonid fish in foothill streams of the east slopes of Alberta have declined since that time. Bull trout and the Athabasca rainbow trout have been particularly affected. The number and size of bull trout have decreased to the extent that they are considered a threatened species in need of special protection and management.

Many factors have contributed to the decline in the fish populations, but two main factors have been, and continue to be, angling pressure and industrial development. Angling has increased because of a greater human population, better road access, and a growing interest in sport fishing. Development of extensive road systems in the foothills region to support the forestry, mining, and petroleum industries is ongoing. These factors have affected bull trout and Athabasca rainbow trout populations. The growth and recovery of fish populations are further limited by the cold, nutrient-poor waters of our foothill streams.

The purpose of this study is directed toward describing the effects of roads, particularly stream crossings, on aquatic habitats.

Stream Crossings

Many studies have shown that stream crossings have significant impacts on water quality and aquatic habitats (Binkley and Brown 1993). One measurable effect of decreased water quality is an increased suspended sediment load. Soil disturbance, soil exposure, and soil erosion at stream crossings are responsible for increasing suspended loads. Culverts, constructed with large fill-sections, may cause more problems than bridges. The fill-sections are often composed of bare, loose soil which acts as a source of sediment for erosion into streams. Water flowing over the ground from rain and snow can pick up and accumulate sediment in ditches and flow directly into streams. Crossings where side hills are cut and filled in road construction can be major contributors of sediment to the streams. Often they are difficult to revegetate and sedimentation may result from even minor precipitation. Each of these factors contribute to the potential for erosion and subsequent sediment deposition into stream channels. Anderson (1976) comments that 90% of the sediment associated with forest harvesting can be traced to road systems.

Precipitation, including rainfall and snowmelt, provides the energy for the erosion of bare soil and the transport of it as sediment into stream waters. Suspended sediment loads usually increase if precipitation is great enough to increase streamflow. Suspended sediment concentrations downstream of road crossings can be many times greater than upstream concentrations (Rothwell 1983).

Although increased suspended sediment concentrations are a concern, these concentrations decline shortly after precipitation. Furthermore, precipitation is unpredictable. Therefore, the monitoring of suspended sediment at crossings is costly and difficult because sampling must be frequent and intense. However, the suspended sediment settles to the stream bottom once streamflow returns to normal and can cause long-lasting effects on fish habitat.

Sediment Intrusion

A large amount of the fine-textured suspended sediment during and after precipitation will settle and collect on the stream bottom. The process of the sediment settling in the gravel interstices of a streambed is called sediment intrusion. As habitat for fish eggs, newly hatched fish, and the aquatic insects on which fish feed, the interstitial spaces are important. The upper 5-10 cm of streambed can be filled and cemented together by the intruded sediment. This cementation can lower the survival rate of fish eggs incubating in the streambed by suffocating them (Lisle and Eads 1991). Sediment intrusion suffocates the eggs for two reasons. First, it impedes the flow of oxygen-carrying water through the gravel where the eggs are laid. Second, the sediment is partly made up of fine organic matter that uses up oxygen as it decomposes (Lisle and Eads 1991). Even if the eggs are not killed by oxygen deprivation, the hatched fry may be entrapped by the sediment and still die. Intruded sediments can also harm the populations of invertebrates on which the fish feed.

Small or low gradient streams are more likely to be seriously affected by sediment intrusion than larger streams because their flows may not be large enough to flush and clean the stream gravels (i.e. substrate) of intruded sediment. Some low gradient streams have very limited spawning substrates because of low velocities and natural sediment deposition. Suitable substrates are critical habitat and additional sediments can become the major limiting factor on the success of fish recruitment in a stream.

Assessment of Sediment Impacts

At present, little monitoring of sediment or its impacts on aquatic habitats is done in Alberta. Resource industries in Alberta must follow guidelines (Resource Road Planning Guidelines 1985, Stream Crossing Guidelines-Operational Guidelines for Industry 1989, Alberta Timber Harvest Planning and Operating Ground Rules 1994) to protect aquatic habitats. These guidelines regulate the forest, mining and petroleum industries. The guidelines are concerned with minimizing the risk of erosion and sediment deposition from stream crossings. They are based on experience and the best knowledge available. They are further refined or compromised by negotiations between the government and industrial users. One problem with these guidelines is that few of them, if any, have been evaluated to determine their effectiveness. This is a major weakness in the credibility of standard ground rules.

Little evaluation has occurred because it is difficult to measure suspended sediment and the effect it has on aquatic habitats. The difficulty is caused partly from the high variability in aquatic systems and patterns of water flow. Although field and laboratory techniques exist, budget constraints of regulatory agencies in Alberta have made evaluation of guidelines impossible. As mentioned earlier, suspended sediment is costly to measure and requires frequent and intensive sampling that must be coordinated with precipitation events. Furthermore, dependable relationships between fish survival and sediment levels do not exist. This makes it difficult to interpret suspended sediment data, and to develop better regulatory standards. Suspended sediment is a common phenomenon in Eastern Slopes streams and fish have adapted to relatively high levels of suspended sediments that occur over short periods of time.

Methods to assess sediment intrusion are even less developed. Most of the work is experimental and research based. However, sediment intrusion may be the most important factor for assessing the effects of sediment on aquatic habitats and fish populations. Sediment intrusion is a more permanent streambed change that remains after precipitation. Unlike suspended sediment, it can be measured and related to streambed conditions. However, reliable methods for detecting sediment intrusion and its effects on streambeds are not currently available. The methods which exist are highly variable and often do not provide comparable results. There is a need to develop better methods so that guidelines may be tested and environmental audits performed. This is especially true today given current Provincial Government policies of downsizing and surrendering regulatory responsibilities to resource agencies.

Objectives

The purpose of this study is to evaluate the impact of sediment intrusion at road-crossings on the aquatic habitats of bull trout and Athabasca rainbow trout. Work by Sterling (1992) at Tri Creeks supports a general agreement among biologists that sediment intrusion has a significant contribution to the deterioration of aquatic habitats and fish stocks of foothill streams. Work by Bjornn (1969) and McCuddin (1977) as referenced by Reiser and Bjornn (1979) indicate that stream substrates with fine sediment levels greater than 20-25 % dramatically decrease the rate of emergence for various species. However, local information on the topic is needed to further support this contention.

The specific objectives for this study are to:

1. Measure and describe the magnitude of sediment intrusion at stream crossings of small to medium sized foothill streams in the Hinton-Edson region.

2. Identify stream types or characteristics such as gradient, substrate types, or other hydrological features that can be used to predict or rank potential sediment

impact between or within watersheds. Conclusions will be based on information measured at actual stream crossings.

Methods

Study Location

The location for the study is the Hinton-Edson area which also includes the Foothills Model Forest.

The area is primarily forested with stands of lodgepole pine, white spruce and aspen, in pure and mixed stands. Elevations vary from 1000 m near Edson to 2800 m at the Jasper Park boundary. Climate is characterized as continental with cold winters and cool summers. Annual precipitation varies from 500-550 mm, with approximately 50-60% occurring as rainfall in the summer months. Runoff regimen is dominated by snow melt, with more than half of annual flow occurring in the months of May and early June. Soils in the region have developed from glacial material and are characterized by lacustrine and aeolian deposits and till material. Soils in general are highly susceptible to erosion. Sediment transport and deposition in streams from road-stream crossings and other similar disturbances is common.

Major rivers in the region are the Athabasca, McLeod, Berland and Pembina. These rivers and their tributaries support wild populations of bull trout, brook trout, rainbow trout, brown trout, Rocky Mountain whitefish, and Arctic grayling. There is a high level of angling use in the area but there is potential to return bull trout and Athabasca rainbow trout population sizes to pre-development levels. The area was selected for study because it has an extensive industrial road system which provides a good population of stream crossings for the study.

Reconnaissance

In June to September, 1995, a reconnaissance of Hinton-Edson area streams was completed. Twelve streams were selected for the study on the basis of size, presence of suitable spawning substrate upstream and downstream of the crossing, and absence of complicating factors such as beaver dams. In 1996, two more streams were added to the study.

Sampling

From September to November the streams were sampled using freeze core sampling techniques. Steel pipes, approximately 1.5 m long with case-hardened conical tips were pounded into the substrate. Dry ice pellets were inserted into the hollow portion of the probe, and ethanol was added for further cooling. After 30 minutes of cooling, the substrate surrounding the probe was frozen to the probe and could be severed from the streambed and extracted with the probe. Once extracted, the samples were bagged and transported to Edmonton for storage until laboratory analysis commenced.

1995

In 1995, the samples were paired upstream and downstream of crossings on the basis of water velocity and the presence of suitable sized spawning substrate (approximate). Distance from the crossing and distance from the bank's edge were also measured. Two to six samples were taken per stream crossing with an average weight of approximately 11.5 kg each. Approximately 650 kg of streambed substrate was collected in 1995.

1996

Criteria for selecting paired upstream and downstream samples were changed for the 1996 field season. Criteria used in 1995 had the following difficulties. In order to pair the samples on the basis of water velocity, the downstream distance from the crossing could be quite large, and very possibly outside of the immediate influence of the crossing. Within the immediate area of crossing influence, downstream samples were often in shallow water but in the middle of the stream. This was by virtue of the fact that the streams were sometimes wider and shallower, and of lower velocity just downstream of the crossing. One may speculate that this is related to the influence of the crossing. When the matching upstream sample location was picked, it was often near the stream bank in order to get comparable a velocity. These types of microsites may be biased toward finer materials because as a stream rounds a bend, suspended sediment is deposited on the inside curve, where the velocity is slower.

In 1996, the location for downstream samples was determined randomly within a distance approximately 1.5 times the width of the right of way. Where possible, a transect across the stream was chosen randomly within that distance. The transect was stratified by thirds so as not to have all samples on one edge or in the middle. Sample locations were then chosen randomly with a minimum of one sample per strata, and a maximum of two. On smaller streams, transects and stratification were not feasible. In such cases the distance downstream of the crossing (within the influenced area) was determined randomly for each sample, or was as close to that location as possible.

To choose the upstream transect, the habitat type of the downstream sample was noted (i.e. upstream edge, middle, or downstream edge of a pool, riffle, or run).

Then, the first similar habitat upstream of the right of way was chosen for the upstream site. The location of individual sample sites was chosen in a similar fashion to those downstream.

In 1996, the number of samples per stream was increased from (2-6) to (6-10). with an average weight of approximately 22 kg each. Approximately 2500 kg of streambed substrate was collected in 1996.

Laboratory analysis

Laboratory analysis began with sieving of dried samples in the following size categories using a mechanical sifter.

>25 mm
16-25 mm
8-16 mm
4-8 mm
2-4 mm
<2 mm

The substrate in the >25 mm category were further defined in the following size categories.

>128 mm
76-128 mm
64-76 mm
50-65 mm
32-50 mm

The fine material less than 2 mm was further analyzed using the hydrometer method described by Black (19) to get percentages of fine material in the following categories.

- total sand(>50µm)
- silt+clay(<50µm)
- total clay(<2µm)
- total silt(2-50µm)
  - fine silt(2-5µm)
  - medium silt(5-20µm)
  - coarse silt(20-50µm)

In order to further classify the sand portion, sonic sifting was used to obtain percentages by weight in the following size categories.

