COST-BENEFIT ANALYSIS OF THE EARLY CLOSURE OF THE VANCOUVER LANDFILL

by

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ABSTRACT

The City of Vancouver owns and operates the Vancouver Landfill in Delta. The Vancouver Landfill is part of the GVRD solid waste management system including 6 transfer stations, a waste-to-energy facility in Burnaby, and a remote landfill in Cache Creek. The Cache Creek Landfill is scheduled to close in 2007. The GVRD is planning a new facility located at Ashcroft Ranch, a few kilometres west of Cache Creek. A review of the GVRD Solid Waste Management Plan is scheduled to commence in 2004. The Plan review will need to determine whether the GVRD is best served by two landfills or alternatively whether the Vancouver Landfill should be closed.

This paper conducts a cost-benefit analysis of the impacts on GVRD residents of closing the Vancouver Landfill, approximately 30 years in advance of reaching capacity, and increasing disposal at Ashcroft Ranch. The paper concludes that early closure of the Vancouver Landfill would increase municipal solid waste transfer and disposal costs, increase the cost of secondary material (asbestos, incinerator ash and sewage treatment plant residuals) disposal, increase closure costs, reduce the GVRD system's flexibility and increase greenhouse gas emission costs. Early closure of the Vancouver Landfill would not impact property values in the vicinity of the Vancouver Landfill. Early closure of the Vancouver Landfill would not impact Burns Bog. The only benefit of early closure would be reduced leachate management costs due to decreased leachate generation following closure of the Vancouver Landfill. The total net present value of the cost of early closure of the Vancouver Landfill is estimated at $81,000,000. The cost is not significantly impacted by reduced operating costs at Ashcroft Ranch or increased leachate management costs at the Vancouver Landfill. The cost of early closure would be primarily borne by Vancouver and Delta as long as economies of scale at Ashcroft Ranch could be realized and captured by GVRD residents. On that basis, to ensure that the rest of the GVRD supports the long term operation of the Vancouver Landfill, Vancouver and Delta should try to increase the benefits of the Vancouver Landfill to other GVRD residents.

DEDICATION

To Mariko, Ben and Josh

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I would like to thank Professor Steven Globerman for his direction in developing and shaping this project. I would also like to thank Ken Carrusca of the GVRD whose comments were the genesis of this project and who provided me with invaluable information on the GVRD's solid waste management system. I would like to thank Brian Davies and Dave Rudberg of the City of Vancouver for their support in my pursuit of an MBA, and for leading and listening to me over the last 15 years. Finally, I would like to thank Mariko for letting me head off to school while she looked after the boys, Wayne and Ellen for looking after Ben and Josh every week, Wednesday chicken dinners and everything in between, and my parents John and Joyce for always supporting whatever new adventure I have pursued.

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1 INTRODUCTION

The Greater Vancouver Regional District (GVRD) is the third largest metropolitan region in Canada with a population of approximately 2,100,000 (GVRD, 2004). Municipal solid waste management is one of the responsibilities of the municipal governments in the GVRD as well as of the GVRD itself.

Since the early 1990s, waste reduction and recycling have been the key municipal solid waste management priorities. All of British Columbia's regional districts were required to develop a solid waste management plan by the end of 1995 with the goal of reducing municipal solid waste by 50% by the year 2000. According to the GVRD (GVRD, 2004), by the end of 2000, approximately 48% of the region's municipal solid waste was eliminated through waste reduction, reuse and recycling.

In spite of the GVRD's success in reducing the overall solid waste stream, approximately 1,100,000 tonnes per year of municipal solid waste require disposal. The 1,100,000 tonnes per year of waste includes residential, industrial, commercial and institutional (IC&I) garbage, but excludes construction, demolition and land clearing waste.

Historically, the GVRD solid waste system included a large number of small landfills located throughout the region. For instance, prior to the early 1980s, each of Surrey, North Vancouver, Coquitlam, Burnaby and Richmond all had local municipal solid waste landfills. In the 1980s, and to a lesser extent in the 1990s, these local landfills reached capacity and were not replaced with new local landfills. Instead, waste transfer stations were developed to provide local disposal capacity. Transfer stations "repackage" garbage to allow economic shipment to large, potentially remote landfills. A similar pattern has occurred across North America.

Currently, there are six transfer stations (a seventh transfer station was added to the system in April 2004), two landfills and a waste-to-energy facility serving the GVRD. Contractors, on behalf of the GVRD, operate five of the transfer stations, one landfill and the waste-to-energy facility. The City of Vancouver owns and operates one transfer station (the Vancouver South Transfer Station, VSTS) and the Vancouver Landfill. All of the facilities work together to provide convenient, cost effective and safe solid waste disposal for the GVRD. Facility users are charged weight-based tipping fees. These fees fund the system's operation. Tipping fees are uniform across the GVRD to encourage waste generators to use the closest disposal facility. Figure 1-1 shows all of the municipal waste disposal facilities in the GVRD.

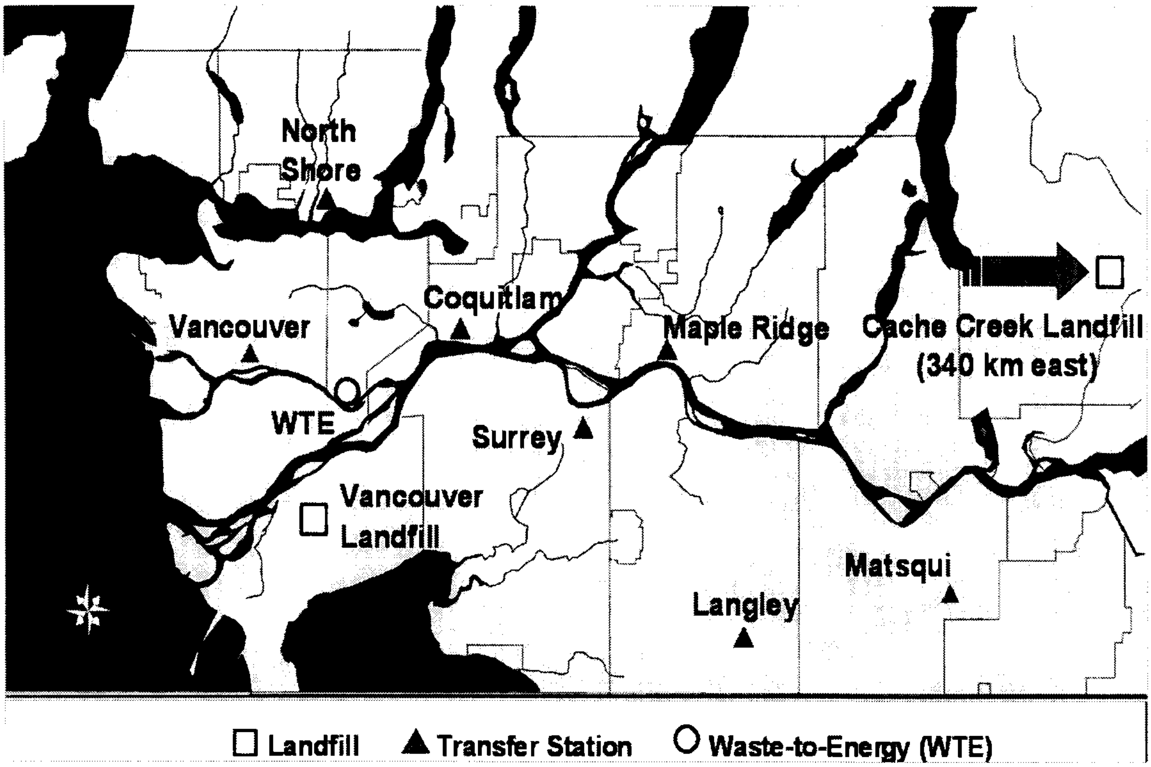

Figure 1-1: GVRD Solid Waste Disposal Facilities (used by permission of the GVRD)

The two landfills in the system are the Vancouver Landfill and the Cache Creek Landfill. Each of these facilities takes approximately 40% of the GVRD's waste. The remaining waste is burned at the Burnaby Waste-to-Energy Facility. Cache Creek is scheduled to close in 2007.

