The Fraser River Debris Trap
A Cost Benefit Analysis

November 27, 2006

Prepared for the Fraser River Debris Operating Committee
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Cover photo:
Wood debris accumulation in Fraser River debris trap
during spring freshet, 1999

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Executive Summary

This report summarizes the results of a preliminary cost benefit analysis of the Fraser River Debris Trap. The debris trap is located in the Fraser River and on its north bank between Agassiz (District of Kent) and Hope in British Columbia, Canada. The trap captures 25,000 to 100,000 m³ (approximately 600 to 2400 highway logging truckloads) of woody debris during the annual spring freshet. Approximately 90-95% of the debris is of natural origin.

Currently, the net cost of operation of the trap is approximately $640,000 per year, including costs associated with the current funding approach, i.e., funds are raised for the operation annually from a diversity of sources. Even with the trap in operation, approximately 5000 m³ of waterborne debris is generated downstream in the lower Fraser River. This study estimates that the annual cost to manage this amount of debris and mitigate its impacts is approximately $1.59 million per year. Based on a conservative volume of 25,000 m³ of debris captured by the trap per year, it is estimated that if the facility were decommissioned, the amount of debris flowing into the lower Fraser River – and the incurred costs to manage it – would increase by at least six times to $9.55 million per year. This means that an investment of $0.64 million per year results in at least $7.94 million in avoided costs per year for respondents interviewed, resulting in net positive savings of $7.3 million. The net present value over 5 to 20 years of the debris trap is $30 to $90.6 million when using discount rates of 10% to 4%. These are conservative estimates as a low debris capture volume was used for the analysis, and estimates of current debris management costs downstream of the trap are based primarily on information from a limited number of survey respondents. In addition, costs are likely to increase more than linearly with increasing debris volumes.

Information from survey respondents suggests that the various interests that directly avoid costs through the continued operation of the trap include:

- Transport companies and saw mills (less damage to boats and barges, less cleaning of debris from log booms) with at least a 40% share in total avoided costs;
- Municipalities and regional governments (less damage to dykes, seawalls, flood boxes, drainage and other infrastructure, less beach clean-up) with a 24% share;
- Federal government agencies and Crown corporations (less habitat restoration required, less damage to pilot boats) with a 19% share.
- Port and airport authorities (less cleaning up of harbour areas and foreshore infrastructure) with a 13% share.

Furthermore, the debris trap helps avoid costs that are more difficult to quantify, for example:

- Dyke and seawall maintenance (less impact during storms)
- Personal injuries/fatalities (fewer accidents on the Strait of Georgia and the Fraser River)
- Foreshore property repair (less impact during storms)
- Pleasure boat repairs (fewer collisions with waterborne debris)
- Degradation of marshland (less smothering of sensitive marsh areas in the Fraser estuary)
- Log spills (fewer log booms failing due to impact of debris)

The debris trap ensures navigability of the Fraser River during the spring freshet. This avoids negative impacts on revenues of the transportation and recreational sectors. Because of the growing importance of these sectors in particular, and the doubling of the population in the region by 2050 in general, the importance of the debris trap as a cost avoidance measure is likely to increase in the future.

About the Study and Author

The Fraser River Debris Trap Operating Committee (FRDTOC; see Appendix A for current committee membership) oversees the operation of the Fraser River debris trap. The FRDTOC undertook this study to contribute objective information about the costs and benefits of the debris trap to aid in decision-making regarding the development of a long-term funding agreement and governance approach for the facility. The reader should be aware that financial resources for this study were limited. As a consequence, the study relies on a literature review and interviews with individuals and organizations with knowledge of and an interest in the Lower Fraser River and associated uplands. The report recommendations include suggestions for further study.

The author of this study obtained his PhD (2006) in physical geography at Utrecht University in the Netherlands, with a special interest in river hydrology and sediment deposition and with experience in cost benefit analysis. The author thanks John Schnablegger of the BC Ministry of Transportation for supporting this project by providing the Net Present Value analyses in Section 4.3. The author is greatly indebted to all interviewees for their friendly and willing cooperation and interest in the study. The author would finally like to thank Bob Purdy and Deana Grinnell of the Fraser Basin Council for their enthusiasm, patience and background information.

Ivo Thonon

November 2006

Contents

1 Introduction

This report summarizes results of a preliminary cost benefit analysis of the Fraser River Debris Trap (henceforth referred to as the 'debris trap' or simply the 'trap'). The trap is located on the north bank of the Fraser River between Agassiz (District of Kent) and Hope, British Columbia, Canada. Since its commissioning in 1979, the trap has captured from 25,000 to 100,000 cubic metres (m^3) of woody debris per year, approximately 90–95% of which is of natural origin. The trap captures approximately 90% of the driftwood generated by the Fraser River system upstream of the trap. This driftwood consists of woody debris (woody pieces ranging from small twigs to large branches) and snags (tree trunks with the roots still attached). The debris primarily flows down the river during the spring freshet, which typically occurs between mid-May and mid-July as the Fraser River and its tributaries discharge snowmelt and water levels rise. Higher water levels pick up woody debris that has collected during the preceding year along the riverbanks and on sandbars.

Albert Gibson, former captain of the Samson V snag puller about the spring freshet in the 1970s:
"*Sometimes you could walk over the driftwood from New Westminster to Surrey. We could not operate. We would take our holidays and tow the vessel on the dry dock for maintenance for at least two weeks.*"

Before the trap was commissioned in 1979, the lower Fraser River was not navigable at times during the spring freshet due to the massive amounts of floating debris in the river (see box at left). The snag puller vessel *Samson V* worked to keep the river free from snags and deadheads, but it could not work during the freshet and was considered costly and inefficient by the end of the 1970s. Furthermore, there was dissatisfaction among the general public about the amount of debris in the river (Sorensen 1977). Cooperation among the forest industry, the provincial government and the federal government led to the installation of the debris trap. This alleviated a major part of the debris problem (see box below).

Fig. 1. Debris in the Lower Fraser estuary. Source: Fraser River Estuary Management Program

Don Cromarty, dispatch manager, Smit Marine Canada:
"*After installation of the trap, there was a marked decrease in debris. That trap absolutely made a difference.*"

Shortly after the commissioning of the trap in 1979 as a cost-effective debris management measure, Transport Canada (Canadian Coast Guard), the BC Ministry of Forests, and the coastal forest industry entered into an informal arrangement as equal funding partners, contributing $180,000 annually each to operate the facility. Debates over operational funding for the trap have continued since that time. Early in 1999, the trap was close to shutting down due to a lack of funding. During and since that year, the Fraser River Debris Trap Operating Committee (FRDTOC), with the support of the Fraser Basin Council, has been annually raising funds to keep the trap operating (see Appendix A for recent funding partners). Appendix A also provides the 2006/07 budget of $585,000, which covers debris trap operations and maintenance, land leases and permits, insurance, project administration and other expenses. In addition to these operating costs, the members of the FRDTOC incur about $55,000 in in-kind costs, of which about half is incurred for securing of the funds for the trap operations. Including these costs, the trap currently costs approximately $640,000 per year to operate.

The annual budget of $640,000 is a net cost with current debris disposal agreements in place. In response to concerns about deteriorating air quality in the Fraser Valley – the collected debris used to be burned in the open air – agreements have been established between the trap operations contractor and organizations that have a use for debris, such as pulp and paper companies. These agreements provide for the processing and transportation of wood material in the form of hog fuel and chips at no additional cost to the operation. Termination of these agreements in the absence of alternatives could result in a significant increase in debris disposal costs. In addition, future costs for major maintenance items and decommissioning may be significant. Accordingly, the FRDTOC is now seeking at least $100,000 in contingency funding per year in addition to the $640,000 operation budget. Notwithstanding the potential – and as yet undefined – need for future significant costs, for the purposes of this study an annual operating budget of $640,000 is assumed.

The FRDTOC encompasses many of the former and current funding partners and oversees the general operations of the trap (Appendix A). To support discussions toward a long-term funding strategy, the FRDTOC requested that a cost benefit analysis of the trap be carried out. The two main questions the analysis is intended to answer are:

1. What costs for debris management and mitigation of debris impacts are avoided by the operation of the Fraser River Debris Trap?
2. Who benefits from the trap, in what way and to what extent?

> Ike de Boer, engineering services coordinator, District of Pitt Meadows: "*It is a pity they installed the debris trap. I always enjoyed the pretty sight of it when the Samson V passed with the steam coming out of its chimney.*"

To investigate the above questions, a literature study and telephone interviews with potential beneficiaries were undertaken. Potential beneficiaries were defined as companies, government agencies and other organizations that use or otherwise have an interest in the Fraser River downstream of the debris trap, including the communities bordering the Strait of Georgia from Horseshoe Bay to Tsawwassen. From this information, direct quantifiable and non-quantifiable costs as well as indirect non-quantifiable costs were identified. The following chapters give an introduction to the lower Fraser River area, an explanation of the methods used in the analysis, the results of the analysis and the main conclusions of the study.

2 Lower Fraser River and Estuary

The Fraser River estuary, which stretches roughly from just east of Maple Ridge to the Strait of Georgia, is characterized by ten reaches or ecological segments: from brackish marsh to riverine channels, to the outer banks where eelgrass is prominent. The reaches of the river support different habitats and its fringes are characterized by varying degrees of urban and economic development.

Urban settlement has concentrated along the Fraser River in the middle of the Fraser Valley to the east (Fig. 3), and in the diverse Greater Vancouver metropolitan area to the west (Fig. 2). In recent decades, the population of the Greater Vancouver region has grown to over two million people, with suburban communities located over the delta floodplain and transforming the shoreline (FREMP 2003; Fig. 2). Over the next 20 years, it is expected that the region will grow by 800,000 residents to almost 3 million inhabitants (FREMP 2003). People move to this area for its natural beauty and economic opportunities, among other reasons. Many residents live or work along the river, and enjoy visiting the recreational beaches, trails and regional and municipal parks located throughout the region. In short, these factors result in many human activities taking place on and along the lower Fraser River and shores of the Strait of Georgia, and these activities are likely to increase over time as the population grows (Table 1).

Table 1. In-river and foreshore activities on and along the Fraser River and its estuary.

In-river activities	Foreshore activities and land uses
Transportation (via bridges and other infrastructure)	Port activities
Commercial shipping	Water dependent and other industry
Recreational boating	Parks and beaches
Water sports	Residential and commercial development
Commercial and sport fisheries	Agriculture
Log storage	Heritage properties and historic sites
Public transportation/ferries	Dykes and foreshore infrastructure
Float plane services (landing and takeoff)	
Bird habitat and flyway	River used for landing, food, etc.
Historical	Related archaeological sites
Salmon spawning	

Foreshore land use in the Fraser River estuary is primarily recreational, followed by industrial and agricultural uses (Fig. 1). Note that the industrial land use is heavily water dependent, with 87% of the sites depending on location at or near water (FREMP 2003). Between 1979 and 2001, more intensive land use has occurred, with a decline of almost 50% in agricultural and open land and an increase in other categories (FREMP 2003). Fig. 2 shows the land use distribution by type for the Greater Vancouver Regional District (Please see Appendix B for larger graphics of the land use images for GVRD and FVRD).