>1 mm
0.5-1 mm
0.25-0.5 mm
0.105-0.25 mm
0.053-0.105 mm

Data Analysis

The data was entered and manipulated so that particle size analysis could be compared between upstream and downstream samples. The 1996 data is considered more reliable at this point and therefore analysis is based on that data. The 1995 data is being re-analyzed.

The data for each stream was pooled for upstream and downstream samples. The values for the upstream data were subtracted from those for downstream. Positive numbers for a certain size class reflect a greater percentage for that size class in the downstream samples. Negative numbers reflect a greater percentage for that size class in the upstream samples. The results for size classes smaller than 2 mm were graphed for visual clarity.

Results

Streams showing greater proportion of particles (smaller than 2 mm) upstream of the crossings than downstream.

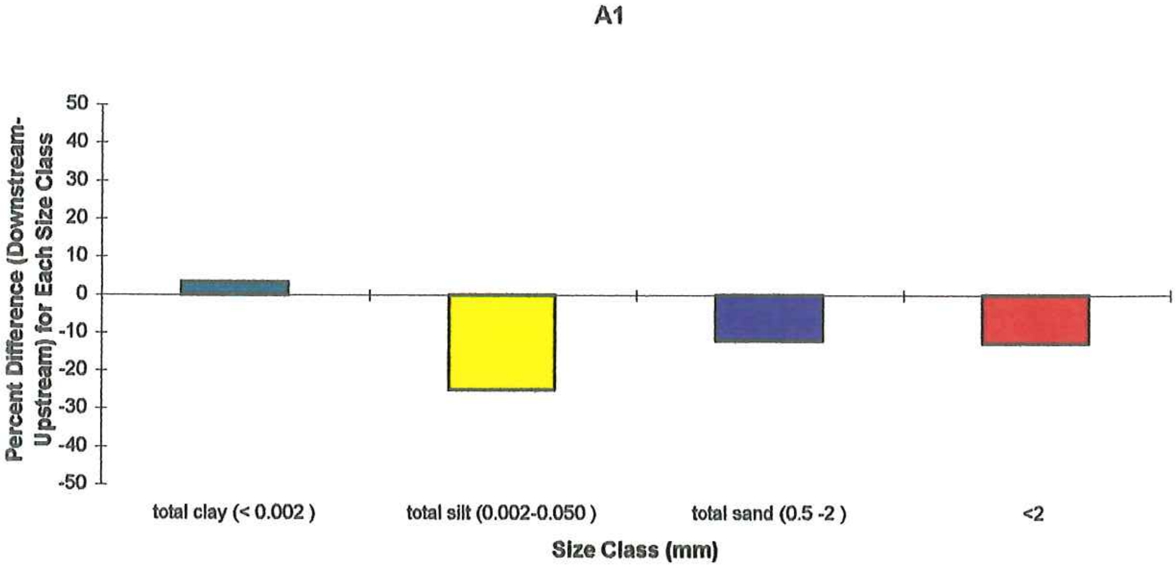


Figure 1. Un-named creek #1 South of Cardinal River Divide (A1)

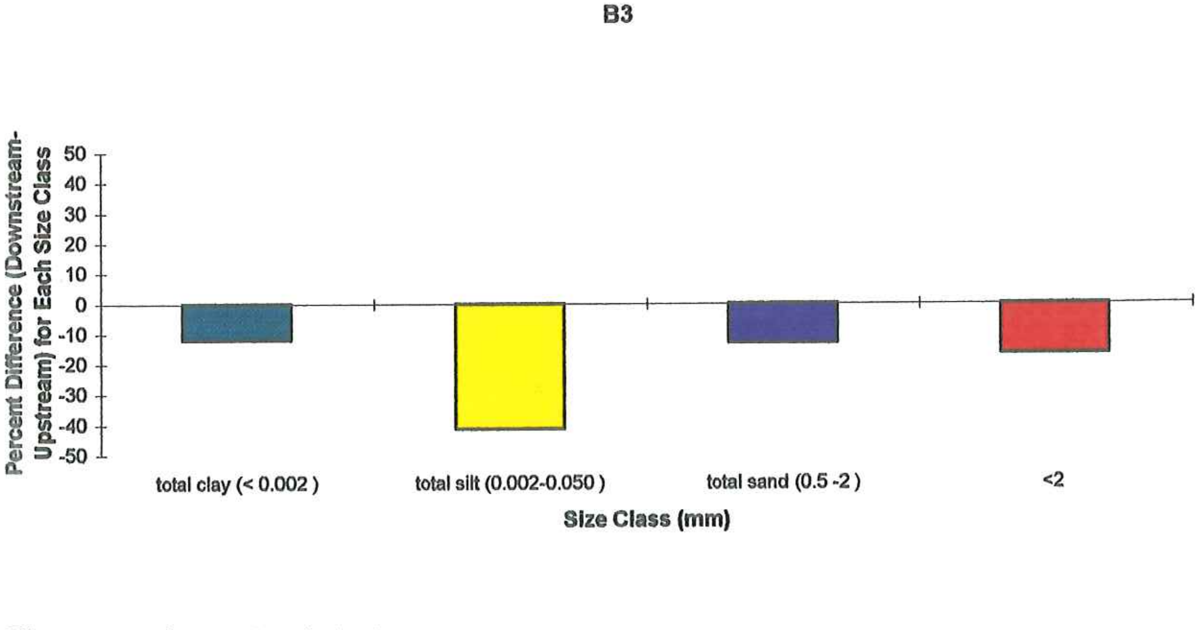


Figure 2. Drinnan Creek (B3)

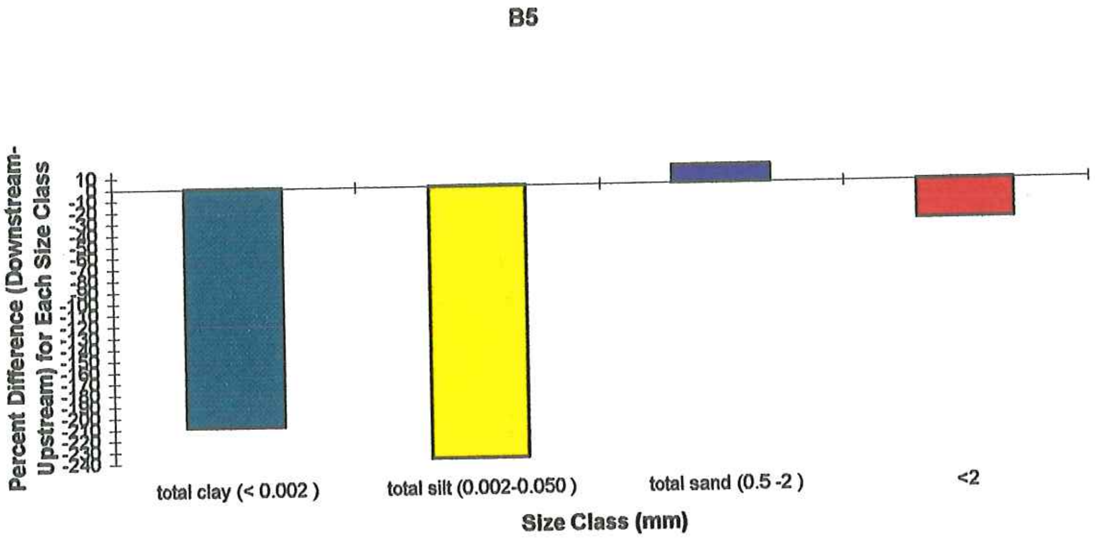


Figure 3. Wildcat/Hightower Confluence (B5)

Streams showing similar proportions of particles (less than 2 mm) upstream of the crossings and downstream.

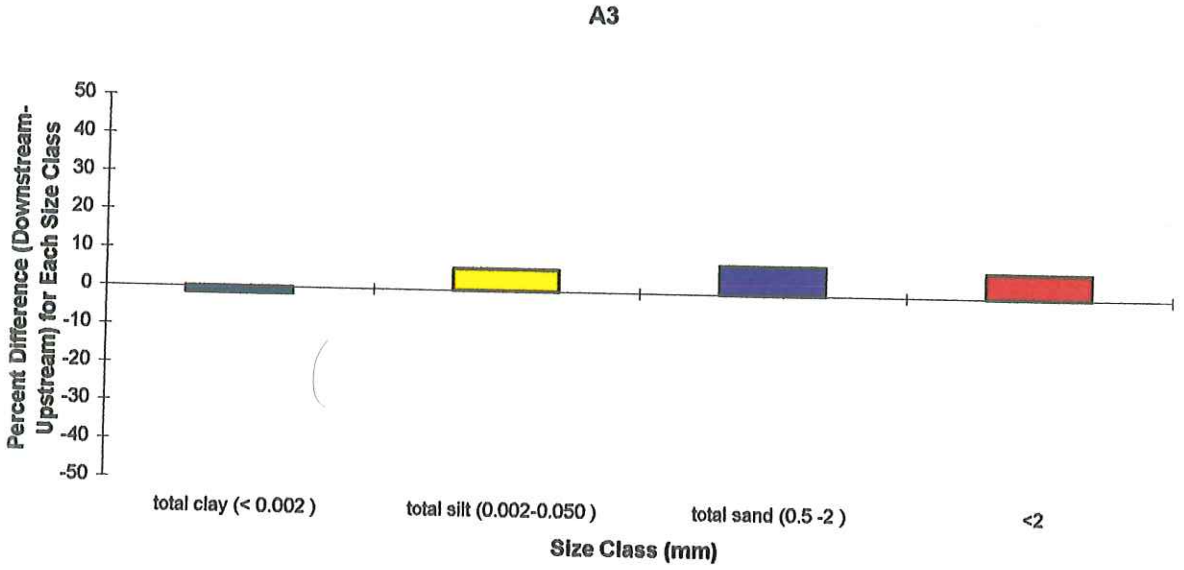


Figure 4. McLeod River Headwaters (A3)

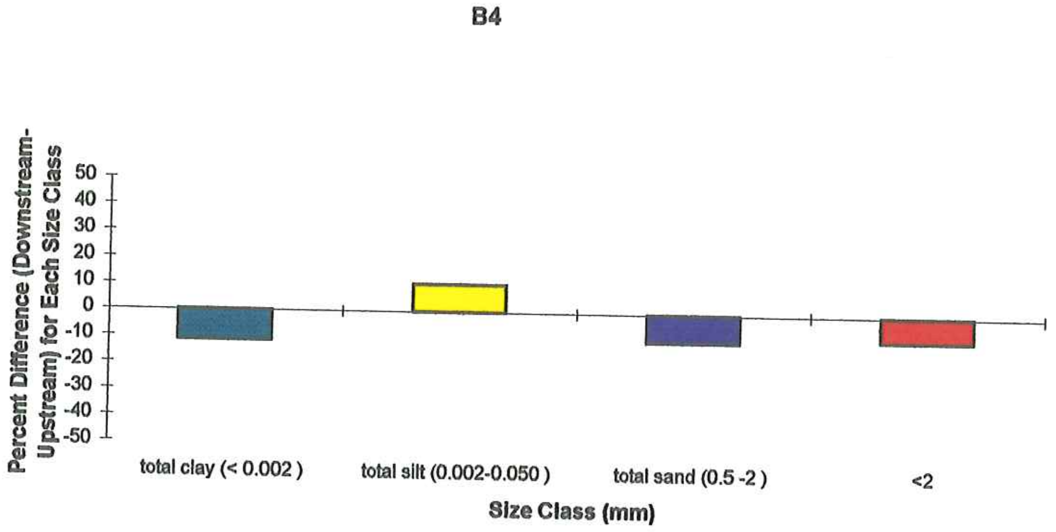


Figure 5. McPherson Creek (B4)

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Streams showing mixed results for particles (less than 2 mm) upstream of the crossings and downstream.