The GVRD is working to replace the Cache Creek Landfill with a new landfill located at Ashcroft Ranch approximately 15 km west of the Cache Creek. The Ashcroft Ranch is an approximately 4200 hectare site that the GVRD purchased in 2000 with the goal of developing a 200 hectare landfill on the site. The GVRD is in the process of permitting the site to develop a landfill. Once Ashcroft Ranch is permitted for landfilling, it will provide effectively unlimited future disposal capacity.

The Vancouver Landfill is in the municipality of Delta, and although owned by the City of Vancouver, the Vancouver Landfill is operated as a financial partnership between the City of Vancouver, the GVRD and Delta. The Vancouver Landfill has been in operation since 1966. The total site area is 635 hectares, while the area of the site filled with garbage is 225 hectares. A plan showing the location of the Vancouver Landfill is shown as Figure 1-2. An air photo showing the Vancouver Landfill is included as Figure 1-3.

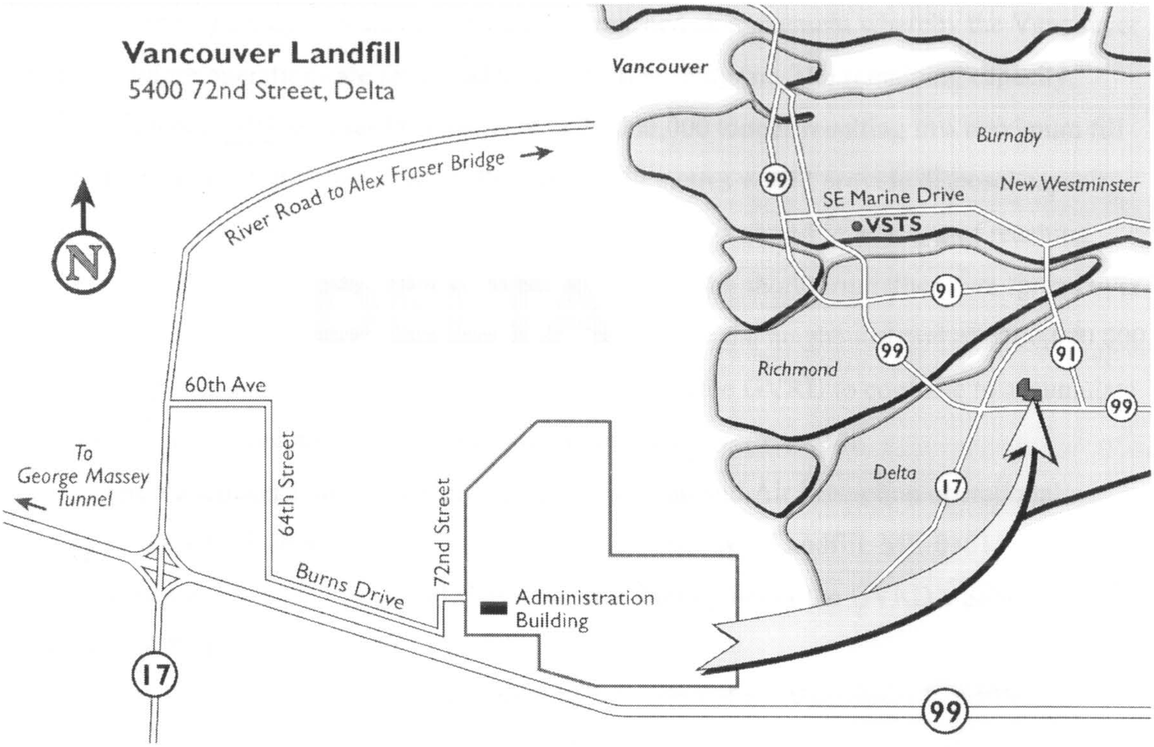

Figure 1-2: Vancouver Landfill Location Plan *(used by permission of the City of Vancouver)*

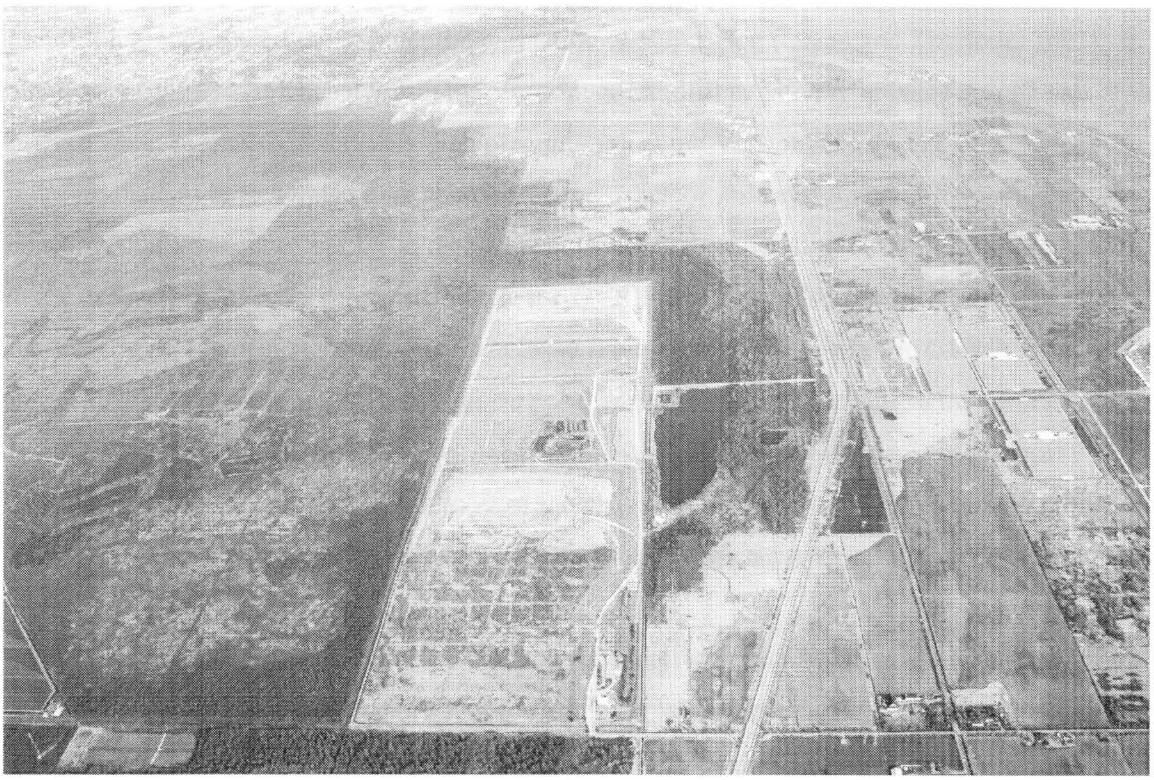

Figure 1-3: Vancouver Landfill Aerial Photograph *(used by permission of the City of Vancouver)*