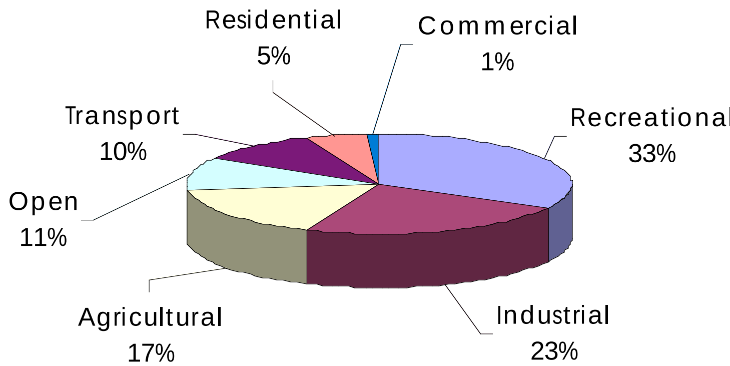

Fig. 1. Land use in the Fraser River estuary. Adapted from FREMP (2003). Geographically, the Fraser River Estuary Management Program (FREMP) applies to the Fraser River side of the dyke downstream from Kanaka Creek (east of the town of Maple Ridge) and Pitt Lake to the Strait of Georgia. The FREMP area also includes Sturgeon Bank, Roberts Bank and Boundary Bay.

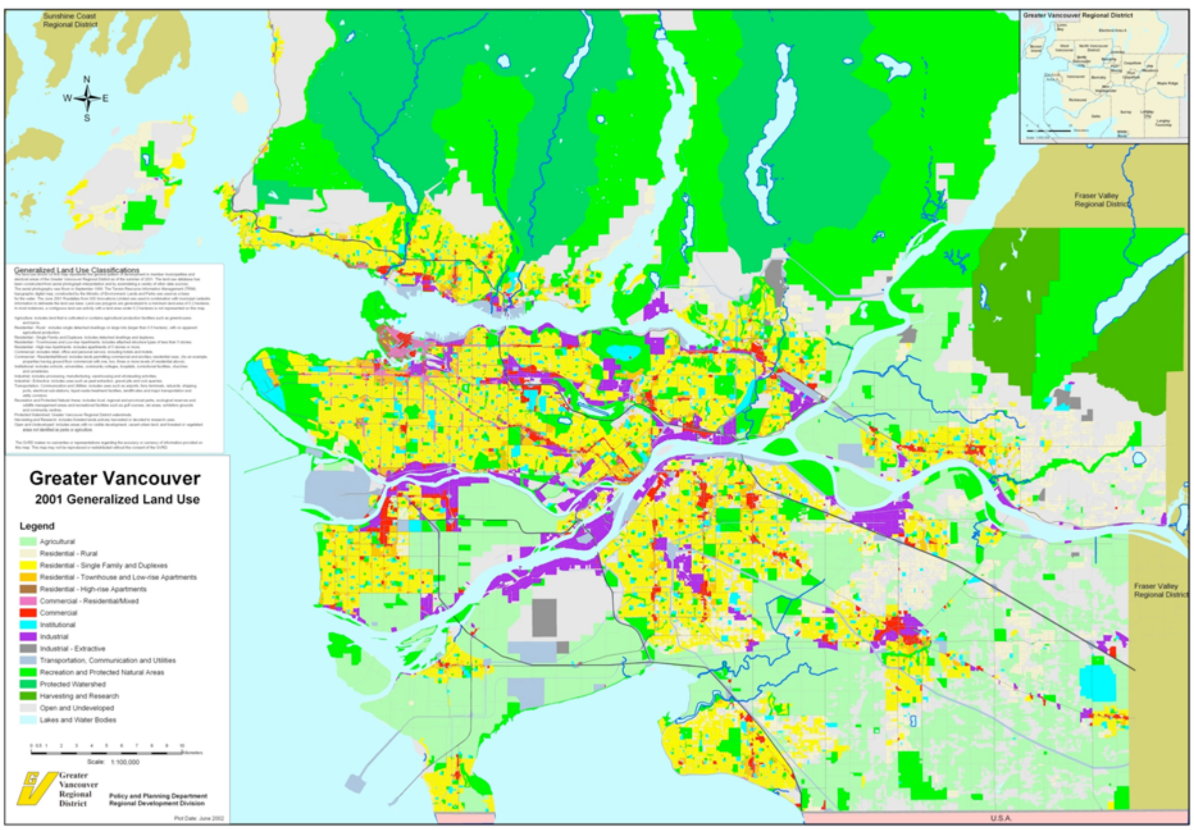

Fig. 2. Land use in the Greater Vancouver Regional District bordering the Fraser River estuary. Source: Greater Vancouver Regional District (GVRD).

Foreshore land uses east of the town of Maple Ridge along the Fraser Valley to the debris trap site include residential, commercial farming, recreational, managed forest lands, utilities and industrial (Fig. 3). Of these, residential, farming and forestlands are the primary uses. The Fraser Valley Regional District provided information regarding land and improvement assessments for properties within 500m of the Fraser River – many of which are on the foreshore – showing that the assessed values reach over $500 million, with half of this value in land values and the other half in improvements.

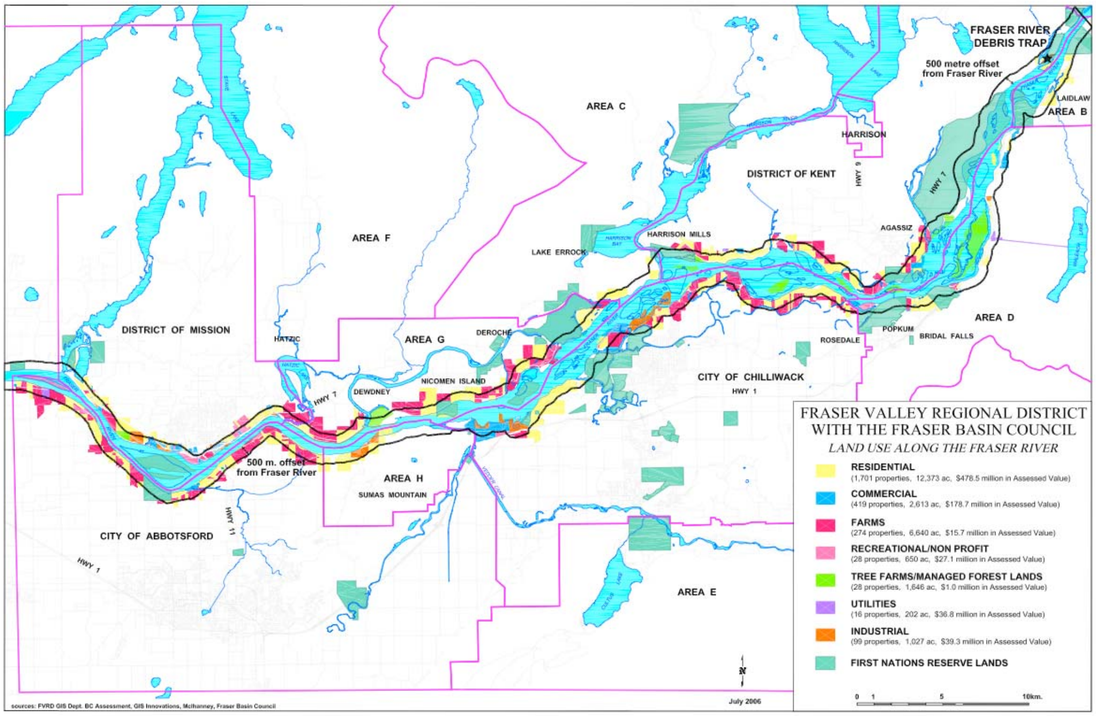

Fig. 3. Land use directly bordering the Fraser River in the Fraser Valley Regional District. Source: Fraser Valley Regional District (FVRD).

Economic activities take place both on uplands and on the river itself. The Fraser River is an important marine transportation route. Barge traffic, international deep-sea vessels such as container ships and bulk carriers, commercial and sport fisherman and recreational boaters all use the Fraser River. The major part of the $26 billion in trade via ports between British Columbia and other countries (Government of Canada 2005) takes place via facilities overseen by port authorities in the Lower Mainland. With the Pacific Gateway Strategy of the federal government this marine transport role is likely to increase (Government of Canada 2005). Dredging undertaken by the Fraser River Port Authority maintains the main navigation channel. Log storage areas located throughout the estuary are also a key component of forest industry operations, as many booms are stored in the river prior to transport to mills for processing.

The estuary also contains rich habitats for many species of fish and wildlife. As one of the largest estuaries along the west coast of North America, the Fraser River estuary is a globally significant ecosystem (FREMP 2003). The estuary's marshes support millions of migrating salmon at a critical stage in their early development before they migrate out to sea, and act as a staging area for adults preparing to migrate upstream to spawn (FREMP 2003).

3 Cost Benefit Study Methods

This study assumes that the benefits of the trap are the actual avoidance of costs of downstream mitigation of debris impact and restoration of impacted structures and other assets. Cost avoidance was assumed to result from minimizing the adverse effects of waterborne debris flowing downstream of the trap.

The approach undertaken to determine avoided costs assumes the following:

avoided costs = **the costs that would be incurred without a trap in place** – **presently incurred costs**

Although the trap captures a significant quantity of woody debris, some downstream sources also contribute waterborne debris to the lower Fraser River. Managing this debris and any debris flowing downstream at times other than during the spring freshet (when the trap operates) results in presently incurred costs (Section 4.2).

This study assumes that the costs for debris management would increase by the same factor as the increase in volume of debris that would flow down the river in the event the trap was not operational. This approach assumes that debris volumes captured by the trap and generated by downstream sources are linearly related to the costs for debris management and mitigation. This simplistic assumption is probably not the case: the interview data show that the impacts of debris flows and related costs in many cases increase more than linearly as debris volumes increase (see Chapters 4 and 6). For instance, a log spill may occur only after passing a certain threshold in the volume of debris hooking to the log booms. Below this threshold, nothing happens, but above the threshold, the debris creates enough drag to rupture the cords holding the log booms and a log spill may occur, incurring a costly clean up. The assumption of a linear relation between debris volumes and incurred debris impact and management costs yields a conservative estimate of the costs without a debris trap.