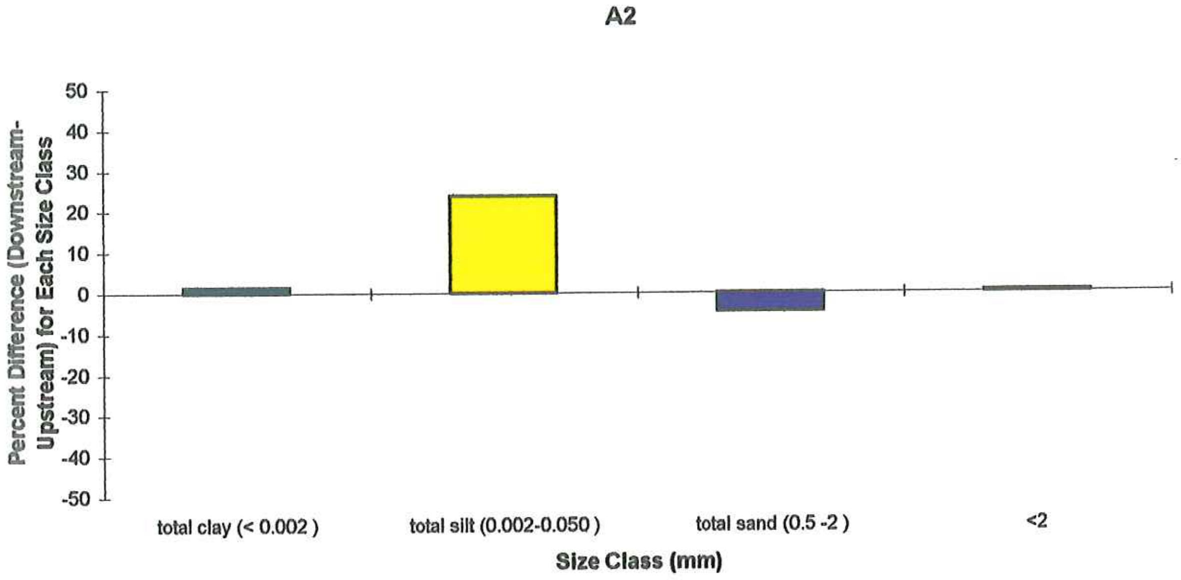

Figure 6. Un-named creek #2 South of Cardinal River Divide (A2)

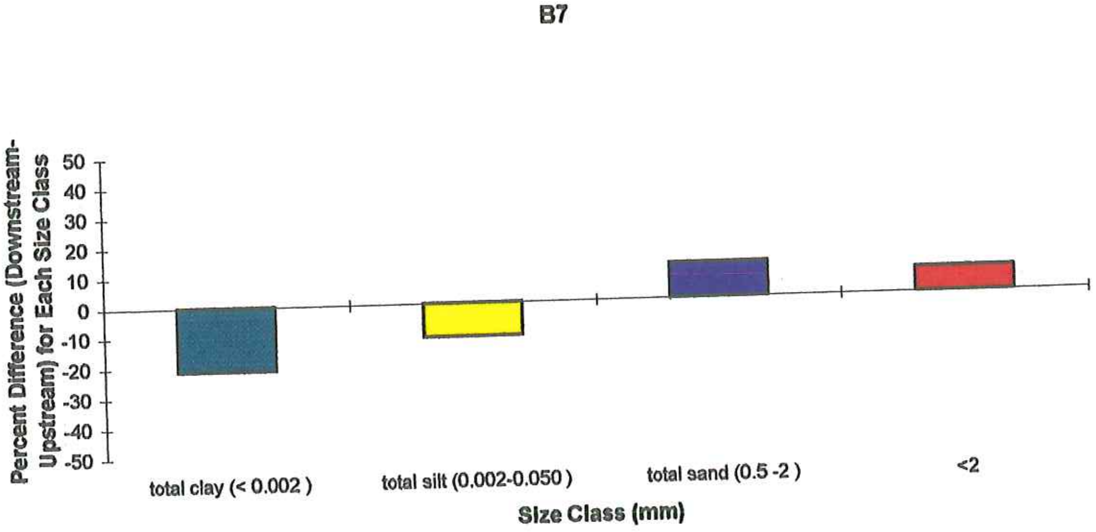

Figure 7. Wampus Creek (B7)

Streams showing greater proportion particles less than 2 mm downstream of the crossings than upstream.

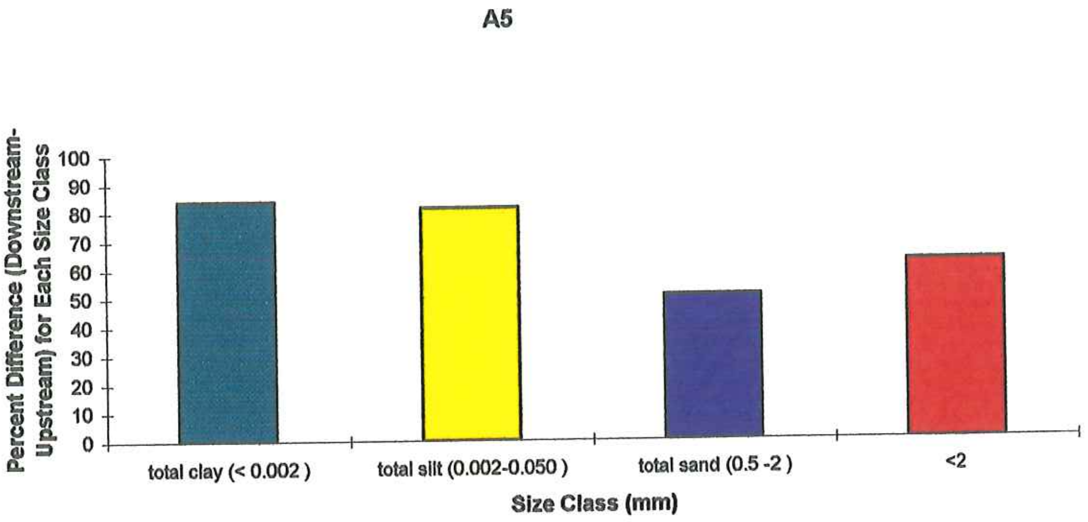

Figure 8. Un-named Creek #3 (A5)

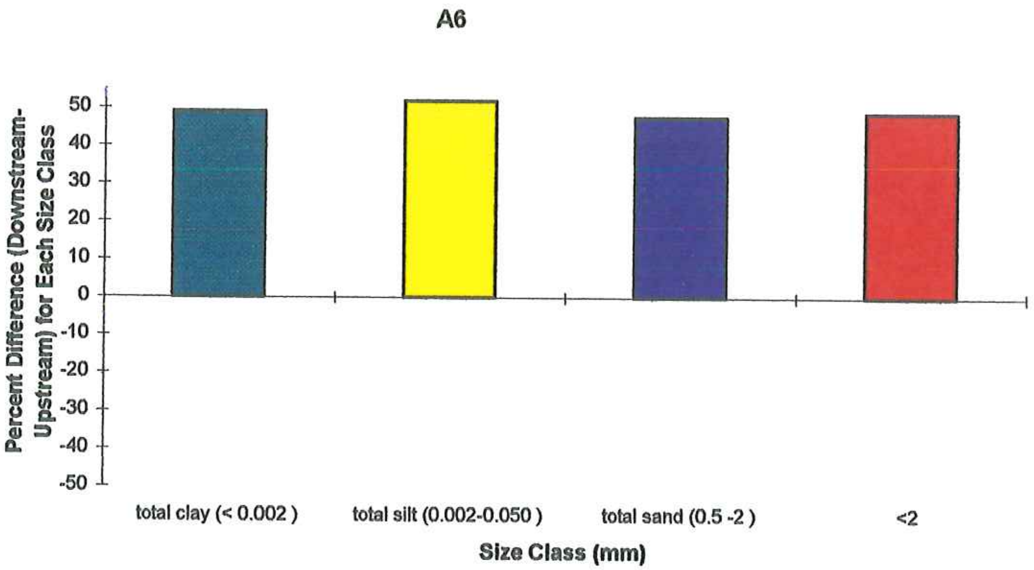

Figure 9. Un-named Creek #4. Tributary to McPherson Creek (A6)

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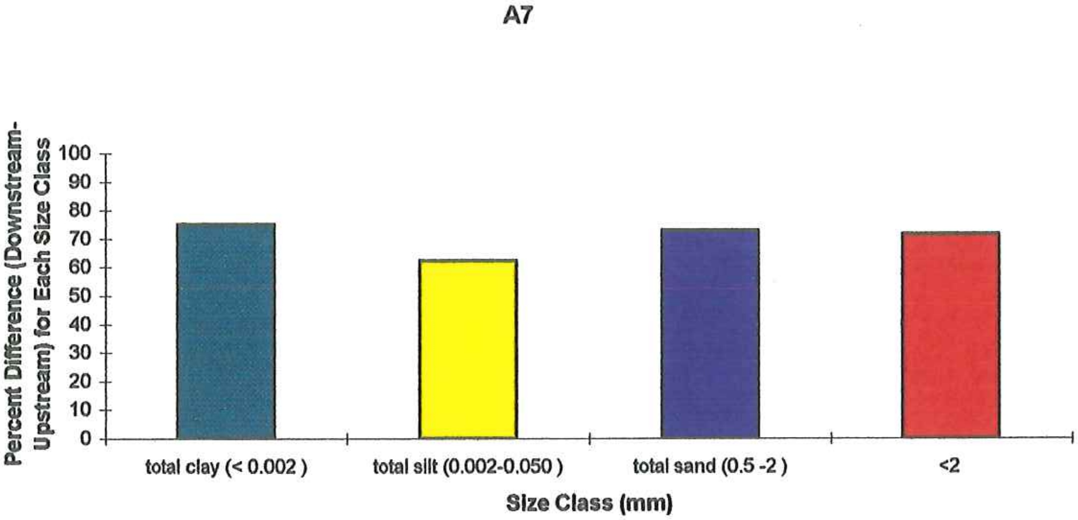

Figure 10. Un-named Creek #5. Tributary to McPherson Creek (A7)