In 1999, the City of Vancouver and Delta reached an agreement whereby the Vancouver Landfill's future operations are restricted to the existing footprint. The remaining capacity, effective October 1997, was set by agreement at 20,000,000 tonnes resulting in a maximum fill height of 39 metres. Filling the existing footprint to 39 metres would provide disposal capacity for approximately 40 more years. If the Vancouver Landfill is closed in advance of reaching capacity, landfill closure costs will need to be funded over the short term rather than spread over up to 40 years. Closure costs are currently estimated to be in the neighbourhood of $100,000,000. Filling to capacity would allow the City of Vancouver and the GVRD to continue to accumulate reserves to fund closure and post-closure care of the Vancouver Landfill.

The Vancouver Landfill's Ministry of Water Land and Air Protection operational certificate MR-01611 authorizes the operation of the Vancouver Landfill. MR-01611 requires that the Vancouver Landfill be included as a disposal facility under the GVRD's Solid Waste Management Plan.

Some members of the public feel that the operation of the Vancouver Landfill negatively impacts Burns Bog. In an October 8, 2003, article in the Delta Optimist, Eliza Olson, the President of the Burns Bog Conservation Society, suggests that the operation of the Vancouver Landfill has contributed to the potential extinction of Burns Bog (Olson and Truelove, 2003). In addition, they feel that leachate from the Vancouver Landfill negatively impacts ground and surface water resources. Relatively high precipitation at the Vancouver Landfill causes much more leachate to be generated than at either Cache Creek or Ashcroft Ranch. There are also concerns that Vancouver and Delta receive benefits from the operation of the Vancouver Landfill at the expense of the other municipalities in the GVRD. Vancouver's garbage is disposed of at the Vancouver Landfill at a cost lower than what other municipalities pay the GVRD for garbage disposal, and Delta receives free garbage disposal as well as direct revenues in the form of royalties. On this basis, and given that Ashcroft Ranch could potentially provide disposal capacity for the entire Region (if not most of the province of British Columbia), a potential course of action would be to close the Vancouver Landfill when the Ashcroft Ranch facility opens.

On February 19, 2002, Delta's municipal council unanimously directed Delta staff to pursue three potential amendments to the GVRD Solid Waste Management Plan. Of the three amendments, the only one with any local significance was pursuing closure of the Vancouver Landfill following a review of the Solid Waste Management Plan (Corporation of Delta, 2002).

A review of the GVRD's Solid Waste Management Plan is scheduled to commence in 2004. One of the issues that the Plan will need to address is whether the GVRD is best served under the current system with two regional landfills, or alternatively whether the Vancouver Landfill should be closed in advance of reaching capacity and all of the GVRD's waste (with the exception of that going to the Waste-to-Energy Facility) be shipped to the new Ashcroft Ranch Landfill. In the event that a decision is made to close the Vancouver Landfill, the earliest that the Vancouver Landfill would likely close would be approximately 2012, because 2012 coincides with filling a portion of the site to capacity.

The GVRD's stated objective is to develop the Ashcroft Ranch as a replacement for Cache Creek without increasing the amount of waste disposed of at the site. For Ashcroft Ranch to replace both the Vancouver Landfill and the Cache Creek Landfill, the GVRD would need to seek approval from the Ministry of Water Land and Air Protection as well as the community of Ashcroft.

In the event that the Vancouver Landfill is closed, waste hauled to VSTS would be transferred from VSTS to the Ashcroft Ranch. Waste currently dropped off directly at the Vancouver Landfill would either be dropped off at a new transfer station in Delta and then transferred to Ashcroft Ranch, or alternatively, dropped off at one of the existing transfer stations or the Waste-to-Energy Facility.

In 1994 as part of developing the 1995 GVRD Solid Waste Management Plan, CH2M Hill reviewed six potential options to provide disposal capacity for the GVRD (CH2M Hill, 1994). The options included:

1. Build new incinerator capacity once Cache Creek is filled while continuing to operate the Vancouver Landfill.
2. Build a new local landfill once Cache Creek is filled.
3. Expand Cache Creek as needed while continuing to operate the Vancouver Landfill.
4. Dispose all waste at Vancouver Landfill and Burnaby Waste-to-Energy Facility once Cache Creek is filled.
5. Close Vancouver Landfill in 1999 and build new incinerator capacity once Cache Creek is filled.
6. Close Vancouver Landfill in 1999 and expand Cache Creek as needed.

Of these options, the ones involving increased incinerator capacity were the most expensive. The least cost option was Option 2, developing a new local landfill once Cache Creek filled. Option 2 is not practical because a new local landfill cannot be sited due to opposition to siting a landfill in an area with any significant population. The next least cost option was Option

4, dispose of all waste at the Vancouver Landfill once Cache Creek is filled. Vancouver's agreement with Delta and the GVRD (City of Vancouver, Corporation of Delta and GVRD, 1989) would prevent all of the GVRD's waste from being disposed of at the Vancouver Landfill. The two remaining options (Options 3 and 6) are effectively the options that are evaluated in this paper: continue to operate the Vancouver Landfill as well as Ashcroft Ranch, or alternatively, close the Vancouver Landfill and ship all waste to Ashcroft Ranch.

This project attempts to compare the options of continuing to operate both landfills, or alternatively, closing the Vancouver Landfill and shipping all of the GVRD's waste to Ashcroft Ranch following 2012. Operating both facilities is considered the status quo option. The cost of the status quo is the calculated average cost of waste transfer and disposal for all of the GVRD's waste if the Vancouver Landfill operates to capacity. The costs and benefits of the alternative scenario, closing the Vancouver Landfill, include all costs and benefits expected to arise as a result of closing the Vancouver Landfill in 2012.

The initial capital costs of siting and constructing the Ashcroft Ranch facility are independent of whether the Vancouver Landfill is closed, because these costs are independent of the annual waste tonnage delivered to Ashcroft Ranch. Only Ashcroft Ranch's annual operating costs would be impacted by closing the Vancouver Landfill and shipping additional waste to Ashcroft Ranch.

The analysis is conducted from the perspective of residents of the GVRD because GVRD residents bear the lion's share of costs associated with managing waste from the GVRD.

The cost-benefit analysis uses a base year of 2002, because financial and solid waste operational data from the City of Vancouver, as well as the GVRD, are readily available for that year. The analysis ignores the impacts of the new Surrey Transfer Station on the GVRD system because there is not yet operational data for the facility, and it is not anticipated that adding the Surrey Transfer Station will materially change the costs and benefits of the two options under consideration. The addition of the Surrey Transfer Station is not expected to significantly change the costs and benefits of the two options because all of the waste from the Surrey Transfer Station will be shipped to Ashcroft Ranch under either scenario. On this basis, any changes in overall system costs by adding the Surrey Transfer Station will be the same for either option.