In order to derive a value for the costs presently incurred for dealing with debris impact, telephone interviews were conducted and literature sources studied. The interviews were conducted from June 19 to July 13, 2006 with 79 interviewees from a wide range of companies, government agencies and non-governmental organizations (Table 2). See Appendix C for the list of interviewees, and References for literature sources.

*Table 2. Breakdown of interviewed groups (*n = *78).*

Group of interviewees	Part of total [%]
Employees of commercial companies	34
Municipal employees	28
Employees of NGOs	22
Federal, regional, provincial employees and employees of Crown corporations	9
Individuals/retired persons	8

The reader is cautioned that the interview sample did not reach all potential stakeholders of the debris trap due to limited time and resources for the study. Please refer to the notes in Chapter 4 and the recommendations in Section 7.2 to see which potential stakeholders lack sufficient sample coverage. The reader is also cautioned that the interviewed organizations were considered *potential* stakeholders of the trap. In other words, some interviewees may have indicated that their organization does not benefit from the debris trap or would incur no negative impact from debris flows whatsoever. The list in Appendix C however contains the names and affiliations of *all* interviewees, including those who indicated that waterborne debris did not affect them or their organizations.

Interviewees were asked the following questions:

1. How does waterborne debris currently affect your organization/interest and how do you deal with it?
2. What costs do you currently incur for debris management or mitigation of debris impacts (lost operations, repair costs, debris removal, etc.)?
3. How would a major increase in debris flows in the river affect your organization and/or its operations?
4. What did your organization do about debris prior to 1979 and what impacts did you observe then?

Chapter 4 provides the direct, quantifiable cost savings based on the results of the interviews, literature study (Munday 1997; FBC 1999; WLSSC 2005) and in one case, on extrapolation. Chapters 5 and 6 provide an overview of the non-quantifiable and indirect costs that the trap helps to avoid. If the interviewee provided a range of costs, this study relied on the lower end of this range. Furthermore, cost estimates for years prior to 2006 were corrected for inflation using the *Inflation Calculator* (Bank of Canada 2006). This study uses the figure of $640,000 as the total annual operating cost for the debris trap, and a conservative 25,000 m^3 capture volume.

4 Direct, quantifiable costs avoided by the trap

The direct, quantifiable costs due to the impact of debris today, with an operating debris trap in place, are estimated to be $1.59 million *for the interviewed stakeholders*.

- More than 40% of these costs arise from damage to boats and infrastructure.
- Debris cleanup accounts for nearly 40% of the costs.
- Of this amount, governments pay 56% of the costs, while the private sector pays 41% (*note however that government agencies were probably more accurately covered in the sample than private sector companies*).

Without an operating debris trap the costs incurred for debris management and impact mitigation are estimated to be about $9.55 million based on extrapolation of the current costs for debris management.

An operating debris trap may contribute to avoiding, at a minimum, $7.94 million in costs, which generates **a net result of $7.30 million in costs avoided** and **a benefit/cost ratio of more than 12**. This means that the trap may help to avoid at least 12 times the current cost of trap operations.

The estimated **net present value** of the debris trap ranges between **$30 million over 5 years up to $90.6 million over 20 years**.

4.1 Presently incurred costs

With a working debris trap, the estimated costs to mitigate waterborne debris amounts to almost $1.6 million. Table 3 below shows how the expenses are distributed across repairs and various types of cleanup. Table 4 below shows how the estimated costs are distributed across the various sectors.

Table 3. Annually incurred costs (by category of expense) due to presence of waterborne debris in the lower Fraser River region and the Strait of Georgia (from West Vancouver to Tsawwassen) and the amount of avoided costs because of the presence of the debris trap.

Category	Subcategory	Annual Costs [$]	Annually avoided costs [$]	Part of total [%]
Repairs		***711,760***	***3,558,800***	***44.9***
	Boats	654,560	3,272,800	41.2
	Docks/wharves/piers	57,200	286,000	3.6
Cleanup		***591,360***	***2,956,800***	***39.0***
	Beaches	300,000	1,500,000	18.9
	Harbours	197,860	989,300	12.5
	Log booms	31,000	155,000	3.3
	Foreshores [1]	26,500	132,500	2.0
	Bridges	20,000	100,000	1.3
	Flood boxes	16,000	80,000	1.0
Habitat restoration		***256,000***	***1,280,000***	***16.1***
Grand total		**1,587,120**	**7,935,600**	**100.0**

[1] Includes float homes.

The incurred costs mentioned in Table 3 relate to a wide variety of debris impacts. Boat repairs mainly consist of propeller repairs of pilot boats, tugboats, water taxis, fishing boats and other powerboats after these have encountered submerged debris (mostly deadheads and snags). Occasionally, hull repairs are also necessary. During storms, collisions of large woody debris with wooden construction such as wharves break their pillars, which need to be replaced in order to preserve the integrity of the structure. Beach cleanup is often necessary after storms have deposited massive amounts of woody debris onshore, and harbours need to be cleaned in order to prevent propeller damage. Clearing log booms of entangled debris is necessary to prevent the occurrence of log spills. Flood boxes and bridge pillars and footings also entangle woody debris. In both cases, the debris has to be removed because it impedes the flow of water. In the case of flood boxes, this sometimes requires the use of divers (Carrie Baron, City of Surrey). Habitat restoration is necessary when woody debris piles up in sensitive marsh area and threatens the survival of a range of species (see also item 7 in Chapter 5).

T*able 4. Annual incurred and avoided costs by sector due to waterborne debris in the lower Fraser River region and the Strait of Georgia (from West* Vancouver to Tsawwassen) and the amount of avoided costs because of the presence *of the debris trap..*

Category	**Subcategory**	**Annual Costs [$]**	**Annually avoided costs [$]**	**Part of total [%]**
Public sector		***896,360***	***4,481,800***	***56.5***
	Federal total	*498,860*	*2,494,300*	*31.5*
	Port authorities	197,860	989,300	12.8
	Other federal	296,000	1,480,000	18.7
	Municipal/regional	377,500	1,887,500	23.8
	Provincial [1]	10,000	50,000	0.7
Private sector		***653,760***	***3,268,800***	***41.2***
	Transport companies (BC Ferries, marine carriers, TransLink) [1]	631,760	3,268,800	39.8
	Sawmills	22,000	110,000	1.4
Citizens		***37,000***	***185,000***	***2.3***
	Pleasure boat owners	31,000	155,000	1.9
	Float homeowners	6,000	30,000	0.4
Grand total		**1,587,120**	**7,935,600**	**100.0**

[1] The BC Ministry of Transportation carries out maintenance of bridges overseen by Translink in the Lower Mainland (the Knight Street Bridge and the Pattullo Bridge). Hence, the bridge cleanup budget of Table 1 of the Ministry is split between the provincial government and transportation companies.

The following notes apply to the estimated costs in Tables 3 and 4 above:

- The author found it easier to reach representatives of the 'Public sector' for interviews than representatives of the other categories in Table 4, possibly resulting in over representation of the 'Public sector' in the cost breakdown.
- Most of the data included in subcategory 'boats' in Table 3 and 'transport companies' in Table 4 is based on a representative sample (n = 6) of members

of the Council of Marine Carriers (CMC) and extrapolated to all 31 members of the CMC.

- Table 3 provides only the costs revealed by the interviewed 'Pleasure boat owners' (*n* = 2), 'Float homeowners' (*n* = 2) and 'Sawmills' (*n* = 3). Since these samples are limited and non-representative, the analysis did not attempt to extrapolate these costs. Chapter 5 discusses the costs for these three categories as non-quantifiable costs.
- For Table 3, the under-sampling of the subcategories 'Pleasure boat owners', 'Float homeowners' and 'Sawmills' of Table 4 probably means that the subcategories 'Boats', 'Docks/wharves/piers', 'log booms' and 'foreshores' are under-sampled as well.

> Kevin Obermayer, Chief Operational Officer, Pacific Pilotage Authority Canada: *"We decided to replace our propeller boats with jet-propulsion boats. Although they are more expensive, we will have to expense less money on propeller repairs due to debris impact."*

Costs for exceptional cases of deleterious impact can be higher than normally incurred per stakeholder per year. Since these events occur infrequently, these costs were omitted from the analysis to avoid skewing the year-to-year numbers. Nevertheless, for the sake of completeness, below is an overview of costs incurred due to unique events within the lower mainland:

- During a recent storm, wood debris pushed inland by the storm impacted the pillars of the Ambleside pier in the District of West Vancouver. This induced the collapse of the pillars and the demolition of the pier. The District rebuilt the pier at a cost of $200,000 (Bill McCuaig, District of West Vancouver).
- The Albion Ferry encountered woody debris on the Fraser River during an exceptionally extreme and unseasonable debris-loaded winter thaw a few years ago. The debris jammed the drive legs, leaving the ferry without steering capacity. This resulted in the ferry running into the dock. The provisional repairs of the dock cost $50,000 to $100,000, but a long-term solution would probably have cost $200,000 (John Stoneson, Albion Ferry).
- A marine carrier using a vessel with a propeller contracted a deadhead in the nozzle. Due to the size of the ship, this cost $500,000 in repairs (Rick Plecas, Seaspan Coastal Intermodal).
- A severe storm in February, 2006 cost the City of White Rock $18,000 in beach clean up costs (Dale Kitsul, City of White Rock). The storm had put massive amounts of woody debris on the beaches (cf. Fig. 4), which the municipality subsequently had to remove.

Fig. 4. Woody debris on a southern Strait of Georgia shoreline. Note the potential for the debris to impact nearby properties during a severe storm. Source: Fraser Basin Council.

4.2 The estimated costs avoided by the trap

To extrapolate the current costs incurred due to negative waterborne debris impact, it is necessary to have a balance of the volumes of waterborne debris entering the debris trap, bypassing the trap and entering the Fraser River downstream of the trap. Doug Cooper (Gulf Log Salvage) provided a tentative 'wood budget' outlined in Table 5.

Table 5 indicates that without an operating debris trap, at least six times more woody debris volume would come down the Fraser River to enter its lower reaches, the estuary and the Strait of Georgia. Using the factor six as the multiplication factor, and the estimate of current debris management costs by stakeholders downstream of the trap at $1.59 million, the costs due to debris impact in the absence of an operating debris trap would be $9.55 million. After subtraction of the current costs for debris management ($1.59 million with a debris trap in place) the direct cost savings currently attributable to the trap are $7.94 million. In other words, the benefit to cost ratio for the debris trap is 12.4, with a positive net result of $7.30 million per year.

Table 5. Tentative 'wood budget' for the lower Fraser River, with annual amounts floating down.