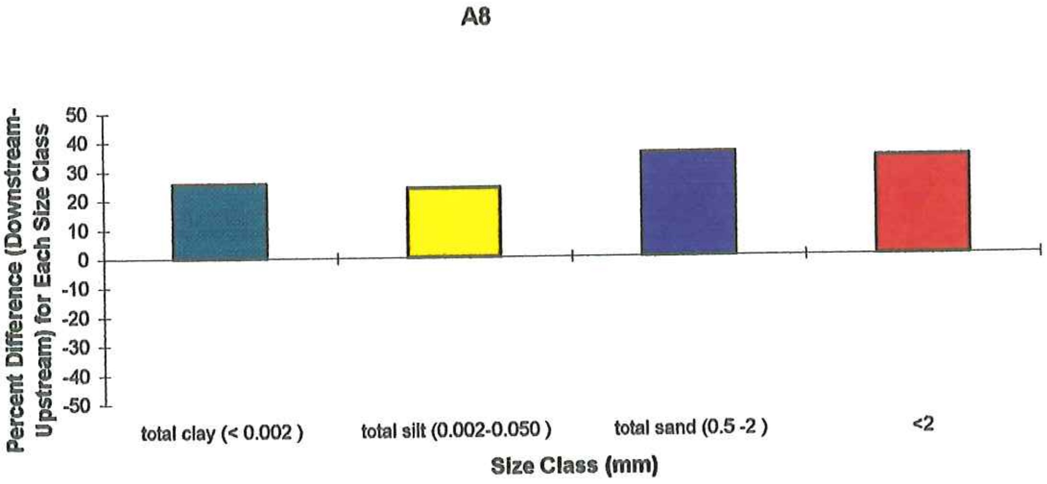

Figure 11. Eunice Creek (A8)

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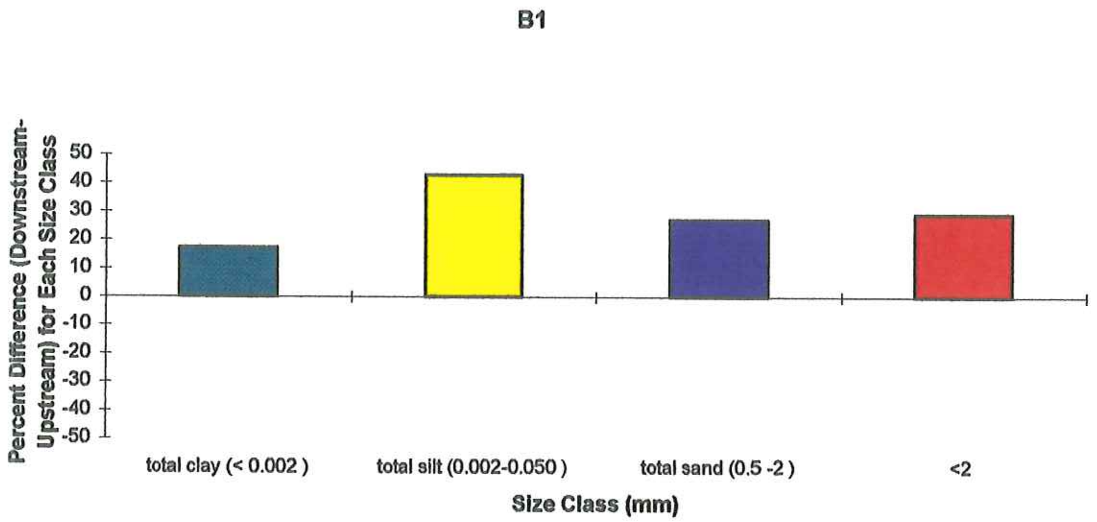

Figure 12. Un-named Creek #6 South of Cardinal River Divide (B1)

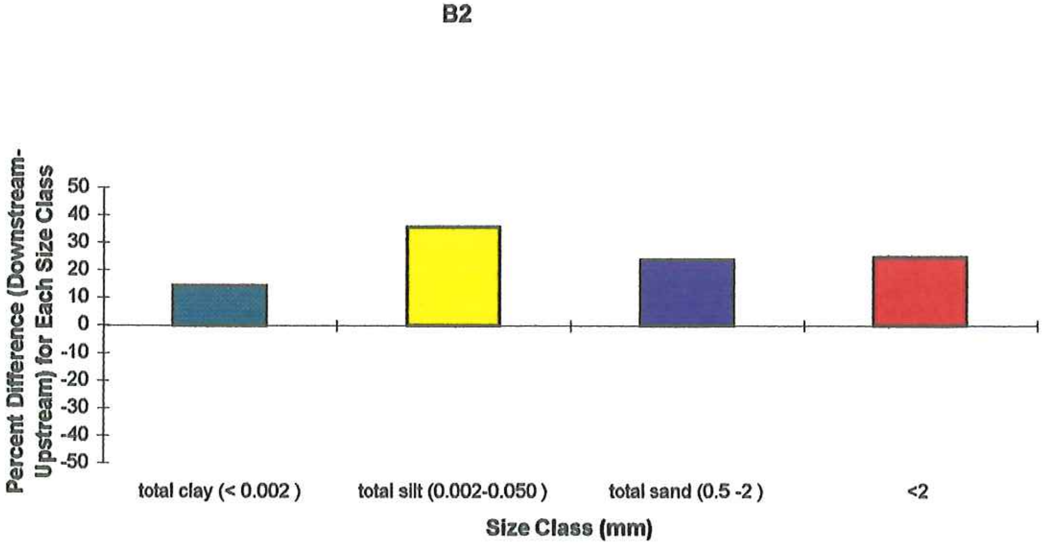

Figure 13. Prospect Creek (B2)

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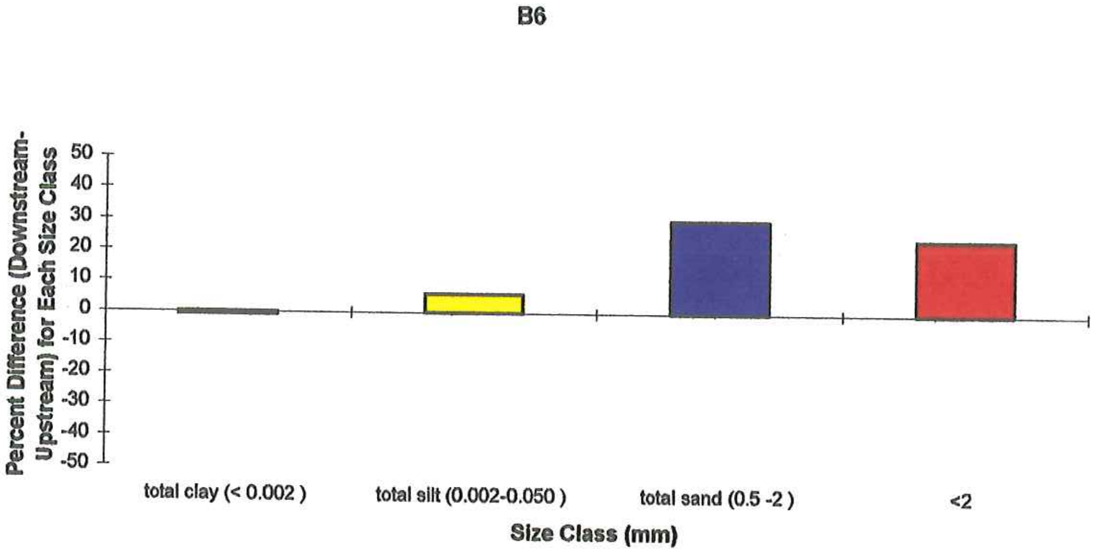


Figure 14. Fiddler Creek (B6).

Discussion of Preliminary Results

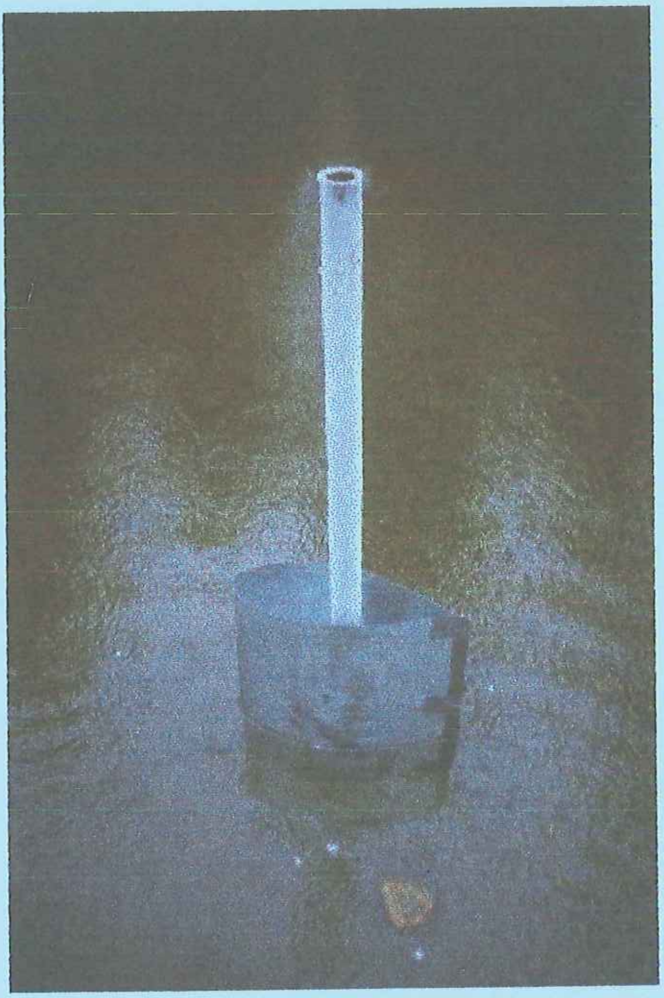
Three out of fourteen streams showed a greater degree of sediment (less than 2 mm) in the upstream samples than the downstream samples as indicated by negative y values. Two of these (A1 and B3) showed less than 20 % difference in the clay, sand, and total < 2 mm categories. The percent difference in silt size particles were 25 and 42 respectively. This may indicate that these crossings have not contributed to sediment intrusion beyond the amount naturally present. The third stream (B5) shows a massive natural sediment source upstream of the crossing with percent difference being over 200 for the silt and clay categories.

Two streams, McLeod River Headwaters(A3) and McPherson Creek (B4), had very little difference between upstream and downstream sample. The percent difference for each size category less than 2 mm was less than 12 %.

Two streams, A2 and Wampus Creek (B7), showed mixed results with some y values being positive and others negative. A2 had 24 % more silt downstream, with other categories less than 2 mm being very similar upstream and downstream. Wampus Creek had 22 % more clay, and 12 % more silt upstream, but 11 % more sand downstream.

Seven out of fourteen streams showed more sediment (less than 2 mm) in the downstream samples as indicated by positive y values. Three of these streams, A5, A6, and A7, showed that all categories (less than 2 mm) had more than 45 % greater sediment downstream of the crossing. Three more creeks, Eunice (A8), B1, and Prospect (B2), showed 14 to 43 % greater sand, silt, and clay particles downstream of the crossings. Fiddler Creek (B6), had 30 % more sand downstream of the crossing than upstream. Clay and silt values for this stream were fairly similar. Certain sites with much higher sediment downstream of the crossings are of particular concern. This may indicate that on these sites, the crossing has contributed a high degree of sediment to the streambed beyond the amount naturally present.