2 COST-BENEFIT ANALYSIS

Cost-benefit analysis provides a method of quantifying the nets benefits of a project or policy and comparing the project to other potential projects or policies. The goal of cost-benefit analysis is to measure the project's ability to achieve potential Pareto efficiency; i.e. the benefits exceed the costs such that it would be possible for the recipients of the benefits to compensate those negatively impacted. A potential Pareto efficiency is more achievable than actual Pareto efficiency because, in most cases, identifying and compensating all of the negatively impacted individuals would be inefficient and impractical. A social cost-benefit analysis involves quantifying costs and benefits realized by society as a whole (Campbell and Brown, 2003). When comparing substitute projects for purposes of capital budgeting, the public sector strategist should presumably select the project offering the largest net social benefit in order to maximize social welfare, thus increasing efficiency.

Boardman et. al. (2001) list the following nine steps in conducting a cost-benefit analysis:

1. Specify alternatives
2. Determine who has standing
3. Catalogue impacts
4. Predict and quantify impacts over the life of the project
5. Monetize impacts
6. Discount benefits to present value
7. Calculate the net present value of each alternative
8. Perform sensitivity analysis
9. Recommend an alternative

Specifying alternatives involves determining a range of potential alternatives for analysis. In practise it is impossible to compare the cost and benefits of all of the possible alternative scenarios. For instance, it would be difficult to compare the costs and benefits of developing the Richmond Airport Vancouver (RAV) rapid transit line to the cost and benefits of all other potential senior government projects in British Columbia. In general, a potential alternative project or policy is compared to the project or policy that would be displaced in the event the alternative project or policy proceeds. The displaced project or policy is normally the status quo.

Determining standing means specifying for whom costs and benefits should be counted. Analysts must determine whether to take a local or global perspective. Standing is often determined based on the constituents of the analyst. For instance, the federal government often takes a national perspective in cost-benefit analysis compared to an international perspective.

Cataloguing a project's benefits and costs over the project's life involves listing all of the impacts of the project and determining the measurement units of the impacts. Only impacts that affect individuals with standing need to be considered. Predicting benefits and costs over a project's life is often challenging. According to Boardman et al. (2001), there are almost no data available comparing actual cost and benefits to pre-project estimates of costs and benefits. One of the reasons that predicting costs and benefits is challenging is that for most projects the impacts will occur over a long time. During that time, many unpredictable factors may affect the costs and benefits of a project. One way to deal with this challenge is to identify the most important factors and conduct a sensitivity analysis of the impacts of changing the values of those factors. Boardman et al. (2001) include this as Step 8 of a cost-benefit analysis.

Step 5 involves monetizing all of the impacts of a project. Impacts with inconsistent units must be standardized to allow calculation of overall costs and benefits. Benefits are often calculated based on measurement of "willingness to pay". Willingness to pay can be calculated for market goods based on market value, but for non-market goods, such as environmental quality, willingness to pay is more difficult to quantify. Costs are calculated as the opportunity costs of the project inputs, the value of the inputs in their best alternative use.

Boardman et al. (2001) note that there is a tendency among some project proponents to count expenditures as benefits. Government expenditures on a project, for instance the 2010 Olympics, may be seen as benefits because the expenditures are made within the community. Cost-benefit analysis considers only the actual benefits realized. Payments to contractors, labour and material suppliers may simply replace payments that they would receive to do other work if the Olympic work were not available. The benefit of a new sports venue built through Olympic funding would be the net value to the community of the venue measured through the community's willingness to pay for the venue, not the cost of the venue.

The cost of the venue would be the value of all inputs required to construct the facility. In addition to the cash cost, if the land where the venue is to be built was previously a children's playground, part of the cost of the project would be the amount of money that would be required to compensate each user of the playground such that they are ambivalent to the loss of the playground.

Steps 6 and 7 of the cost-benefit analysis process involve discounting the benefits and costs to present values and calculating a net present value of the alternative. Discounting allows benefits and costs incurred at different times to be compared. A $100 cost incurred today is not the same as a $100 cost incurred in 10 years.

One of the critical issues in determining the cost and benefits of alternatives is to determine the rate at which to discount future costs and benefits. A higher discount rate tends to minimize future costs and benefits. Analysts use either a nominal or a real discount rate. A nominal rate includes an allowance for inflation. A real rate is net of inflation. Analysis can be done using either method. If a nominal rate is used, all future costs and benefits must be scaled up for expressed inflation. If a real rate is used, future costs and benefits are not adjusted for inflation. In the analysis presented in this paper, a real discount rate is used.

Boardman et al. (2001) suggest that various methods can be used to calculate social discount rates. Rates for government projects vary in different jurisdictions. Boardman suggests real rates used in government projects range from approximately 3% to 10%, with municipalities in the U.S. using rates of around 3%. Some U.S. federal agencies use discount rates tied to the U.S. Treasury's borrowing rates as measured by U.S. government securities yields (Boardman et. al., 2001).

Newall and Pizer (2003) suggest that social discount rates used for evaluating long term benefits, such as benefits from reduced greenhouse gas emissions, need to be very low. They suggest that for projects with timelines of 100 years, a real discount rate of 2% is appropriate. They suggest for 200 year horizons that 1% is appropriate and 0.5% for 400 years.

For this project, the social discount rate is assumed to be the "long-term interest rate" as indicated by the Bank of Canada long-term bond rates. A rate derived from long-term Bank of Canada bond rates is the most reasonable discount rate for analysis of the operation of the Vancouver Landfill because the Landfill is publicly funded and the cost of long-term capital for the City of Vancouver is effectively the cost of long-term bonds. According to the Bank of Canada (Bank of Canada, 2004), the average yield on bonds with a term of more than 10 years is currently (June 29, 2004) approximately 5.4%. According to Statistics Canada (Statistics Canada, 2004), the inflation rate for May 2004 is 2.5%. Using the current inflation rate as a forecast of future inflation, the real interest rate is 2.9% based on the method described by Newell and Pizer (subtraction) or 2.83 % based on the method described in Boardman et at. (2001) (compounding).

Newell and Pizer (2003) present long term U.S. government bond yields from 1790 to present. Nominal rates vary from 4% to 8% with the exception of the period 1970 to approximately 1990, when nominal rates reached a maximum of 12% and real rates reached a maximum of approximately 7%. If current real and nominal interest rates are compared with those provided by Newell and Pizer, the current rates are among the lowest in history.

Ken Bayne (2003), the City of Vancouver's Director of Financial Planning and Treasury, advises that for City of Vancouver projects, he currently uses a nominal discount rate of 6% based on 10 year borrowing costs. On this basis, based on the method described by Boardman et al. (2001) to calculate real interest rates, the real rate used by the City of Vancouver would currently be 3.4%. Given the current low interest and inflation rates, a 4% real interest rate seems more plausible and is used in this project. The analysis therefore assumes that a 4% real interest rate will be the average real cost of borrowing for the City of Vancouver over the analytical period of approximately 40 years.