Source/Sink	Debris [m^3]	Comment
Fraser Basin	26,000	Mainly generated during spring freshet
Harrison River	1,000	Natural source downstream of debris trap
Chilliwack River	2,000	Natural source downstream of debris trap
Pitt River	1,000	Natural source downstream of debris trap
Other natural and human sources	2,000	Mainly human and some natural sources downstream of debris trap (spillage, industrial damage, missed logs, picked up logs from beaches during high tide, boom sticks that break, escape from debris bags)

Subtotal coming downstream	***32,000***	
Debris trap	–25,000	Trap captures most (25,000 m³ out of 26,000 m³ generated above trap). Most of captured material recycled as hog fuel and wood chips
Various sinks	–2,000	Personal use for fire wood, root bucking/log salvage, shake & shingle, removal by debris bags
Total est. debris volume coming downstream with operating debris trap	**5,000**	
Total est. debris volume coming downstream *without* operating debris trap	**30,000**	The present amount of woody debris coming down increased with the amount currently captured by the debris trap
Estimated multiplication factor	6	Estimated magnitude of increase over current volumes in the event debris trap is not in operation.

Two notes apply to this approach:

- The volumes of waterborne debris annually captured by the debris trap (25,000 m^3) and naturally generated downstream (4000 m^3) are based on a low spring freshet scenario during which less debris is transported. Earlier studies used higher estimates of 90,000 m^3/y (Munday 1997) or 75,000 m^3/y (Golder 2001) of debris captured by the trap. Currently, these estimates of average long-term capture amounts are believed to be in the range of 45,000–55,000 m^3 per year (Jim Girvan, formerly Industrial Forestry Service). However, interviewees and literature specifically gave cost indications for the last ten years. During these recent years, low spring freshets have typically prevailed (Doug Cooper, Gulf Log Salvage; Terry Slack, Fraser River Coalition; Don Cromarty, Smit Marine Canada). Consequently, a low estimate for the amount of captured debris ensures consistency with the period over which the stakeholders incurred costs. Another advantage of this approach is that it also yields a conservative estimate of the direct, quantifiable costs avoided by the operation of the debris trap.
- This approach does not take into account the loss of economies of scale that would occur if the debris trap were removed, potentially resulting in more costly "piece by piece" management practices. To give an indication of the magnitude of this loss, the current costs per cubic metre of captured debris were recalculated to 1997 dollars and compared to Munday (1997). Fig. 5 indicates that the debris trap is a particularly cost-efficient solution for debris management, even when a conservative estimate for the amount of captured debris is used. The conclusion in Munday (1997) that the debris trap is one of the "*most economical means to remove wood debris from the lower Fraser River*" therefore still appears valid.

> Sorensen (1977): *"Scaled down on a financial level, the expenditure of each dollar by the board [that oversees the operation of the debris trap] can mean a cost-saving to the public of at least two dollars or more. Statistics show that damage to fishing and pleasure boats from water-borne debris is between $800,000 and $1.5 million a year."*

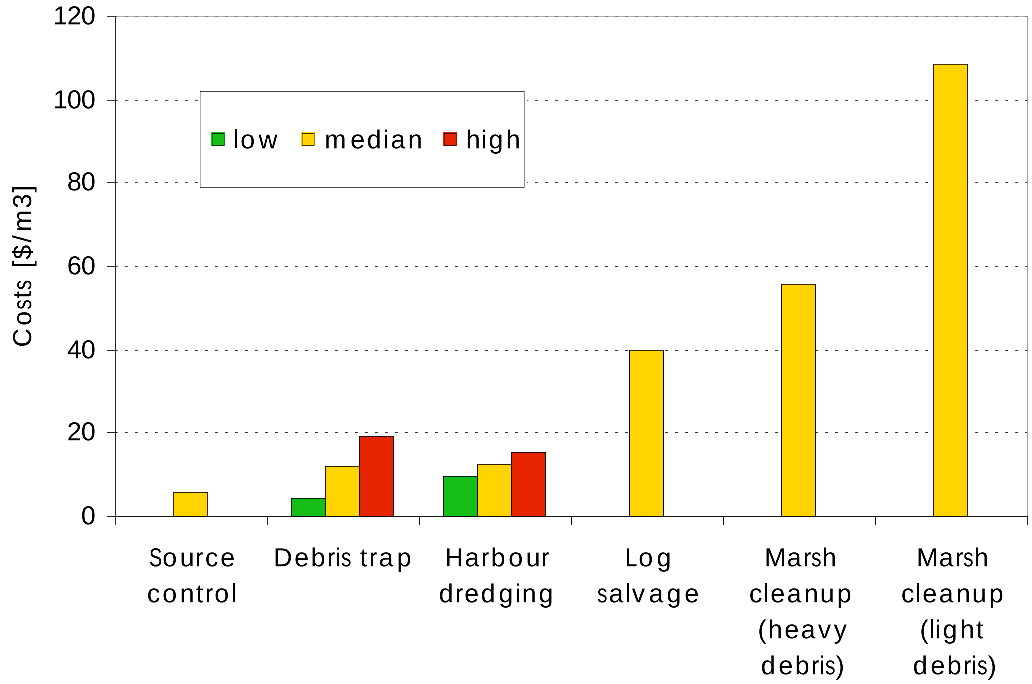

Fig. 5. Low, median and high cost estimates per cubic metre of collected woody debris for different collection methods. Adapted from Munday (1997). Note that the costs are in dollars for 1997. The high estimate for the debris trap is recalculated from the 2006 figures using only direct trap costs ($585,000, Appendix A) and a capture of 25,000 m^3 of waterborne debris, with the result recalculated to 1997 dollars using Bank of Canada (2006). The low estimate for the trap is from Munday (1997), the median is the average of the high and low estimate.

4.3 Net present value

The net present value (NPV) methodology reduces a stream of costs and benefits to a single number in which costs or benefits forecasted to occur in the future are discounted by an interest rate that reflects the value of money over a specified investment period. The BC Treasury Board prescribes this interest rate, which is currently 6%. However, since the interest rate may vary over the period used in NPV analysis (5 to 20 years), different scenarios with interest rates at 4, 6, 8 and 10% have been calculated to explore future value of avoided costs (Table 6).

The results in Table 6 show that the net avoidance of costs by the trap may return $26.2 and $90.6 million in benefits (as future avoided costs) over the next 5 to 20 years when using 10% and 4% discount rates, respectively. This suggests that the debris trap will return more in value of avoided costs than it costs to operate, and is therefore economically feasible.

Table 6. Results of the NPV analysis using the annual net result from Section 4.2 as input.

Period	**Discount Rate**			
	4%	6%	8%	10%
5 year period	$30,720,000	$29,070,000	$27,550,000	$26,160,000
10 year period	$51,310,000	$46,940,000	$43,110,000	$39,740,000
20 year period	$90,640,000	$77,000,000	$66,280,000	$57,730,000

4.4 Future developments and uncertainties

When extrapolating to the future, uncertainties arise. This section discusses these uncertainties as they apply to the outlook given by Sections 4.2 and 4.3. This section nevertheless also applies to the following chapters. The following uncertainties and new developments with respect to volumes and impacts of waterborne debris are to be borne in mind:

Climate change

Both in 1987 and 1999 the Fraser River experienced an exceptionally strong spring freshet (Doug Cooper, Gulf Log Salvage; Bob Purdy, Fraser Basin Council). The volume of debris floating down was estimated to be 100,000 m^3 in 1999. Climate change models indicate these exceptional discharge events could happen more frequently in the future. The general variability in temperature and precipitation increases globally (IPCC 2001). In the Fraser River Basin, the amount of snow falling during winter in the highest parts has already increased over the last 41 to 63 years with 4% to 6% per decade and may continue to increase (BC MLAWP 2002). In the future, the combination with higher spring temperatures and earlier thawing of tributaries in the basin (BC MLAWP 2002) may give rise to more frequent peak discharges such as the events in 1987 and 1999.

Economic and demographic developments

Currently, around 2 million people live in Greater Vancouver. The number of inhabitants will probably increase to 3 million in 2025 (FREMP 2003) and double to 4 million in 2050 (UBC 2006). This increase in population will most certainly give rise to more economic development in the region and a further intensification of the land uses along the shores of the Fraser River. In addition, the Pacific Gateway Strategy of the federal government aims to strengthen the infrastructure in the Fraser River estuary thereby increasing the importance of the river and the ports for trade (Government of Canada 2005). The promotion of the Fraser River as an alternative short sea-shipping route to complement road transportation will further enhance the river's role as a transportation axis. All of these developments increase the vulnerability of the infrastructure and properties on and along the Fraser River to the impact of waterborne debris. According to the following equation, this means that the risks of debris impact increase, even if debris volumes and impact probabilities would remain constant:

$$\text{risk} = \text{vulnerability} \times \text{hazard}$$

With risk = the total amount of costs resulting from debris impact [$], vulnerability = the amount of assets the debris can affect [$] and hazard = the probability of debris impact [between 0 and 1].

5 Direct, non-quantifiable avoided costs

Direct, non-quantifiable cost items avoided with an operating debris trap are noted below in order of highest to lowest estimated magnitude:

1. **Less sea dyke and seawall repair and maintenance** due to reduced deleterious impacts of deadheads and snags mainly during storms;
2. **Fewer accidents, injuries and fatalities** due to reduced collisions with waterborne debris;
3. **Less repair and replacement of damaged property**, float homes and public utilities on seaside boulevards;
4. **Fewer pleasure boat repairs** – mainly propellers;
5. **Less debris cleanup due to break up of water-stored timber booms**, which collect woody debris during storage;
6. **Reduced interference with port operations**, due to reduced impact of debris with tugs and propellers of berthed deep sea vessels;
7. **Less degradation of marshland**, mainly because of reduced smothering of the marshes by waterborne debris;
8. **Fewer marine search and rescue actions** due to fewer collisions between debris and vessels.

Direct non-quantifiable cost savings are cost avoidances that the trap currently facilitates but are not sufficiently quantifiable within the scope of this study. The benefits of the trap are proposed to be the cost savings resulting from less deleterious debris impact. Since the cost savings discussed here are non-quantifiable, it is not possible to extrapolate them from presently incurred costs. Yet, to give an idea of the importance of the individual non-quantifiable costs avoided by the trap, the *current* non-quantifiable costs in order of highest estimated magnitude are noted here:

Fig. 6. February 2006 storm and consequential damage done to sea dykes along shore of southern Strait of Georgia . Source: Corporation of Delta.

1. Municipalities: Repairs and maintenance of sea dykes and seawalls

In contrast to river dykes, which are thought to be minimally impacted by debris (Erik Gilfillan, formerly City of Richmond; Carrie Baron, City of Surrey; Neil Calver, City of Chilliwack), sea dykes and seawalls can be severely impacted by debris (Hugh Fraser, Corp. of Delta; Fig. 6). Logs and snags have severely damaged the sea dykes protecting the Corporation of Delta. Often during storms, the tides and the wind roll the logs onto the riprap, where large debris pieces grind the riprap away (René Payer, now Township of Langley). In addition, snags are lodged by their roots between blocks of riprap and act as levers to pull the blocks out of their structure. A large part of the dyke maintenance costs the Corporation of Delta incurs is due to the impact of waterborne debris during storms. Hugh Fraser (Corp. of Delta) estimates the damage done over the years to the sea dykes in the municipality to have cost between $1 to $2 million in repairs. He attributes a major part of this damage to debris impact during storms.