Further analysis will determine the significance of these findings, and synthesize stream and crossing attributes which may contribute to higher or lower sediment intrusion rates.



Freeze Core Sampling for Sediment Intrusion From Road Stream Crossings in Alberta's Foothills

-A Preliminary Discussion

Liane C. Spillios and Richard L. Rothwell

Freeze-Core Sampling For Sediment Intrusion From Road Stream Crossings in Alberta's Foothills -A Preliminary Discussion

Liane C. Spillios[1] and Richard L. Rothwell[2]

Abstract

Sediment intrusion into streambed gravel can impair aquatic habitat and can negatively affect fish populations. Road stream crossings from industrial development are a primary source of sediment for erosion and sedimentation into Alberta's foothills streams. Local information on the extent and effects of sediment intrusion from road stream crossings is limited, and sampling and monitoring methods suitable for local conditions are poorly developed. Such information is needed to evaluate guidelines and operating ground rules and to perform environmental audits. The purpose of this research is to provide baseline information on the level of sediment intrusion in foothill streams of west central Alberta and to adapt existing freeze-core sampling techniques for local use. The hypothesis selected for testing was, "is the degree of sediment intrusion higher downstream of road stream crossings than upstream?". In this paper, first year observations are reported and used as a basis to discuss the logic and suitability of sampling methods used for sediment intrusion.

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Introduction

Background Information

The Government of Alberta has identified bull trout (*Salvelinus confluentus* (Suckley)) as a species of special concern (Alberta Environmental Protection 1994) and protected it by limiting sport fish limits to zero (Alberta Environmental Protection 1997). The extensive network of resource extraction roads in the foothills may have been a significant factor in the decline of this species. Road stream crossings are a primary source of erosion and associated sedimentation in streams (MacDonald et al. 1991). During rainfall and snowmelt, suspended sediment concentrations downstream of crossings can be high (Rothwell 1983) and can be harmful to fish (MacDonald et al. 1991). Such concentrations can be short-lived, which makes monitoring logistically difficult and often expensive. Following high flows, suspended sediment settles on and into streambed gravels, which can impair aquatic habitat and result in the mortality of incubating fish (Sterling 1992) and benthic aquatic invertebrates (MacDonald et al. 1991). Sediment intrusion can affect fish populations by suffocating fish eggs, hindering the removal of metabolites and preventing newly hatched fish from emerging (MacDonald et al. 1991). It can also disturb benthic macro-invertebrate populations which inhabit the interstitial spaces of streambed gravel (MacDonald et al. 1991).

Sediment intrusion is the focus of this study on the basis that it may result in long term habitat alteration and may have more permanent effects on fish habitat and community structure than suspended sediment loads. Resource industries of Alberta, such as forestry and petroleum, must follow operating rules designed to minimise erosion and stream sedimentation (Alberta Environmental Protection 1994, Canadian Association of

Petroleum Producers 1993). The effectiveness of these guidelines has seldom, if ever, been evaluated. One reason for this may be the lack of reliable methods and the high cost of testing the guidelines and monitoring compliance. Reliable and consistent methods to appraise guidelines and to perform environmental audits are clearly needed, particularly given current Alberta Government policies to downsize and transfer management responsibilities to resource industries.

Study Area

The study area is located in the Hinton-Edson foothill region of west central Alberta. The area is primarily forested with pure and mixed stands of lodgepole pine, white spruce and aspen. Elevations vary from 1000 m near Edson to 2800 m at the Jasper Park boundary. Climate is characterised as continental with cold winters and cool summers. Annual precipitation varies from 500 to 550 mm, with approximately 50 to 60% occurring as rainfall in the summer months (Environment Canada 1996). Runoff regimen is dominated by snowmelt, with the greatest proportion of annual flow occurring in the months of May and early June (see figure 1).

Figure 1. Average Annual Hydrograph (1954-1973) for the McLeod River above the Embarras River Lat. 53 28 10 N, Long 116 37 45 W (Water Survey of Canada 1974)

Soils in the region have developed from glacial material and are characterised by lacustrine and aeolian deposits and till material. Soils in general are highly susceptible to erosion. Sediment transport and deposition in streams from road stream crossings and other similar disturbances are common (Rothwell 1983).

Major rivers in the region are the Athabasca, McLeod, Berland and Pembina. These rivers and their tributaries support wild populations of rainbow trout (Oncorhynchus mykiss (Walbaum)), bull trout, Arctic grayling (*Thymallus arcticus* (Pallas)), and mountain whitefish (*Prosopium williamsoni* (Girard)) (Nelson and Paetz 1992). The area was selected for study because it has an extensive industrial system of roads and road stream crossings developed over the last 40 to 50 years to support forestry, petroleum, and mining industries.

Objectives

The objective of this paper is to discuss the logic and suitability of freeze-core techniques to sample for sediment intrusion in Alberta Foothill streams. We feel that given the early progress of our research, discussion of our methods and the rationale for sampling is a valuable contribution to these proceedings. Full reporting of baseline information on sediment intrusion and information on successful adaptation of freeze-core techniques to local conditions will follow at a later date.

The primary hypothesis selected for testing in this study was "is the degree of sediment intrusion higher downstream of road stream crossings than upstream?". The hypothesis reflects a commonly held belief that sediment intrusion associated with roads has significantly contributed to the deterioration of aquatic habitats (MacDonald et al. 1991, Sterling 1992).

Materials and Methods

Selection of Study Stream Crossings

Twelve road stream crossings (bridges and culverts) were selected for study and sampling. Criteria used for the selection of road stream crossings were based on surface substrate size and similarity of upstream and downstream reaches. The initial focus of the study was to concentrate on evaluating sediment intrusion in substrate suitable as or similar to spawning material for salmonid species endemic to the region. Consultation with local biologists and a review of the literature indicated gravel size 2.5 to 4 cm in diameter was a preferred spawning substrate size for local rainbow and bull trout.

Sampling Within the Stream

One to four paired upstream and downstream sample sites were selected at each road stream crossing based on location of substrate in this size class. Criteria for the pairing the sample locations were, the presence surface substrate the size suitable for local spawning fish (1-4 cm), and similar velocity. Streambed material was sampled using the freeze-core method (Walkotten 1976, Everest et al. 1980). The use of a constant volume method, such as the one described by Rood and Church (1994) was not possible because of the presence of large flat rocks horizontally aligned in the throughout substrate. These large rocks also made removal of frozen core samples very difficult (see figure 2).

Figure 2. Photograph of extracted freeze-core sample with platy rocks.

The freeze-core samples were obtained by driving a hollow steal probe, with a case-hardened conical tip into the streambed to a depth of 30 cm. Dry ice was inserted into the probe causing the stream substrate near the probe to freeze and adhere to the probe. Samples were cooled for 30-40 minutes. Once frozen, the substrate sample was extracted by forcibly rocking the probe back and forth until the frozen sample separated from the surrounding unfrozen substrate. Once separated, the sample was lifted out of the streambed. Following removal from streams, the frozen substrate was carefully removed from the probes by use of a cold chisel. Several well-placed strikes with the chisel and hammer were usually sufficient to fracture the frozen substrate into large pieces that could be bagged and stored while they thawed. Very minimal damage occurred to individual grains or cobbles and very little of the samples were lost by chiselling. The use of a blowtorch to melt the samples was tested but proved ineffective. The top 10-15 cm of substrate was bagged separately from the bottom substrate for comparative purposes. Samples were then thawed, stored, and later analysed in the laboratory for fine sediment content.

A road stream crossing was considered to be a source for sediment intrusion if the downstream samples contained a higher percentage of fine sediment (less than 2 mm) than upstream samples. For the illustrative purpose of this report, all upstream samples for each stream were combined, as were the downstream samples. The comparison between upstream and downstream was calculated as follows:

$$\mathbf{S_A} = \frac{(\mathbf{D_A}-\mathbf{U_A})}{\mathbf{D_A}} * 100$$

where $\mathbf{D_A}$ = percent by weight of sand, silt or clay for all downstream samples of stream A, $\mathbf{U_A}$ = percent by weight of sand, silt or clay for all upstream samples of stream A, $\mathbf{S_A}$ =

percent difference of fine sediment for downstream compared with upstream samples of stream A.

If S_A is greater than 0, then more fine sediment is present in the samples taken downstream of the crossing than upstream. In this case it is assumed that sediment intrusion has occurred with the crossing being the source. If S_A is less than or equal to 0, then there is not more sediment present in the downstream samples than upstream of the crossing. It is assumed, in this case, that sediment intrusion has not occurred.

At each sample location, measures of channel width and depth, and distance to the stream crossing were obtained. Scaled black and white photos of *in-situ* substrates were also obtained for each sample location.

Results

Frozen samples were usually 30-40 cm in length, 15 to 35 cm in diameter, and conical in shape. Samples weighed 11.3 kg on average, but up to 28 kg. 25 % of the samples were greater than 15 kg. The average weight of combined samples in a stream was 52.8 kg.

Seven out of twelve streams showed a greater amount of fine sediment (sand, silt and clay) downstream than upstream. Five streams showed more sediment upstream of the crossing than downstream. Please see figures 3 and 4 for an example of each.

Figure 3. Percent difference of fine sediments upstream and downstream of a road stream crossing showing a greater amount of fine sediment downstream.

Figure 4. Percent difference of fine sediments upstream and downstream of a road stream crossing showing a greater amount of fine sediment upstream.

The overall substrate of sample streams was highly heterogeneous and consisted of gravels, finer sediments, and often large, platy rocks. Table 1 shows the distribution of average particle sizes for upstream and downstream samples.

	Downstream	Upstream
%>25mm	29	40
%>2mm	51	44
%0-2mm	20	16
Total	100	100

Table 1: Average particle size distribution for upstream and downstream samples.

Discussion

Selection of Study Stream Crossings

The selection of similar upstream and downstream reaches at road stream crossings was difficult to achieve. Many stream crossings were characterised by changes in gradients that made upstream and downstream reaches very different. For instance, a channel may have been soft bottomed downstream of the crossing because of a low gradient, while upstream the channel was gravel bottomed and steep. Changing gradients were often a reflection of road location on benches or breaks in slope, or may have been caused by the crossing itself. As such, the sample size was limited, and the use of some criteria, such as the age of crossing, was not possible.

Sampling Within the Stream

The weight of samples using our methodology (average 11.3 kg) was larger than or comparable to methods used by other researchers. Lisle and Eads (1991) used a tri tube sampler and produced samples often 10 to 15 kg. A study comparing several substrate extraction methods by Grost and Hubert (1991) yielded samples averaging 1.4 kg by freeze-coring with carbon dioxide gas, 4.8 kg by excavated coring, and 3 kg by shovel extraction. A review by Rood and Church (1994) indicated the following (see Table 2)

Method Of Sample Extraction	Coolant	Weight of Extracted Samples (kg)
excavated core methods	not applicable	6 to 15
freeze-core sampling with a single tube	liquid carbon dioxide	1.5-2
tri tube corer	liquid carbon dioxide	up to 20
single probe	liquid nitrogen	10-15
modified, constant volume, freeze-core apparatus	liquid nitrogen	maximum 13.5

Table 2: Summary of sample weights extracted using various methods and coolants (Rood and Church 1994)

A greater weight per sample, or at least a larger number of samples to provide a greater sample weight in a given stream would be desirable in order to properly represent larger cobble sizes (Rood and Church 1994).