Detractors of cost-benefit analysis do not agree that it is appropriate to monetize all benefits and costs and sum them to calculate the net benefit of a project. In colloquial terms, detractors of cost-benefit analysis liken it to "comparing apples to oranges". Valuing lives in particular seems untenable to some. Alternative approaches to cost-benefit analysis include qualitative analysis, cost effectiveness analysis and multigoal analysis.

Qualitative analysis involves monetizing only some of the benefits and costs and subjectively estimating the relative importance of the remaining impacts. Qualitative analysis is appropriate if only some of the benefits and costs can be reliably monetized.

Cost effectiveness analysis involves determining the ratio of the cost to the major benefit achieved. Boardman et. al. (2001) use, as an example, the cost per dolphin saved of a policy restricting fishing practices to illustrate cost effectiveness analysis. Cost effectiveness analysis is most useful if analysts cannot or will not monetize the primary cost or benefit of a policy. It may also be appropriate if the measure of effectiveness captures most of the major benefits and costs of the project.

Multigoal analysis involves specifying a range of policy objectives and assessing the impacts of particular projects in achieving each of those objectives. For instance, a multigoal analysis of the RAV line compared to a light rapid transit line along the Arbutus corridor might look at impacts of each option on a range of goals including minimizing total cost, maximizing transit ridership, minimizing impacts on property values, tailoring development along the corridor, reducing single occupancy vehicle traffic, and reducing greenhouse gas emissions. Multigoal analysis is the most general analytical framework. Cost-benefit analysis in comparison measures the effectiveness of the project in achieving a single goal, efficiency. Multigoal analysis is therefore most appropriate when there are multiple goals for the policy.

In the case of determining the appropriate solid waste disposal strategy for the GVRD, measuring the efficiency of the alternative strategies should provide the best solid waste management strategy. In addition, the benefits and cost of each strategy can be monetized. On this basis, cost-benefit analysis is the appropriate analytical tool.

3 THE GVRD SOLID WASTE MANAGEMENT SYSTEM

Figure 3-1 provides a value chain for the solid waste industry. The value chain shows the process of waste generation to disposal. The City of Vancouver footprint occupies a significant portion of the value chain. The City of Vancouver collects municipal solid waste from single-family dwellings, and operates VSTS and the Vancouver Landfill. The GVRD footprint includes only waste transfer and waste disposal, with six transfer stations, a waste-to-energy facility and a landfill.

Solid Waste Services Industry Value Chain

Waste Generation	Waste Collection	Waste Transfer	Waste Disposal

City of Vancouver Activities

Figure 3-1: Solid Waste Services Value Chain

3.1 Waste Collection

Waste collection includes three primary components: commercial waste collection (front-end and roll-off business), small-scale clean-up, and single family residential collection. The City of Vancouver is one of the few municipalities in the Lower Mainland that uses City crews to collect garbage, recyclables and yard trimmings from single-family and some multi-family homes.

For single family residences, waste collection and disposal fees are funded as a separate utility. Utility fees are collected as a separate line item in the property tax notice. Multi-family, commercial and institutional waste generators normally contract with a commercial waste hauler that charges them a monthly service fee for collection and disposal of solid waste. These fees are generally based on the size of collection container provided to the waste generator and the frequency of removal of solid waste.

3.2 Waste Transfer

One of the impacts of urbanization throughout North America is that landfills close to urban areas are closing and being replaced by distant landfills. In many cases, solid waste is transported hundreds of kilometres from the point of origin. To facilitate transport of municipal solid waste, transfer stations have been constructed in major centers across North America. Transfer stations provide convenient garbage drop-off locations for residents and businesses as well as reduce the truck traffic delivering waste to landfills. In most cases, the net cost of managing the waste is reduced as a result of the use of transfer stations compared to direct hauling to remote landfills.

Vancouver owns and operates a single transfer station (VSTS) at the southern edge of Vancouver at 377 West Kent Avenue North. VSTS serves Vancouver, Richmond and UBC. In addition to VSTS, there are five municipal waste transfer stations in the GVRD: North Shore, Coquitlam, Matsqui, Langley and Maple Ridge. A sixth GVRD transfer station opened in April 2004 in Surrey. Contractors operate the six GVRD transfer stations on behalf of the GVRD.

3.3 Waste Disposal

Landfills receive approximately 80% of the municipal solid waste disposed of in North America. The other primary disposal option is waste incineration. Incinerators typically burn garbage and generate either electricity or heat for sale. Under the current energy-pricing environment, landfills typically operate at 50% of the cost of incinerators. Landfills have an additional benefit of being very flexible with respect to waste throughput. Incinerators have a maximum daily capacity and to operate efficiently must operate at or near their capacity. Waste flow into a landfill can be increased or decreased by simply adding or subtracting staff and mobile equipment as required. In particular, if waste is initially delivered to transfer stations prior to final disposal, waste flow into a particular landfill can increase dramatically by hauling new transfer station waste to the facility. Flexibility is important to accommodate seasonal variations in waste flows, as well as system disruptions caused by mechanical failure, labour disruptions, inclement weather and the like.

The City of Vancouver owns and operates the Vancouver Landfill in Delta. The Vancouver Landfill is one of three facilities that serve the GVRD. The other two facilities are operated by the GVRD and include the Burnaby Waste-to-Energy Facility and the Cache Creek Landfill. The Vancouver Landfill serves approximately 900,000 people or slightly more than 40% of the GVRD. The Burnaby Waste-to-Energy Facility serves roughly 20% of the GVRD. The Cache Creek Landfill serves the remaining population.

Waste from VSTS moves to the Vancouver Landfill. Waste from each of the other transfer stations moves either to the Vancouver Landfill, the Burnaby Waste-to-Energy Facility, or alternatively to Cache Creek. Both the Burnaby Waste-to-Energy facility and Cache Creek are capped at a maximum annual waste capacity. Burnaby is capped based on physical constraints, and Cache Creek is capped based on the requirements of its Ministry of Water Land and Air Protection Operational Certificate.

Waste transferred between facilities within the GVRD (e.g. from North Shore Transfer Station to the Waste–to-Energy Facility) is hauled in self-unloading "walking floor" trailers. Because the trailers are self-unloading they can be used to haul waste between different facilities. The walking floor trailers are used for single direction hauling to haul waste from one facility to another without hauling anything back to the originating facility. The walking floor trailers are not suitable for backhauls because debris gets stuck in the floorboards of the trailers making them hard to clean.

Waste hauled to Cache Creek is hauled in trailers that are unloaded in Cache Creek using a "tipper". The trailers are driven onto the tipper and the entire trailer is lifted to a steep angle to allow the garbage to slide out of the trailer. The trailers are then cleaned and used to haul wood chips back to the Lower Mainland. Back-hauling wood chips reduces waste hauling costs by about 50%, but creates a cost risk in the event that wood chips are not available. In 2001, the wood chip plant in Cache Creek shut down for several months impacting the GVRD's hauling costs.

Figure 3-2 provides a summary of the GVRD waste transfer and disposal system. Figure 3-2 is based on a 2000 GVRD document outlining waste flow alternatives and costs for each of the GVRD's solid waste facilities, as well as the 2002 Vancouver Landfill Annual Report (City of Vancouver, 2003). GVRD 1999 costs have not been adjusted for inflation because using the GVRD 1999 costs, 2002 GVRD system costs and revenues balance with the GVRD's reported operating surplus (GVRD, 2003).