2. Recreational water users: Accidents, injuries and fatalities

Recreational water users may collide with waterborne debris during motorized boating, canoeing, fishing, kayaking or sailing. In some cases this has already resulted in the loss of human life. *The Province* newspaper reported in its October 23, 1998 issue:

> "*Jean Williams of White Rock (...): 'Our son, his wife's father and his brother-in-law were all killed together as they headed back to Keats Island after a fishing trip off Lasquetl Island,' Williams said of the accident on July 27, 1968. 'They hit a deadhead [a submerged log]. That's what the RCMP thought. They were all killed instantly. It probably took the bottom right out of their boat.'* "

> Jim Risling, active sport fisher: *"I got hit by a log once while we were fishing for sturgeon around Chilliwack. The log got us nearly drowned. That was back in the 60s and the chances of being hit are much smaller these days."*

Other interviewees reported incidents that did not result in injury, yet could have had far more serious consequences. For instance, Fred Helmer (Fraser Valley Angling Guides Association) reported a near-accident from his childhood. While fishing at night, a snag came down the river and hooked its roots up to the rear of the boat. His father cut the anchor line to allow the boat to float freely, but because the roots had engulfed the boat it could no longer be steered. Mr. Helmer's father tried to cut off the roots with an axe as the boat drifted towards a bridge pillar. Just before hitting the pillar, the roots were cut loose and a serious accident was averted.

3. Residents: Repair and replacement of shore property, float homes and utilities

Sometimes, the storm waves transport the debris over the seawalls that protect shore property and damage the residences behind (Hugh Fraser, Corp. of Delta; cf. Fig. 4, 7 & 8). In the City of White Rock, debris damages lampposts, garbage cans and benches during storms (Dale Kitsul, City of White Rock).

There are about 100 float homes located along the Fraser River (Don Flucker, Float Home Association Pacific). On an annual basis, 5 to 10% of these experience deadheads or snags getting caught underneath. It costs $300 to $800 per incident to remove this wood. Float homes have been known to sink because of deadheads piercing them during falling tides (Don Flucker). Ron Francis, a float home resident in New Westminster, has already spent about $30,000 over the past ten years to repair his docks and the cable and sewerage lines linked to his home. Although his case is exceptional – he is the furthest upstream floathome owner on the Fraser River and is

Fig. 7. Damage to shore property after the February 4, 2006 storm in Delta. Source: Corp. of Delta.

consequently severely impacted by woody debris – it shows that costs can be considerable, even for individual property owners, even with an operating debris trap in place.

4. Recreational boaters and fishers: boat repairs

The category 'pleasure boat owners' in Table 4 reflects only a small part (i.e., $31,000) of the costs of repairs, primarily propellers, for pleasure and powerboats. Allan Murray, the former president of the BC Marine Insurance Association, says that claims arising due to costs for repair of deleterious debris impact are "*substantial*", with the insurance companies being seriously "*affected by the debris*". Ross Right (Burnaby Power & Sail Squadron) has to buy two new propellers per year at $300 per propeller due to debris impacts. Cascade Marine in Chilliwack estimates it performs four to six boat repairs per year because sport fishers or pleasure boat owners hit submerged debris, with another two to three incidents involving other floating debris. The company estimates the costs to the boat owners to be about $5000 per incident. With on average 5,000 to 6,000 sport fishers on the river during an August weekend (Fred Helmer, former president of the Fraser Valley Angling Guides Association; Jim Risling, recreational fisher), the repair costs are likely far more considerable than Tables 3 & 4 indicate.

Fig. 8. Damage of foreshore property due to debris impact during the February 4, 2006 storm in the Corporation of Delta. Source: Corp. of Delta

5. Wood-processing Industry: Cleanup of debris from water-stored logs

Only a small part of the cleanup costs for shore-based forest companies is taken into account in Section 4.1 and Table 3. The actual costs are probably a few times higher. Forest products industries often store logs for long periods in the river alongside their facilities. By the time the logs are needed in the production, woody debris has collected on the logs. As Kevin Pabin (Howe Sound Pulp & Paper) puts it, "*the log bundles act as big nets catching everything from plastic to woody debris*". The industry generally collects the debris in so-called debris bags and disposes it or uses the debris for hog fuel. For the removal of the woody debris the wood-processing industry incurs labour, transport and disposal costs.

6. Port Operations: Interference with tugs berthing deep-sea vessels

Mike Armstrong, a river pilot, argues that an increase in woody debris if the debris trap were closed would have a minor impact on deep-sea vessels when these are underway. However, he stated that there is a much greater concern when the vessels are using tugs to berth. Debris could impact the tugs, resulting in the tugs becoming disabled during berthing. This could result in very serious impacts, such as the vessel and cranes being damaged. Problems could also arise at the auto terminal: the vessels berth stern upriver, leaving propellers vulnerable to getting clogged with debris. This would impact the ability of the vessels to manoeuvre when leaving their berths.

7. Ecology: Degradation of marshland

"*By far the greatest and most chronic threat to habitat quality in the productive marshes of the estuary is related to driftwood*" (Kistritz *et al*. 1992). Terry Slack, (Fraser River Coalition), confirms that this is still the case. "*Considering the impact of driftwood, there is not yet light at the end of the tunnel*," he says. The figure of $256,000 in Table 1 reflects only part of the costs needed for habitat restoration. In reality, this is not enough to mitigate the continued impact of waterborne debris on the estuarine marshes. Mr. Slack thinks the total costs for doing that are "*huge*". In the 1980s, $15,000 was expended to clean 'half a block' of marshland. Cleanup costs for marshes may therefore be significant, considering that these days many voluntary woody debris-clogged marsh cleanup programs have been terminated

(FREMP 1997; Thomas 2002). The Great Canadian Shoreline Cleanup program does not clean woody debris from the beaches (Tiffany Lavigne, Vancouver Aquarium).

Fig. 6. Accumulation of woody debris smothering marshes along the Fraser River. Source: Kistritz et al. *(1992).*

Bratty (2000) summarizes the negative impacts of an overabundance of debris on marshes as follows:

- Physical injury to vegetation: The movement of large pieces of industrial wood debris flattens, grinds and scours wetland vegetation.
- Competitive exclusion: Invasive plant species will quickly invade wetlands that have been degraded by wood debris. This prevents native plant species from growing, affecting other species dependent on them for food.
- Reduced primary production: woody debris can compact and scour sediments, which can result in poor soil fertility, affecting plants and habitat values. In addition, higher biological oxygen demand for the decomposition of debris lowers the amount of oxygen available for fauna.
- Displacement: Where woody debris accumulations are heaviest, marsh vegetation can be completely displaced, resulting in loss of habitat for fish and invertebrates.

Notwithstanding these findings, some users with an interest in the gravel reach upstream of the Fraser River estuary believe that the debris trap reduces the amount of debris in this reach, thereby negatively affecting ecosystem health.

8. Canadian Coast Guard: Search and rescue actions

WLSSC (2005) reports that the Canadian Coast Guard had to conduct 60 search and rescue actions due to debris impact on vessels between 1999 and 2003. This averages more than one search and rescue action per month. Since the labour and material used in these actions varies widely it is difficult to estimate the costs incurred in the actions (Wayne Dutchak, Canadian Coast Guard).

6 Indirect, non-quantifiable avoided costs

There is a wide variety of indirect (potential and probable) costs the debris trap is currently helping to avoid. **The largest cost avoidances are estimated to be**:

- **Fewer adverse effects on the tourism and recreational sector**,
- **Fewer log spills** (the loss of logs from booming grounds) and
- **Lower probability of collisions** between debris and boats, floatplanes, etc.

The indirect avoided costs consist of 'potential' and 'probable' avoided costs. The debris trap generates potential cost savings because its operation inhibits events from occurring that would occur without the trap in operation. In other words, these events do not occur with a trap in place but have the potential to occur without a functioning debris trap. For instance, the Fraser River is currently navigable during the spring freshet. If the Fraser River were not navigable during the spring freshet – as was the case before the installation of the debris trap (Mike Forrest, Forrest Marine; Ozzie Isfelt, former Public Works Pacific Canada; Doug Cooper, Gulf Log Salvage; Albert Gibson, former *Samson V* captain) – transport companies would be severely hindered in their work. This could give rise to higher costs to industry for boat damage and also lower revenues. A potential cost is considered equal to a cost saving, since it does not occur with an operating debris trap.

'Probable avoided costs' are costs that also arise with a debris trap in place, but that are more likely to occur without a trap in place. In other words, the costs are probable with a trap and more probable to occur without a trap. For these costs no data exist. An example of such a cost is the medical expenses or loss of income that a recreational boater or wake boarder may incur if injured after a collision with debris. This study did not find information about the actual occurrence of such impacts, but it is not unlikely that they happen, and not unlikely that they would increase in frequency in the event the trap was not operating.

The following sections provide an overview of the indirect avoided costs. The headers indicate if a cost is a potential avoided cost or a probable avoided cost. An attempt was made to sort the costs by expected magnitude – beginning with presumed highest avoided costs.

6.1 Indirect economic costs

1. Negative impact on sport fishing revenues (potential avoided cost)

Sport fishing (mainly for salmon and sturgeon) has evolved into a major economic sector in British Columbia over the years. For the province, direct revenues from recreational sport fishing on rivers are $128 million (FOC 2000). For the Fraser River reach between Mission and Hope, Rodney Clapton (BC Drift Fishers Federation) suggests $20 million in revenues generated for the communities along the river. Fred Helmer (Fraser River Angling Guides Association) estimates a figure of between $9 to $12 million in revenues for sturgeon fishing only, which he derived from an economic study by Fisheries and Oceans Canada.

> Mr. Mussel, member of the crew of the DFO patrol boat on the Fraser River: "*In case of debris trap closure, I would be less inclined to patrol upstream on the river. The combination of driftwood and fast-flowing water can be very dangerous.*"

Without a debris trap, these revenues may decrease. Mr. Clapton supposes that of the over 900 members of the Drift Fishers Federation, many would avoid the lower Fraser River reach without an operating debris trap in place. This is because waterborne debris is a major safety concern for fishermen. The concern would become "*severe*" without a working trap: during fishing, fishermen watch their angle downstream of the boat, while the waterborne debris appears out of sight from upstream. Mr. Helmer thinks that many sport fishers would avoid fishing during the spring freshet and would only fish on the river in the autumn. In addition, he thinks the amount of waterborne debris coming down the river during a freshet would be "*aesthetically unpleasing*", leading to fewer tourists and decreased tourist revenues during the freshet.