Future sample collection will address this concern by leaving the samples to freeze for a longer period of time to increase the average weight per sample, and by extracting more samples per stream.

Preliminary illustrative tests display differences among streams for sediment intrusion. Only about half the streams show sediment intrusion from the road stream crossing. Several factors may contribute to the inconsistency. First, there is extreme variability within each stream. Second, outside factors such as the age of the crossing, the degree of reclamation, stability of the stream, and natural sources have not been taken into consideration in this preliminary analysis.

In order to overcome the problems associated variability, future sampling and analysis will attempt to increase the sample size, and the number of samples within each stream. As well, individual samples will be taken from similar habitat types (i.e. pool, riffle, run) upstream and downstream. Future analysis will also include assessing the significance that crossing age, crossing type, and stream and crossing conditions have on the level of sediment intrusion.

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In the 1995/96 season, the Fisheries Management Enhancement/Buck for Wildlife Programs provided major funding, and the Foothills Model Forest (Watershed Division) gave monetary and in-kind support. The Department of Environmental Protection, Fish and Wildlife staff in Edson provided expertise and assistance, and northwest hydraulic consultants ltd. provided a loan of sampling equipment. M. Henry and C. Harper assisted in field work. We would like to thank all of these programs, organisations, and individuals for their valuable contributions. Without them, the first year of study would not have been possible.

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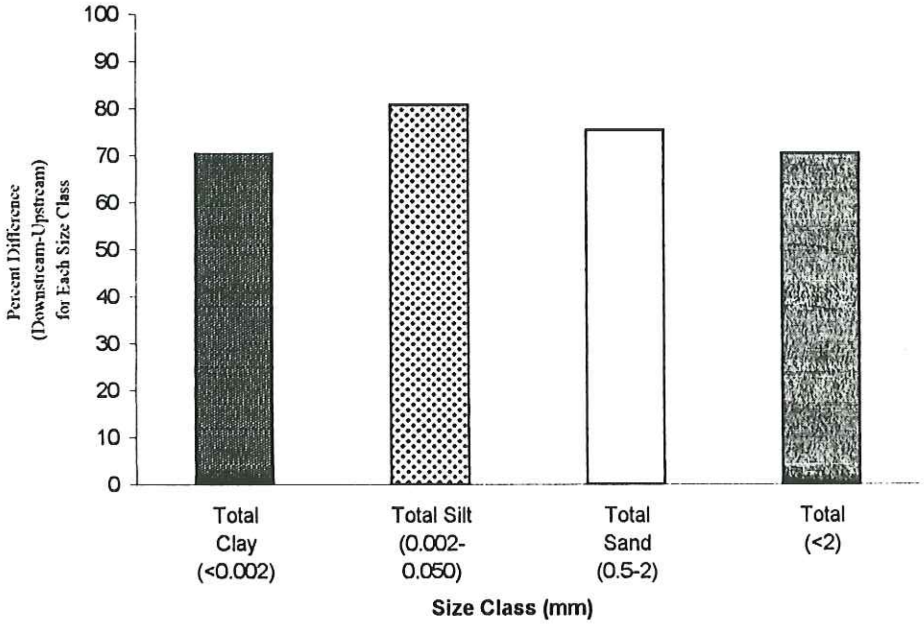


Figure 3. Percent difference of fine sediments upstream and downstream of a road stream crossing showing a greater amount of sediment downstream

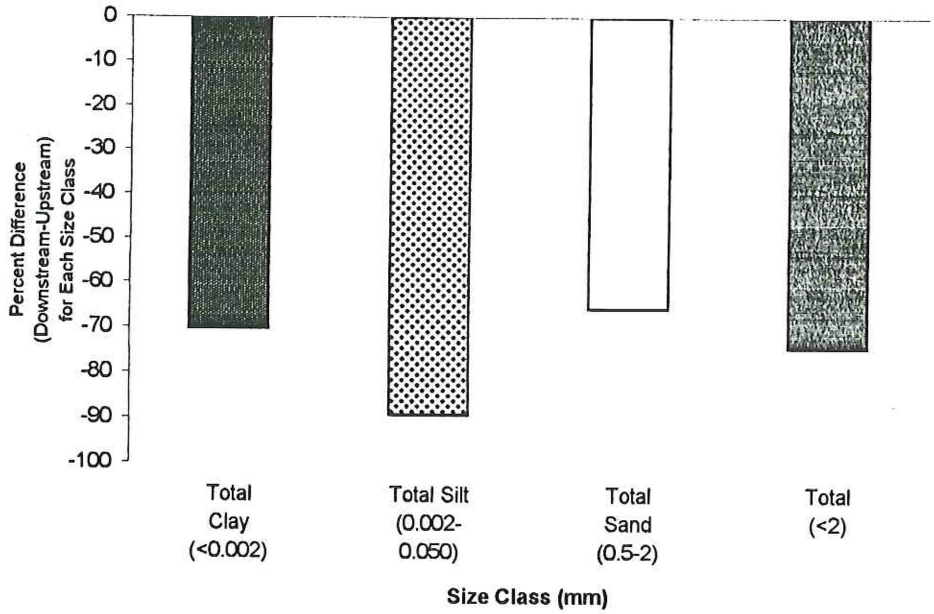


Figure 4. Percent difference of fine sediments upstream and downstream of a road stream crossing showing a greater amount of sediment upstream

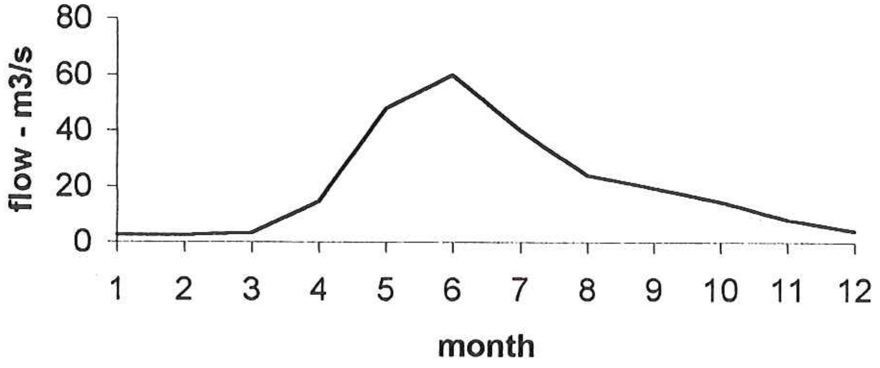


Figure 1. Average Annual Hydrograph (1954-1973) for the McLeod River above the Embarras River Lat. 53 28 10 N, Long 116 37 45 W (Water Survey of Canada 1974)

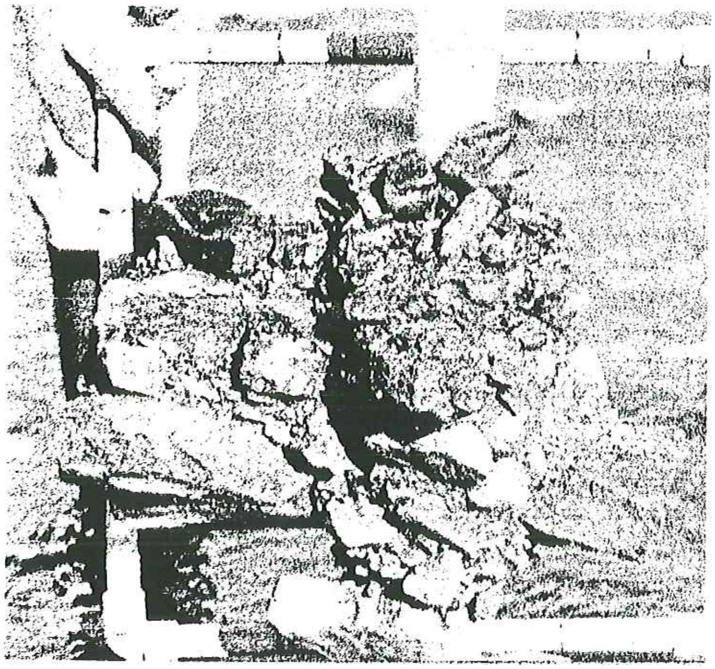
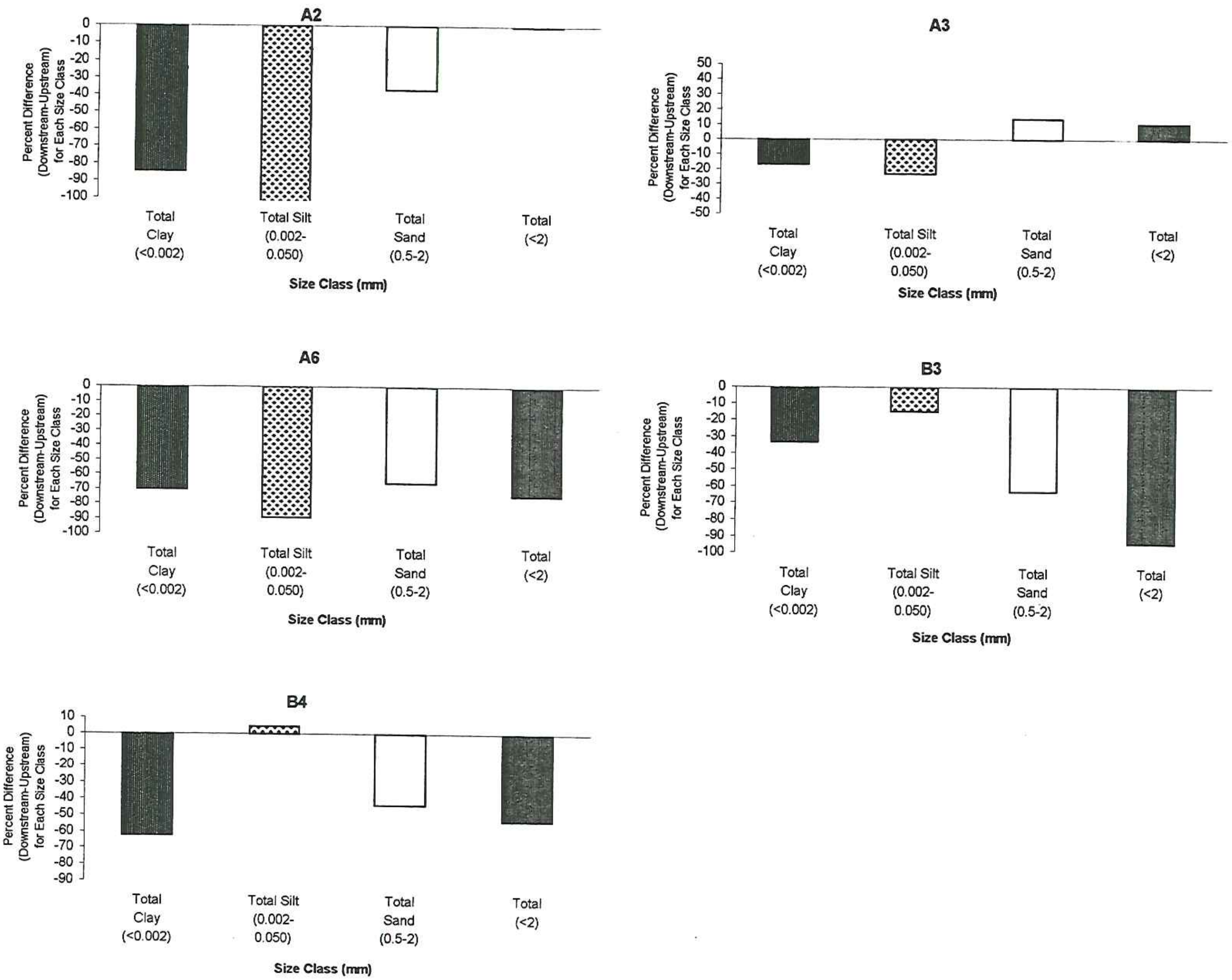