The text boxes in Figure 3-2 indicate the name of a facility and the operating cost per tonne of the facility. The arrows indicate the disposal facilities that waste from the facility is transferred to. The number adjacent to the arrows represents transfer costs. As an example, as indicated in the figure, waste from the North Shore Transfer Station (NSTS) is transferred either to the Burnaby Waste-to-Energy Facility, the Vancouver Landfill or Cache Creek. The total cost of transfer and disposal of waste originating at NSTS and transferred to Cache Creek is $52.98 (i.e. $13.85 + $16 + $23.13). A GVRD administration cost of $3.67 is added to the total disposal cost for a net cost of $56.65. These costs are the actual expenditures by the GVRD to provide transfer and disposal.

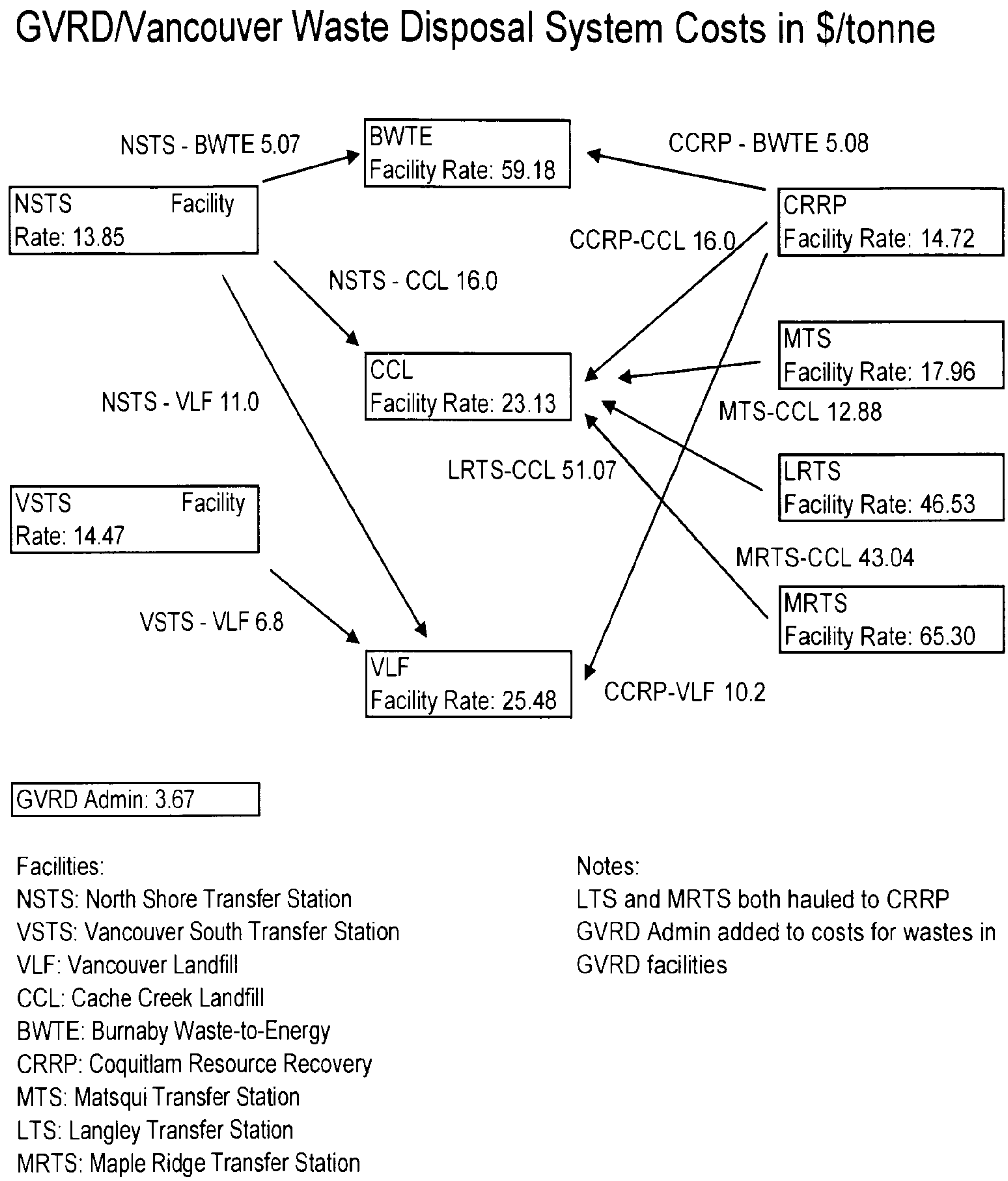

Figure 3-2: GVRD/Vancouver Waste Disposal System

The distribution of waste within the GVRD is shown in Table 3-1. Table 3-1 shows that the cost of operating the entire GVRD solid waste system in 2002 was approximately $64,300,000. Based on a system-wide tonnage of 1,088,258 tonnes in 2002, the average cost per tonne for waste transfer and disposal in 2002 equalled $59.

Table 3-1: 2002 GVRD Waste Flow and Financial Model

2002 Regional Waste Flow and Financial Model

	Annual Direct Haul (tonnes)	VLF (tonnes)	Burnaby (tonnes)	Cache Creek (tonnes)	Costs ($)
Coquitlam TS	327,792	10,225	8,529	309,038	19,754,796
North Shore TS	175,987	40,272	99,633	36,082	12,792,224
Matsqui TS	66,679			66,679	3,990,071
Langley TS	9,527			9,527	1,206,118
Maple Ridge TS	12,717			12,717	1,746,044
Burnaby	156,198		156,198		10,160,680
VSTS	247,750	247,750			12,127,359
VLF	91,608	91,608			2,535,708
	1,088,258	389,855	264,360	434,043	$64,313,000

Average Cost/Tonne $59.10 $/tonne

3.4 Fixed and Variable Costs

Fixed and variable costs for the disposal facilities are of interest. Fixed costs are the costs of operating a facility that are independent of waste quantity. Leachate management costs for example are not impacted by the amount of waste received at a landfill. Leachate is liquid generated when rainwater infiltrates into a landfill. For the Vancouver Landfill, leachate management costs will only change as portions of the landfill are closed and capped with an impermeable cover reducing rainwater infiltration into the landfill. Variable costs are costs that vary based on the amount of waste processed at the facility. Variable costs increase proportionally with increasing waste hauled into a landfill. For instance, more heavy equipment such as bulldozers is required if additional waste is hauled into a landfill. Nonetheless, in the event that a landfill is closed, the majority of fixed expenditures would no longer be required. For instance, administration costs would shrink to almost nothing. The concept of fixed and variable costs therefore only applies to a reasonable range of operating scenarios, such as doubling the amount of waste hauled into a facility. Once fixed and variable costs are understood, one can calculate impacts of changes in waste quantities.

Fixed and variable cost data are available for the Vancouver Landfill but not for Cache Creek or Ashcroft Ranch. Table 3-2 shows estimated fixed and variable costs for the Vancouver Landfill for 2002. Fixed costs include salaries, administrative and overhead costs, environmental protection expenses, and fees associated with the discharge of leachate to the Delta sewer system. Vancouver pays Delta based on the total volume of leachate discharged to sewer.