2. Negative impacts on recreational revenues (potential avoided cost)

Without a debris trap, foreshore recreation would probably be difficult if not impossible. In fact, before the debris trap was in place there was no recreation possible on the beaches along the coast of the Strait of Georgia: the beaches were inaccessible (Doug Cooper, Gulf Log Salvage). Even in the situation with a debris trap it is necessary to clean the beaches from debris: "*The beaches become so congested with logs that there is no safe access to the water or even space to put down a blanket for a picnic*," says Richard Wallis (GVRD Parks). Increasing costs for cleanup is most often impossible, given that cleaning the beaches more rigorously is already considered "*cost prohibitive*" (Dale Kitsul, City of White Rock). All in all, the negative impact on the recreational sector in the river and southern waters of the Strait of Georgia may be severe in the event the debris trap was decommissioned.

> Doug Cooper, general manager, Gulf Log Salvage: "*When the trap had just been installed, I was called by a man from New Westminster who was not amused. Every freshet he would bet his friends a few beers he could cross the river by hopping on the debris to the other side. He made it four out of five times. With the debris trap, that was not possible anymore and he complained we stole his drinking money.*"

3. Negative impacts on commercial fishing revenues (potential avoided cost)

Although commercial salmon fishing has decreased in economic importance over the years, the sector may still generate considerable revenues. According to G.S.Gislason (2006), the net present value of the GDP contribution of sockeye fishing in the Fraser River is between $360 and $920 million over the next 50 years. Salmon fishing is estimated to generate about $25 million in annual revenues in the Fraser River. If there were no trap in place, it would be dangerous, if not impossible to fish during the spring freshet (Mike Forrest, Area E Gillnet Fishers Association). In addition, higher costs would be incurred for boat and gillnet repairs. Since debris gets entangled in the nets, fishermen have to avoid places with concentrations of debris, although these often are the places where the fish seek shelter and so are good fishing grounds. At places with less debris, less fish are present leading to lower landed values. Hugh Fraser (Corp. of Delta) suggests that in extreme cases the build-up of debris would lead to inaccessible fishing harbours. In this way, more debris would lead to less revenues and higher expenses (Mike Forrest, Forrest Marine & Area E Gillnet Fishers Association).

6.2 Indirect costs caused by damage

1. Forest and wood-processing industry: Log spills (potential avoided cost)

> Don Cromarty, dispatch manager, Smit Marine Canada: *"I would hate to see the debris trap being shut down. We in the marine world would experience substantial impact."*

Various sources (Sorensen 1977; Clay Brown, Coast Forest Products Association; Phillip Nelson, Council of Marine Carriers; John Bowles, Harken Towing) indicate that massive amounts of debris hanging to log booms can lead to log spills. With a debris trap, log spills are less likely to occur because cleanup activities can keep up with the amount of waterborne debris hooking up to the log booms. However, in case of major volumes of debris coming down the river, more entangling of log booms would occur. When the flowing water exerts enough drag on the entangled debris to break the lines between the log booms, a log spill occurs. Such a log spill could easily lead to $100,000 in cleanup costs and lost logs (Clay Brown, Coast Forest Products Association).

2. Ferry operators: Ferry outage (probable avoided cost)

The damage to the ferry propellers and hull by waterborne debris can be so severe that the ferry has to be taken out of service and repaired in dry dock. This has impacts on the service, the reputation of the service provider and revenues (Alicja Rudzki, BC Ferries). This risk is already present, and is expected to increase without an operating debris trap. This would have a "*significant*" impact on operations, safety and the financial situation for the ferries (Alicja Rudzki, BC Ferries).

3. BC Hydro: Damage to hydropower plants (potential avoided cost)

Currently, the outlets of the Ruskin hydropower plant near Maple Ridge are not protected against the influx of waterborne debris. BC Hydro does not consider this necessary, since the plant is somewhat upstream from the Fraser River (Dick Brighton, BC Hydro). However, without a debris trap BC Hydro reports that it would be necessary to protect the plant outlets. Dick Brighton calls the installation of a shear boom "*a costly business*". Moreover, if debris were to enter the outlet tubes despite the shear boom, this could seriously damage the power plant.

4. Public interest: Damage to heritage sites (potential avoided cost)

Parks Canada and the City of North Vancouver both manage historical heritage sites along the Fraser River and the Burrard Inlet, respectively. Before the trap was installed, debris collected under the Gulf of Georgia Cannery National Historic Site (dating from 1894) and caused damage to the plumbing and the floors during storms. Since the debris has been cleaned and the trap was commissioned this has not reoccurred. Without a debris trap, however, the concern exists that debris would damage the historic site's plumbing, sprinkler installation and floor panels (Margaret Fraser, Parks Canada).

Currently, the debris collected under the historic Burrard Dry Dock Pier is only a passing concern. The City does not have to remove it frequently, with the exception of one big log that had to be removed a few years ago. Nevertheless, David Turner (City of North Vancouver) estimates that the debris could become a threat for the site if there were a major increase in debris volumes.

6.3 Indirect costs due to accidents

1. Float plane companies: Float plane flight accidents (probable avoided cost)

Jim Devlin (West Coast Air) says that "*woody debris is not a big problem, but it is a big concern.*" Without a debris trap, "*a six-fold increase in debris volumes would mean a six-fold increase in hazard. However, since we fly airplanes the acceptable amount of hazard is actually zero*." Prior to the debris trap installation, deadheads and snags posed a severe threat to the floatplanes, although Mr. Devlin attributes a major part of this threat to logging activities downstream of the trap. In short, the collision of a floatplane (with on average sixteen passengers) with a submerged log could lead to injuries and loss of life.

2. Ferry companies: Ferry accidents (probable avoided cost)

In the event that the debris was to damage the steering equipment of a ferry, it would no longer be navigable and could collide into another vessel or land, with the possibility of personal injury. The Albion Ferry on the Fraser River already experienced this once (Section 4.1). This has not happened yet to BC Ferries, but since the company transports people, "*BC Ferries cannot afford a big safety risk*" (Alicja Rudzki, BC Ferries). Without a debris trap, this safety risk would nevertheless increase "*significantly*".

6.4 Ecological impacts

1. Habitat quality: Release of toxic substances (probable avoided cost)

Accumulation of debris on marshes and other natural areas leads to a huge stock of organic material (Kistritz *et al*. 1992; Munday 1997). Micro-organisms decompose this material and derive their energy from it. However, by doing this they use oxygen that is contained in the soil. This could lead to the depletion of oxygen in the marsh soil and the creation of anaerobic conditions (Bratty 2000; WLSSC 2005). Under those conditions, other micro-organisms start to use sulphate (SO_4) to derive energy. These micro-organisms generate the toxic gas hydrogen sulphide (H_2S), which results in deterioration of environmental conditions for other organisms. Tannins are a second toxic element that waterborne debris may release (Munday 1997; Bratty 2000; WLSSC 2005). This substance naturally occurs in trees but may be released when the wood is water stored (Munday 1997). Similar to H_2S, tannins have a detrimental effect on habitat quality (WLSSC 2005).

2. Air quality: Air contamination (potential avoided costs)

Currently, the debris captured at the debris trap is processed into hog fuel and wood chips for use in pulp and paper production. Without the debris trap in place, the waterborne debris would disperse itself to downstream sites, where it would be partially collected and transported to a collection site for recycling. The dispersed nature of the debris would however increase the transport costs, because the economies of scale currently at the debris trap would not be achieved (Munday 1997). There could be an increase in air contamination due to increased truck traffic moving debris from various cleanup sites to the collection sites. Air quality could also be affected if open burning is used as a disposal technique.

6.5 Other impacts

1. Lower amenity for foreshore residential property (potential avoided cost)

Residences – other than float homes – along the Fraser River are currently very attractive and popular. Houses and condominiums provide a nice view over the river, which is often reflected in property values. Without the debris trap working, this view might deteriorate because of accumulation of aesthetically unpleasing debris on the foreshores. This could lead to a decline in the property values, which subsequently would lead to lower property tax revenues for the municipalities bordering the Fraser River.

2. No escape route in case of an earthquake (potential avoided cost)

In the event of an earthquake in the Greater Vancouver region, the Fraser River would be the major transportation avenue for relief, rescue and evacuation (Allan Galambos, BC Ministry of Transport). This is because it is assumed roads and train tracks would no longer be accessible. If the earthquake were to occur during spring freshet and there was not a debris trap in place, the river would not be navigable. This would deprive the region of its most reliable emergency transportation route, leading to severe problems with provision of aid, rescue teams and movement of evacuees.

7 Conclusions and Recommendations

7.1 Conclusions

- According to the very conservative approach adopted in this study, the debris trap is economically feasible. The debris trap avoids each year an estimated $7.94 million in additional costs for downstream debris management and mitigation measures. After subtracting the costs to run the debris trap ($0.64 million per year), the study estimates its annual net benefit to be $7.3 million. The net present values of the debris trap benefit ranges from between $30 million over 5 years up to $90.6 million over 20 years when using a 4% discount rate.
- The study shows a wide range of stakeholders who may directly or indirectly avoid costs because of the trap. The stakeholder groups that probably benefit the most from the debris trap are the marine and river transport companies (primarily costs due to boat and dock repairs and log boom cleaning), followed by ports and harbour authorities, and habitat protection and management agencies, which avoid costs for debris management in harbours and costs for habitat restoration.
- The avoided costs quantified here are very conservative. In addition to the quantifiable costs, the debris trap may avoid many other costs that are not quantifiable within the limited scope of this study.
- In the event there was not a debris trap in place, many other costs would arise. These costs would result from events set in motion by massive amounts of waterborne debris released or mobilized during peak discharges or storms.
- Without the debris trap, the Fraser River would not be navigable during the spring freshet. This would have a significant negative economic impact on the river transport, (commercial and sport) fishing and recreational sectors.

7.2 Recommendations

- The method used to calculate the direct, quantifiable avoided costs in Section 4.2 relies heavily on an estimated 'wood debris budget'. However, there is limited empirically confirmed information available about the exact amounts of waterborne debris captured by the debris trap or discharged by the tributaries of the Fraser River downstream of the trap (Doug Cooper, Gulf Log Salvage). Although the study took a 'safe' approach by estimating low amounts of debris captured by the debris trap, it is recommended that the debris budget be more accurately defined.
- Within the limited time available for the study it was not possible to sufficiently investigate the costs of deleterious debris impact to:
    - sport fishers and recreational boaters on the lower Fraser River,
    - sawmills and pulp and paper plants;
    - owners of float homes.