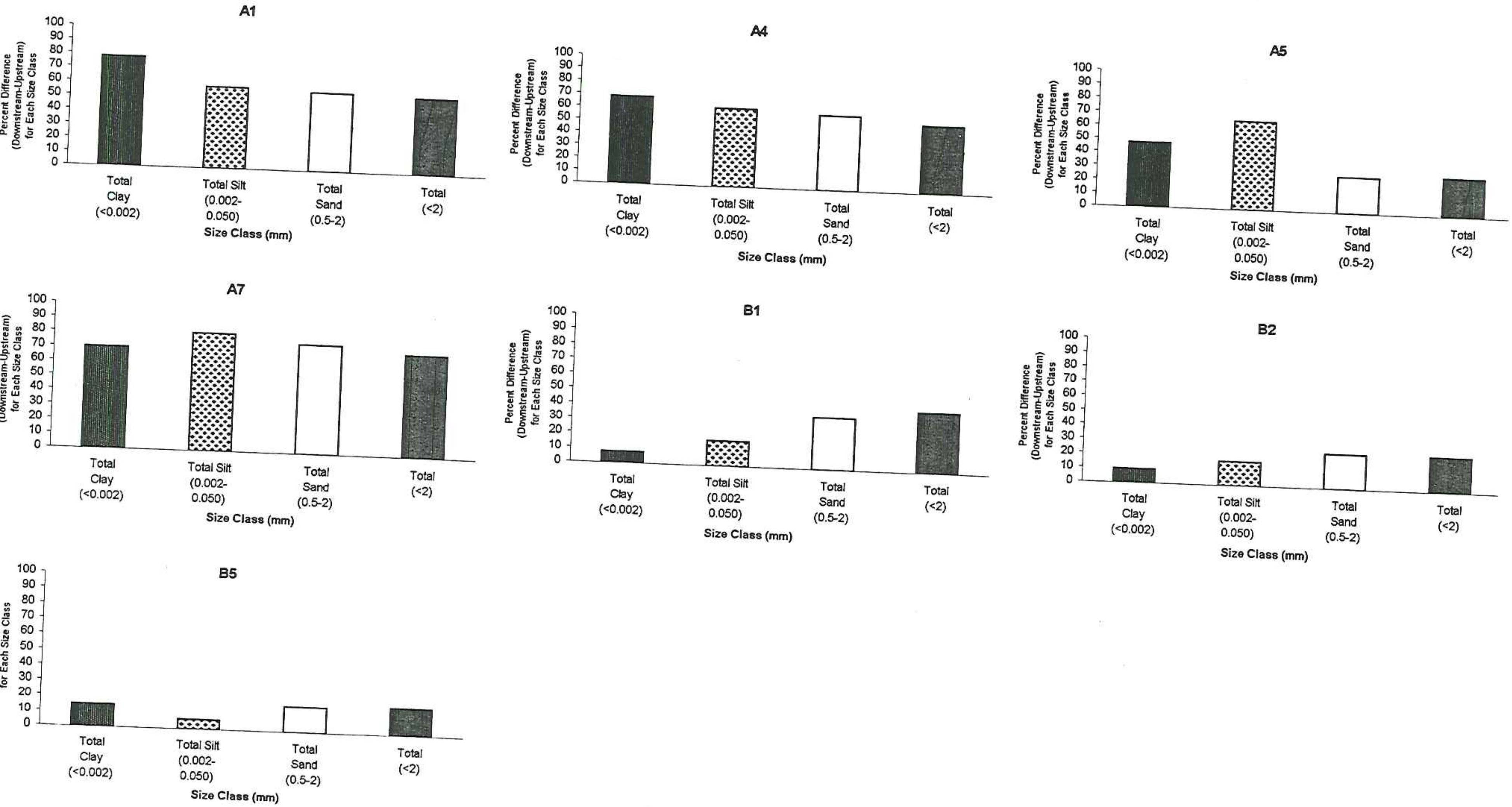
Figure 2. Photograph of extracted freeze-core sample with platy rocks.

photographs by Liane Spilllios



1995 Data

Streams showing greater proportion of particles (<2mm) upstream of the crossings than downstream.



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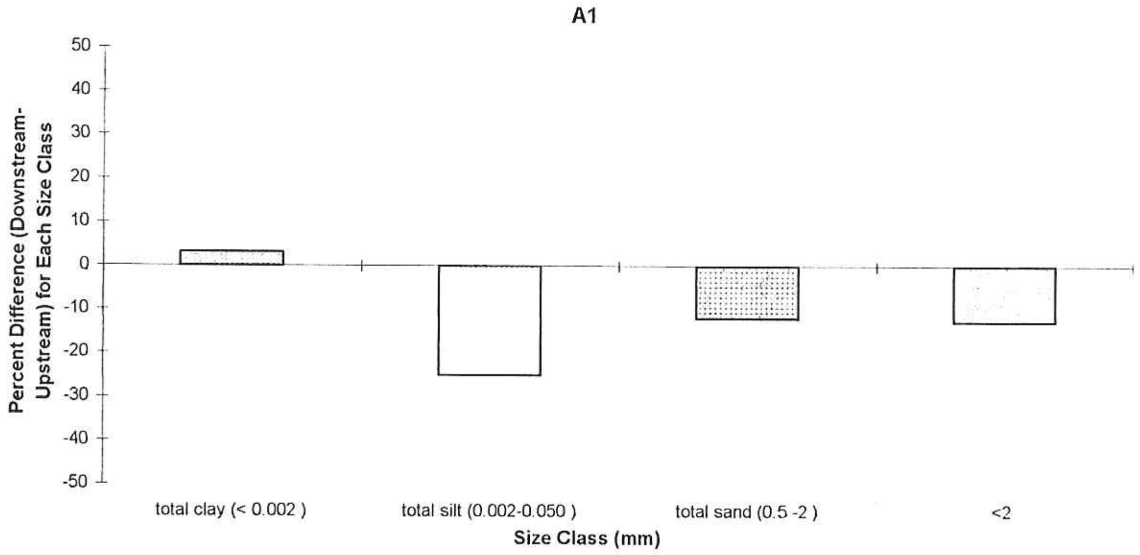

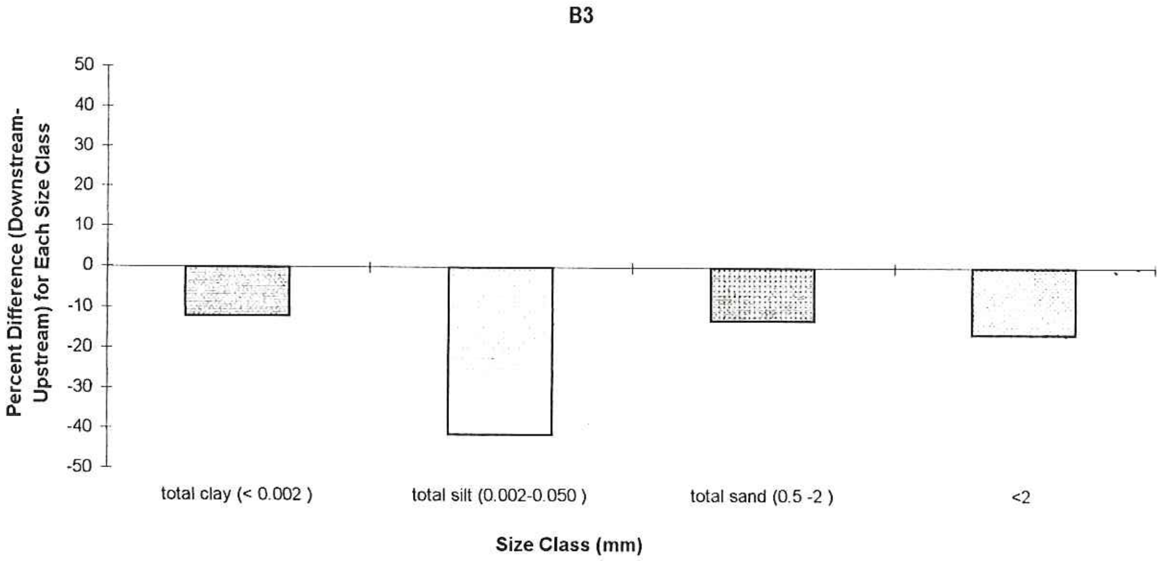

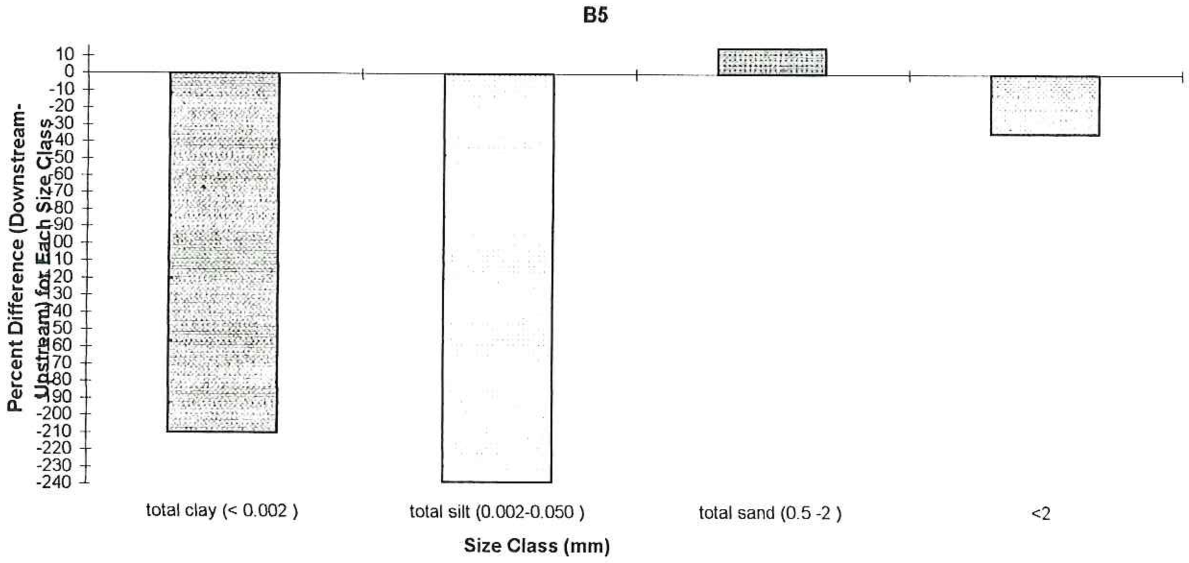

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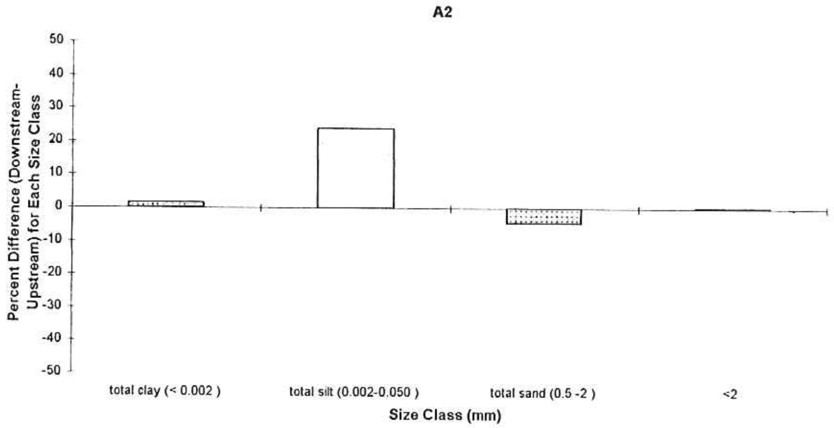