Variable costs include labour costs, equipment costs, and costs for road and cover materials purchased. Table 3-2 shows that fixed costs make up approximately 47% of the Vancouver Landfill's operating costs.

Table 3-2: Vancouver Landfill Fixed and Variable Costs

2002 Vancouver Landfill Costs

Fixed Costs	
Salaries, Administration and Overhead	2,884,150
Environmental Protection	933,900
Leachate Management	962,405
Total Fixed Costs	4,780,455
Variable Costs	
Wages	1,415,945
Vehicle and Equipment	2,484,800
Roads and Cover	1,407,100
Total Variable Costs	5,307,845
2002 VLF Operating Cost	27.54 $/tonne
Fixed Costs	13.05 $/tonne
Variable Costs	14.49 $/tonne

Source: City of Vancouver, 2003

For Cache Creek, based on Figure 3-2, the facility's total costs equal $23.13 per tonne. If unit variable costs (in dollars per tonne) for Cache Creek are equal to the Vancouver Landfill's unit variable costs, fixed costs for Cache Creek (and in the future Ashcroft Ranch) can be calculated by subtracting the Vancouver Landfill variable cost per tonne from the Cache Creek total cost per tonne. Calculating Cache Creek's fixed and variable costs from the Vancouver Landfill variable costs is reasonable because labour and equipment costs for both facilities are comparable, and basic landfill processes such as covering the garbage and road construction are required at both sites. The estimated fixed costs for Cache Creek are therefore $8.64 per tonne. Vancouver's fixed costs are higher than Cache Creek's because Vancouver's costs include administration, whereas GVRD's administration costs are not included in the Cache Creek operating costs but instead are an additional cost as indicated in Figure 3-2. In addition, leachate management costs at the Vancouver Landfill account for 20% of fixed costs. High precipitation at the Vancouver Landfill results in high leachate volumes. In comparison, leachate management costs at Cache Creek are insignificant due to minimal precipitation. As described in Section 4.1, using fixed and variable costs for Ashcroft Ranch derived from the Vancouver Landfill's costs provides the same operating cost as using a relationship developed by Sperling Hansen Inc. (2001) based on reviewing the operating costs of 31 British Columbia landfills.

4 QUANTIFYING COSTS AND BENEFITS

This chapter summarizes the incremental benefits and costs associated with the proposed alternative scenario of closing the Vancouver Landfill in 2012 and shipping all of the GVRD's waste (with the exception of that going to the Waste-to-Energy Facility) to Ashcroft Ranch. If there are positive net benefits (in present value terms), the Vancouver Landfill early closure option is preferred to the option of operating the Vancouver Landfill to capacity.

4.1 Transfer & Disposal

In the event that the Vancouver Landfill is closed in 2012, it is anticipated that the total cost for transfer and disposal of the GVRD's garbage will be greater than it would be in the event that the Vancouver Landfill continued to operate. This is in spite of decreased disposal costs at Ashcroft Ranch due to economies of scale.

In the event that the Vancouver Landfill closes in 2012, either a new transfer station at the existing Vancouver Landfill site would be required or alternatively waste would need to be delivered to one of the GVRD's existing transfer stations. From a societal cost-benefit perspective, developing a new transfer station at or near the Vancouver Landfill would be the least cost option because if no new transfer station is built, residents and businesses would incur greater costs delivering waste to existing facilities than the cost to the GVRD of constructing and operating a new transfer station at the Vancouver Landfill. This analysis therefore assumes that a new transfer station would be developed at the Vancouver Landfill site.

In the event that the Vancouver Landfill closed, system costs would be identical to those shown in Figure 3-2 with the exception of:

- VSTS Transfer Costs : $17/tonne
- New Vancouver Landfill Transfer Station Facility Cost: $17/tonne
- New Vancouver Landfill Transfer Station Transfer to Cache Creek: $17/tonne
- Ashcroft Ranch Operating Cost: $19/tonne

Estimated costs for VSTS and the Vancouver Landfill Transfer Station are based on comparisons with existing GVRD facilities. Ashcroft Ranch costs are based on calculated variable and fixed costs from Table 3-2. Sperling Hansen (2001) reviewed operating cost data from 31 landfills in B.C. ranging in annual waste tonnage from 250 tonnes to 450,000 tonnes. Sperling Hansen developed a first order equation to model reductions in operating costs with increasing operating tonnage. The equation predicts that an increase in operating tonnage from 434,000 to 825,000 tonnes per year (the impact of closing the Vancouver Landfill) would result in a 17% reduction in operating costs. Given that the Sperling Hansen relationship is based on a first order equation, increasing waste tonnage by a fixed proportion would result in a fixed proportionate decrease in cost. In this case, increasing waste tonnage by a factor of 1.9 leads to a 17% reduction in cost. The calculated reduction in operating cost for Ashcroft Ranch based on the information in Table 3-2 is 18%.

Table 4-1 shows that the total annual GVRD system costs without the Vancouver Landfill would be approximately $67,200,000 per year. Table 3-1 shows the total annual GVRD system cost including the Vancouver Landfill equals approximately $64,300,000. The costs shown in Table 4-1 are not discounted or inflated, and therefore represent the annual costs if the Vancouver Landfill were closed today. The costs shown in Table 4-1 are approximately $2,900,000 per year (4.5%) higher than the costs based on the Vancouver Landfill continuing to operate as shown in Table 3-1.

In 1994, CH2M Hill analysed the overall system cost per tonne of various disposal options for the GVRD (CH2M Hill, 1994). After accounting for capital upgrading requirements at each facility, CH2M Hill concluded that the average GVRD system cost per tonne with long-term operation of the Vancouver Landfill would be approximately 3.5% cheaper than if the Vancouver Landfill closed and all of the GVRD's wastes were shipped to an expanded Cache Creek facility. The 4.5% estimate above is therefore close to the CH2M Hill estimate. Some of the capital upgrades CH2M Hill included in their analysis of the Vancouver Landfill costs have not been required, which explains the slightly lower CH2M Hill estimate of the difference between the options.

Table 4-1: GVRD Costs Without Vancouver Landfill

Regional Waste System Model Without Vancouver Landfill

	Annual Direct Haul (tonnes)	Burnaby (tonnes)	Ashcroft Ranch (tonnes)	Costs ($)
Coquitlam TS	327,792	8,529	319,263	18,484,286
North Shore TS	175,987	99,633	76,354	12,630,554
Matsqui TS	66,679		66,679	3,717,354
Langley TS	9,527		9,527	1,167,153
Maple Ridge TS	12,717		12,717	1,694,032
Burnaby	156,198	156,198		10,160,680
VSTS	247,750		247,750	13,968,145
New VLF TS	91,608		91,608	5,396,627
	1,088,258	264,360	823,898	$67,218,831

Average Cost/Tonne	$61.77	$/tonne
Increased Cost	$2,905,831	$/year

4.2 Secondary Materials Disposal

The primary material received at the Vancouver Landfill is residential, commercial and institutional solid waste. In addition, the Vancouver Landfill receives waste asbestos, bottom ash from the Burnaby Waste-to-Energy Facility, and residuals from the GVRD's sewage treatment plants.