  Nevertheless, the economic importance of industrial, fishing and recreational interests is such that they merit more study. The same recommendation applies to the float homeowners, since this group is very vulnerable to debris impact. With a wider sample it would also be possible to provide a more accurate assessment of stakeholder groups and the degree to which they benefit from the continued operation of the trap.

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Appendix A Fraser River Debris Trap background information

Operating Committee 2006

Title	Name	Surname	Position	Organization
Mr.	Clay	Brown	General Manager, Security	Coast Forest & Lumber Products Assoc.
Ms.	Shannon	Daniel	Senior Policy Advisor	Ministry of Environment
Ms.	Donna	Bartel	Security and Emergency Planning Manager	Fraser River Port Authority
Ms.	Alicja	Rudzki	Manager, Environmental Department	British Columbia Ferry Services Inc.
Mr.	Erv	Mihalicz	Operations Manager	Catherwood Towing / Council of Marine Carriers
Mr.	Byron	Mah	Senior Business Officer	Western Economic Diversification
Mr.	Steve	Langdon	Field Unit Superintendent	Coastal British Columbia
Mr.	Pat	Cruickshank	Regional Manager, Programming, Partnerships and Planning	Ministry of Transportation
Mr.	Doug	Leavers	Manager, Park Services	District of West Vancouver
Mr.	Gary	Townsend	Executive Director	Minstry of Forests, Operations Division
Mr.	Bob	Sisler	Regional Manager, Environmental Services	Transport Canada
Mr.	John	Stoneson	Manager of Operations & Personnel	Translink - Albion Ferry Operations

Consolidated Funding History 1999–2006

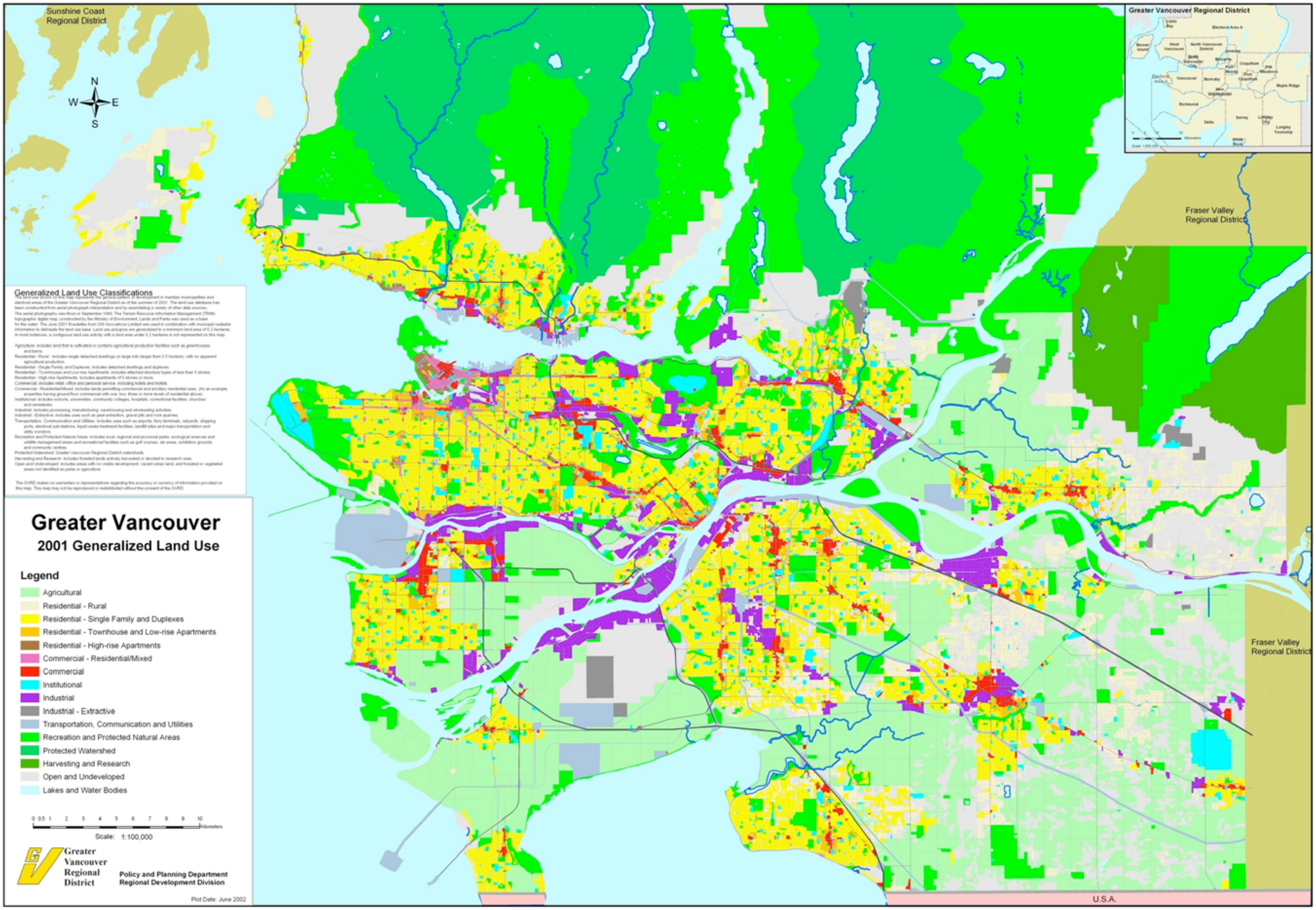
Partner	1999/2000	2000/2001	2001/2002	2002/03	2003/04	2004/05	2005/06	TOTALS
Federal Gov't & Port Authorities								
Fisheries & Oceans Canada	$75,000	$75,000	$80,000	$80,000	$45,000	$60,000	$60,000	$475,000
Environment Canada	$10,000							$10,000
Indian Affairs Canada	$10,000	$10,000						$20,000
Parks Canada		$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$60,000
Fraser River Port Authority	$30,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$180,000
North Fraser Port Authority	$25,000	$25,000	$25,000					$75,000
Vancouver Port Authority	$12,500							$12,500
Western Diversification Canada	$40,000	$35,000	$40,000		$75,000	$85,000	$55,000	$330,000
Natural Resources Canada				$65,000	$15,000			$80,000
Transport Canada							$35,000	$35,000
Total Federal Gov't & Port Authorities	**$202,500**	**$180,000**	**$180,000**	**$180,000**	**$170,000**	**$180,000**	**$185,000**	**$1,277,500**
Provincial Gov't & Crown Corporations								
Ministry of Environment	$10,000	$10,000	$80,000					$100,000
Ministry of Transportation	$10,000	$10,000	$20,000		$20,000	$20,000	$40,000	$120,000
Ministry of Forests and Range	$100,000	$55,000	$50,000	$135,000	$110,000	$110,000	$155,000	$715,000
Ministry of Small Business, Tourism & Culture		$5,000						$5,000
Land and Water BC		$25,000						$25,000
BC Ferry Services Inc		$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$300,000
BC Hydro		$25,000						$25,000
Total Provincial Gov't & Crown Corporations	**$120,000**	**$180,000**	**$200,000**	**$185,000**	**$180,000**	**$180,000**	**$245,000**	**$1,290,000**
Industry								
Coastal Forest Industry	$162,500	$180,000	$180,000	$180,000	$170,000	$0	$0	$872,500
Total Industry	**$162,500**	**$180,000**	**$180,000**	**$180,000**	**$170,000**	**$0**	**$0**	**$872,500**
Other								
Fraser River Estuary Management Program	$5,000	$5,000						$10,000
BC Council of Marine Carriers	$1,000							$1,000
TransLink		$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$60,000
Greater Vancouver Regional District		$20,000						$20,000
Fraser Valley Regional District		$5,000	$10,000					$15,000
District of West Vancouver Parks		$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$60,000
Total Other	**$6,000**	**$50,000**	**$30,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$166,000**
GRAND TOTAL	**$491,000**	**$590,000**	**$590,000**	**$565,000**	**$540,000**	**$380,000**	**$450,000**	**$4,231,000**