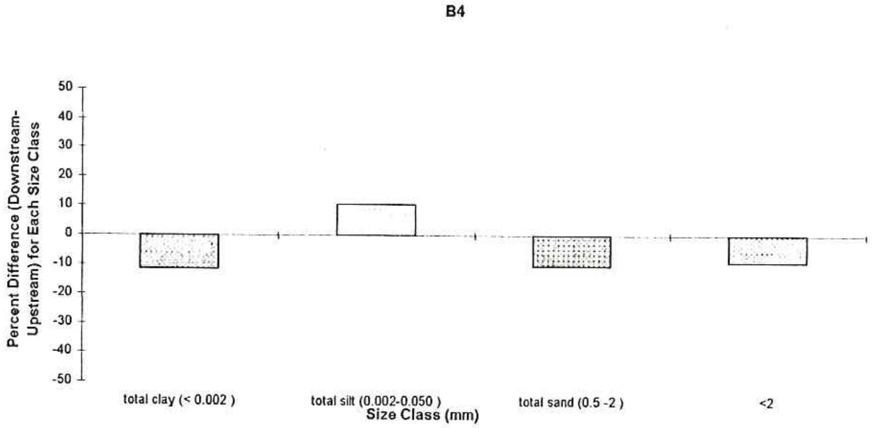

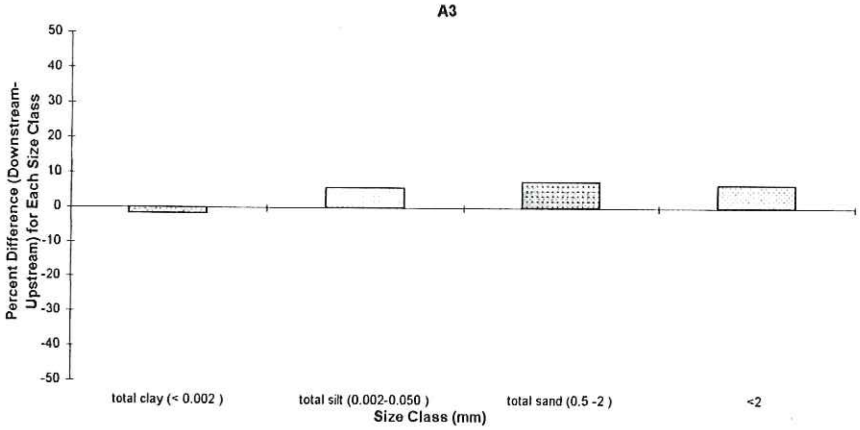

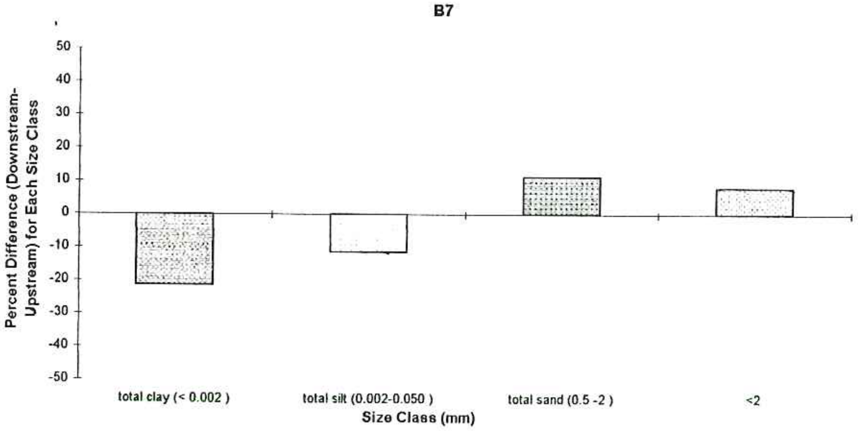

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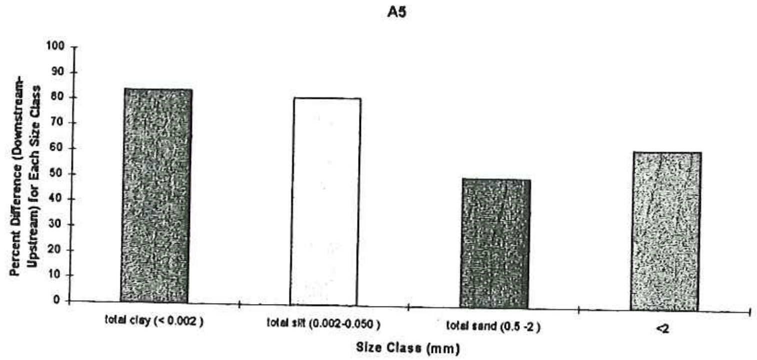

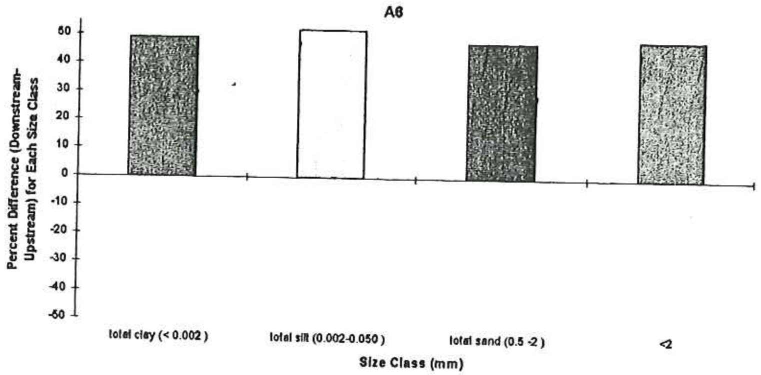

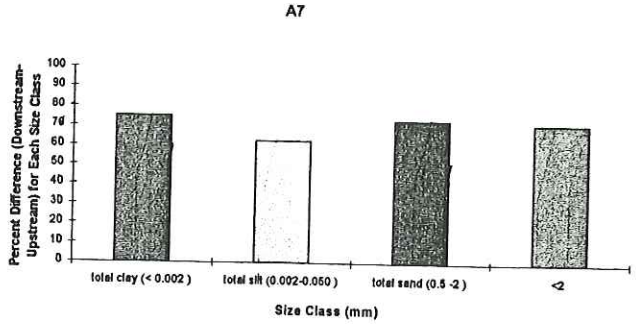

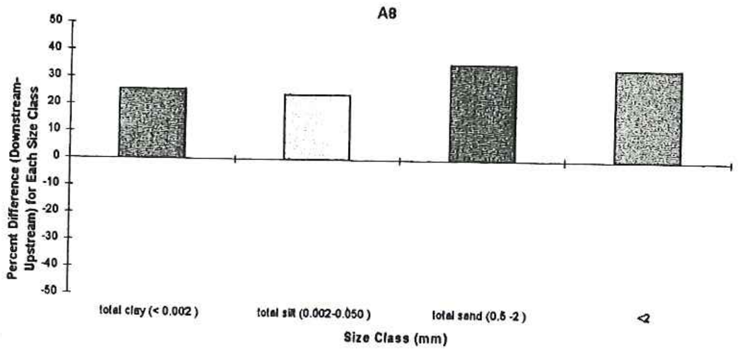

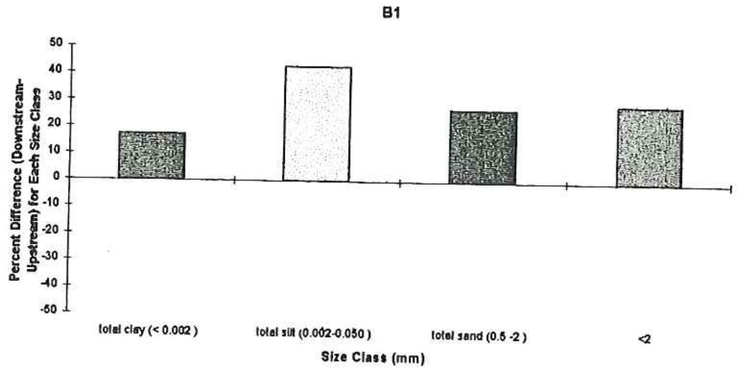

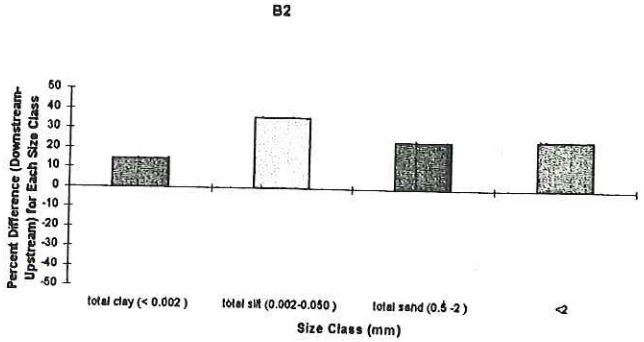

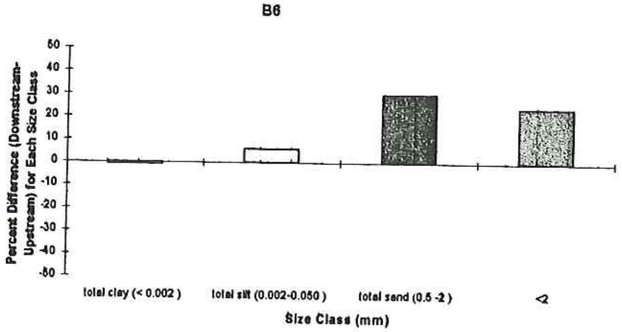

1996 data

Streams showing greater proportion of particles (<2mm) downstream of the crossing than upstream.