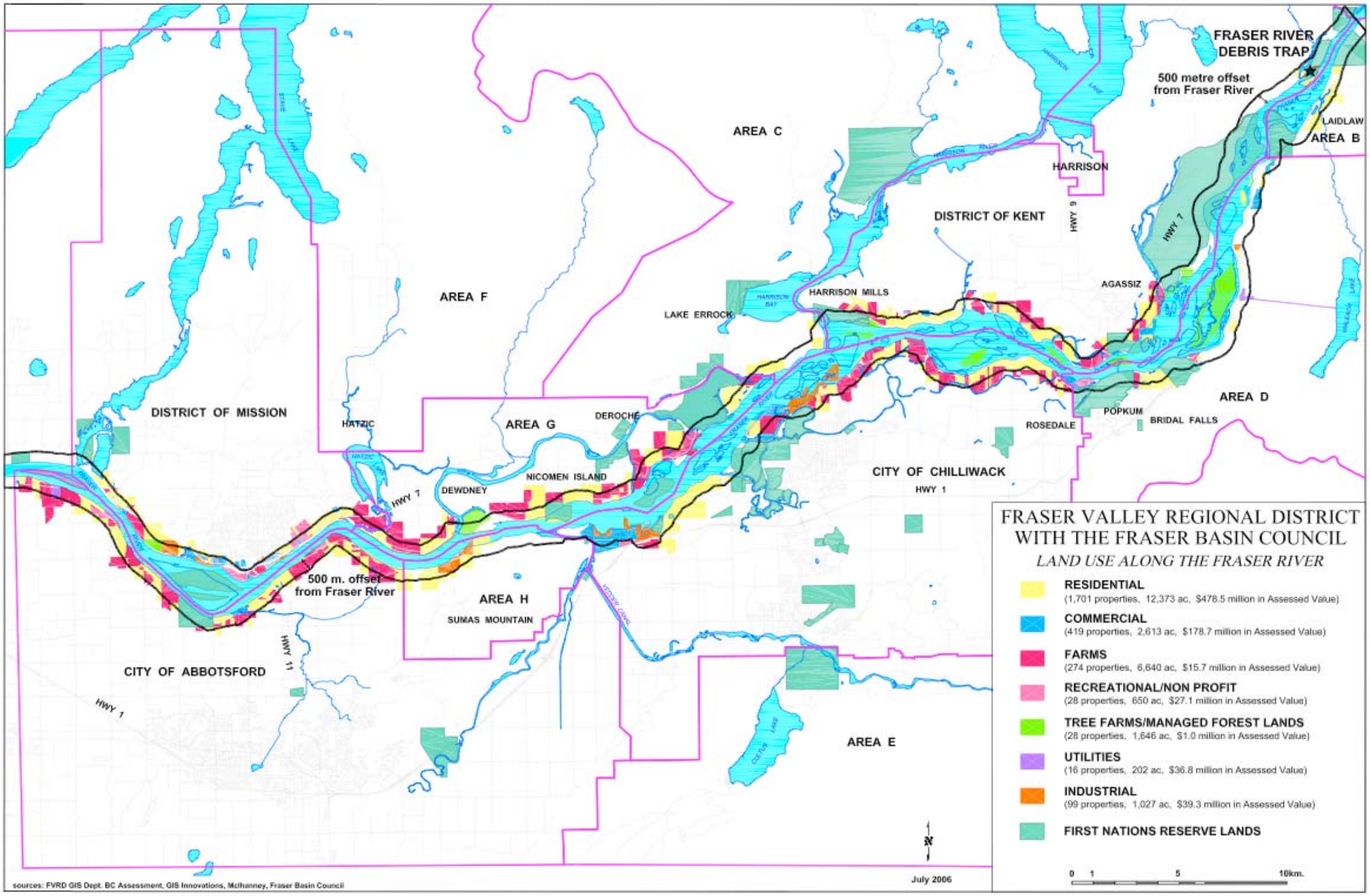
Final budget 2006/07

REVENUES	2006/07
Federal Government	
Transport Canada	$35,000
Parks Canada	$10,000
Total Federal Government	**$45,000**
Provincial Government	
Ministry of Forests and Range	$175,000
Ministry of Transportation	$40,000
Ministry of Environment	$35,000
Ministry of Agriculture and Lands	$15,000
Total Prov. Gov't & BC Ferries	**$265,000**
Regional/Local Governments & Others	
Greater Vancouver Regional District	$205,000
BC Ferry Corporation	$50,000
TransLink	$10,000
District of West Vancouver	$10,000
Total Regional/Local Government & Others	**$275,000**
GRAND TOTAL REVENUES	**$585,000**

EXPENSES	2006/07
Operations & Maintenance	
Lease/License	$40,500
First Nations Community Grant 2006	$11,500
Maintenance	$50,000
Operations	$368,740
Project Management & Engineering	$51,000
Insurance	$14,000
Total Operations & Maintenance	**$535,740**
Support Services	
Debris Trap Cost/Benefit Study	$17,354
Operating Committee Secretariat	$3,962
Communications	$3,600
Fundraising and Financial Administration	$19,438
Total Support Services	**$44,354**
Other	
Carry-Forward of 2005/2006 Budget Deficit	$4,906
Total Other	**$4,906**
GRAND TOTAL EXPENSES	**$585,000**

Appendix B Land Use in the Lower Fraser and Estuary




FRASER VALLEY REGIONAL DISTRICT
WITH THE FRASER BASIN COUNCIL
LAND USE ALONG THE FRASER RIVER
RESIDENTIAL
(1,701 properties, 12,373 ac, $478.5 million in Assessed Value)
COMMERCIAL
(419 properties, 2,613 ac, $178.7 million in Assessed Value)
FARMS
(274 properties, 6,640 ac, $15.7 million in Assessed Value)
RECREATIONAL/NON PROFIT
(28 properties, 650 ac, $27.1 million in Assessed Value)
TREE FARMS/MANAGED FOREST LANDS
(28 properties, 1,646 ac, $1.0 million in Assessed Value)
UTILITIES
(16 properties, 202 ac, $36.8 million in Assessed Value)
INDUSTRIAL
(99 properties, 1,027 ac, $39.3 million in Assessed Value)
FIRST NATIONS RESERVE LANDS
0 1 5 10km.
FRASER RIVER DEBRIS TRAP
500 metre offset from Fraser River
LAIDLAW
AREA B
AREA C
HARRISON
DISTRICT OF KENT
HWY 9
HWY 7
AGASSIZ
AREA F
HARRISON MILLS
LAKE ERROCK
AREA D
POPKUM
BRIDAL FALLS
ROSEDALE
DISTRICT OF MISSION
HATZIC
AREA G
DEROCHE
NICOMEN ISLAND
CITY OF CHILLIWACK
HWY 1
DEWDNEY
500 m. offset from Fraser River
AREA H
SUMAS MOUNTAIN
HWY 11
CITY OF ABBOTSFORD
HWY 1
AREA E
N
July 2006
sources: FVRD GIS Dept. BC Assessment, GIS Innovations, McIhanney, Fraser Basin Council

Appendix C List of interviewed persons

Municipalities

Title	Name	Surname	Position	Department	Organisation
Mr.	Steve	Scheving	Planner	Planning Department	City of New Westminster
Ms.	Kim	Allan	Director of Forestry	Forestry Operations	District of Mission
Mr.	Brad	Badelt	Environmental Manager	Engineering Department	Township of Langley
Ms.	Carrie	Baron	Drainage and Environment Manager	Utilities Divsion	City of Surrey
Mr.	Gordon	Barstow	Parks manager	Parks, Recreation and Cultural Services	City of Richmond
Mr.	Rick	Bomhof	Director of Engineering	Engineering Department	District of Mission
Mr.	Neil	Calver	Assistant Operations Supervisor	Engineering Department	City of Chilliwack
Mr.	Owen	Croy	Manager of Parks	Parks, Culture & Recreation	City of Surrey
Mr.	Ike	De Boer	Engineering Services Coordinator	Engineering Department	District of Pitt Meadows
Mr.	Terry	Flyer	Dike clerk	Albion Dike District	District of Maple Ridge
Mr.	Hugh	Fraser	Manager of Utilities		Corporation of Delta
Mr.	Lorne	Graham	Superintendent Roads & Drainage	Engineering Department	City of Burnaby
Mr.	Dave	Halliday			Corporation of Delta
Mr.	Dale	Kitsul		City Operations	City of White Rock
Mr.	Bill	McCuaig	Community Forester	Parks department	District of West Vancouver
Chief	Jack	Mussel		First Nations fishing	Skwah First Nations
Ms.	Julie	Pavey	Manager of Environmental Services		City of Port Moody
Mr.	René	Payer			Township of Langley
Mr.	Don	Petersen		Parks Maintenance	City of Burnaby
Mr.	Wayne	Randell		Engineering Department	Township of Langley
Mr.	Dave	Turner	Superintendent Park Operations	Parks department	City of North Vancouver
Mr.	Andrew	Wood	Municipal Engineer	Engineering Department	District of Maple Ridge

Regional, provincial and federal government agencies

Title	Name	Surname	Position	Organization
Mr.	Roger	Bean	Manager , Operations	Greater Vancouver Regional District
Ms.	Dayle	Burge	Property Manager	Fraser River Port Authority
Mr.	David	Crook	Environmental manager, Westshore Terminals	Vancouver Port Authority
Mr.	Wayne	Dutchak		Canadian Coast Guard
Mr.	Alan	Galambos		BC Ministry of Transport
Mr.	C J	Mussel	Patrol boat employee	Fisheries & Oceans Canada
Mr.	Kevin	Obermayer	Chief Operational Officer	Pacific Pilotage Authority Canada
Mr.	John	Schnablegger	Manager, capital program	BC Ministry of Transport
Mr.	Richard	Wallis	Operations supervisor, Parks west	Greater Vancouver Regional District

Non-governmental organisations

Title	Name	Surname	Position	Organization
Dr.	Bert	Brink		Fraser River Coalition
Mr.	Clay	Brown	General Manager	Coast Forest Products Association
Mr.	Herb	Buchanan	Member	Council of BC Yacht Clubs
Mr.	Rodney	Clapton	President	BC Federation of Drift fishers
Mr.	Norm	Dyck	Former president	Council of BC Yacht Clubs
Mr.	Don	Flucker	Executive Director	Floating Home Association Pacific
Mr.	Fred	Helmer	Former President	Fraser Valley Angling Guides Association
Mr.	Jack	Hobson	President	Council of BC Yacht Clubs
Mr.	Frank	Kwak	President	Fraser Valley Salmon Society
Ms.	Tiffany	Lavigne	Program coordinator	Vancouver Aquarium
Ms.	Anna	Mathewson	Program manager	Fraser River Estuary Management Program
Mr.	Allan	Murray	Former president	Marine Insurance Association of BC
Mr.	Phillip	Nelson	President	Council of Marine Carriers
Mr.	Grant	Rawstron		Fort Langley Canoe Club
Ms.	Ross	Right	Board member	Burnaby Power & Sail Squadron
Mr.	Terry	Slack	Director	Fraser River Coalition

Companies

Title	Name	Surname	Position	Organization
			Terminal Sawmill employee	Terminal Forest Products
			Mainland Division employee	Terminal Forest Products
				Cascade Supply & Marine Ltd
			Manager of Maintenance	Roads & Bridges, TransLink
Mr.	Kim	Aliprandini		Valley Towing
Mr.	Barry	Anderson		BC Hydro
Mr.	John	Bowles	Operations Manager	Harken Towing
Mr.	Dick	Brighton	Senior Engineer, Power Supply Engineering	BC Hydro
Ms.	Edith	Çan	Property Manager	Canada Forest
Mr.	Doug	Cooper	General Manager	Gulf Log Salvage
Mr.	Don	Cromarty	Dispatch Manager	Smit Marine Canada
Mr.	Jim	Devlin	Chief pilot	West Coast Air
Mr.	Claudio	Eddis	Division Controller	Panel & Fibre Division, CanFor
Mr.	Leo	Edwards		Leo Edwards & Sons
Mr.	Mike	Forrest	Principal	Forrest Marine
Mr.	Harry	Malbet		Lehigh Cement
Mr.	Erv	Mihalicz		Catherwood Towing
Mr.	Kerry	Moir	Principal	Riverside Towing
Mr.	Kevin	Pabin	Plant manager	Howe Sound Pulp & Paper
Mr.	Rick	Plecas	Managing Director	Seaspan Coastal Intermodal
Mr.	Simon	Robinson	Environmental manager	Vancouver International Airport Authority
Ms.	Alicja	Rudzki	Manager	Environmental Department, BC Ferries
Mr.	Larry	Smith	Operations Manager	Hodder Tugs
Mr.	Chick	Stewart	Owner	F&R Sawmills
Mr.	John	Stoneson	Manager of Operations & Personnel	Albion Ferry, TransLink
Mr.	Don	Westmoreland		Seaspan

Individuals

Title	Name	Surname	Position	Organization
Mr.	Mike	Armstrong	River pilot	
Mr.	Walter	Beutler	Sport fisher	
Mr.	Erik	Gilfillan	Former Public Works Director	City of Richmond
Cpt.	Albert	Gibson	Former Captain of the Samson V	Samson V snag puller
Mr.	Erik (Ozzie)	Isfeld	Former Public Works Pacific Canada	EBA Consultants
Mr.	Ron	Francis	Floathome owner	
Mr.	Jim	Risling	Sport fisher	