Waste asbestos is a hazardous waste that can be safely handled at a landfill only if it is hauled and disposed of separately from other waste. Bottom ash from the Burnaby Waste-to-Energy facility is used as a material to cover other garbage at the Vancouver Landfill and therefore received at a nominal fee. Sewage treatment plant residuals include sand and grit from the plant inlet, as well as other materials that are removed from the sewage during the treatment process. Sewage treatment plant residuals are odourous and have high moisture content. Sewage treatment plant residuals are therefore not suitable for disposal at a transfer station.

For each of asbestos, bottom ash and sewage treatment plant residuals, the generators would pay higher costs in the event that the Vancouver Landfill closed due to higher transportation and disposal costs to facilities outside of the GVRD. Asbestos and sewage treatment plant residuals would need to be hauled directly to some remote disposal facility. The asbestos and sewage treatment plant residuals would require special handling and therefore incur high costs once delivered to a landfill. Ash could likely be hauled to a transfer station and then shipped to Ashcroft Ranch or alternatively hauled directly to Ashcroft Ranch.

The quantities currently disposed of at the Vancouver Landfill and the estimated cost of disposal for each of asbestos, sewage treatment plant residuals, and incinerator bottom ash are shown in Table 4-2. The cost for sewage treatment plant residuals is based on costs currently incurred by the GVRD to ship some sewage treatment plant residuals to a landfill in the United States (Carrusca, 2004). Asbestos costs are based on the costs to ship asbestos contaminated with gypsum to Alberta. Asbestos contaminated with gypsum is not acceptable for disposal at the Vancouver Landfill, but is handled in exactly the same fashion as other asbestos at private landfills in Alberta. Bottom ash disposal costs are the costs currently incurred by the GVRD to ship and dispose of fly-ash from the Burnaby Waste-to-Energy Facility to Cache Creek, adjusted for reduced future costs at Ashcroft Ranch. If the Vancouver Landfill closed, other less expensive options might develop. For instance, in some jurisdictions, bottom ash from incinerators is recycled into road aggregate. Since lower cost opportunities are uncertain, no reduction in cost compared to the costs currently incurred for similar materials is assumed.

Wood waste construction and demolition materials are also received at the Vancouver Landfill, but these materials are not expected to be received at the site beyond 2012, and therefore any benefit would be the same under either alternative.

Table 4-2: Secondary Material Costs

Secondary Material Costs

Material	Quantity (tonnes/year)	Vancouver Landfill Cost ($/tonne)	Cost if Exported ($/tonne)	Increase ($/year)
Asbestos	2,900	80	250	$493,000
Sewage Treatment Plant Residues	2,600	50	127	$200,200
Incinerator Ash	40,000	10	43	$1,320,000
Total Annual Additional Cost				$2,013,200

4.3 Landfill Closure

Under the 1989 Tripartite Agreement (City of Vancouver, Corporation of Delta and GVRD, 1989), closure and post-closure care costs at the Vancouver Landfill will be shared by the GVRD and Vancouver proportionally based on the amount of waste the GVRD contributes to the Vancouver Landfill. Closure involves installing an impermeable plastic cap and ancillary works on the surface of the landfill to minimize rainwater infiltration into the landfill. Minimizing rainwater infiltration reduces the leachate generated in the landfill, reducing leachate management costs as well as the potential for the leachate to impact the environment.

Closure and post-closure care costs are estimated to be in the order of $100,000,000. If the Vancouver Landfill is filled to capacity, closure will occur over approximately 40 years. The site would be closed progressively in nine phases as each phase reached capacity. The fill plan for the site is shown in Figure 4-1.

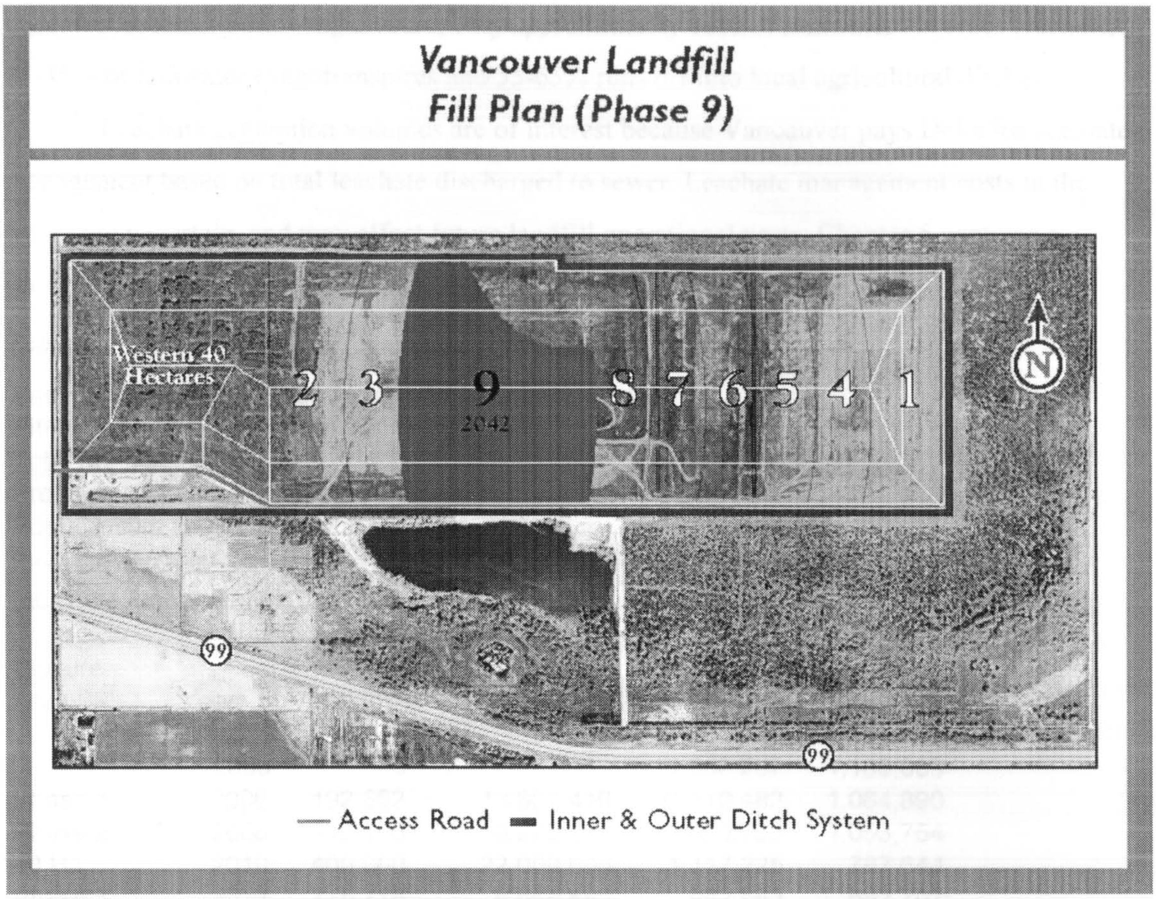

Figure 4-1: Vancouver Landfill Fill Plan (used by permission of the City of Vancouver)

If the Vancouver Landfill is closed in advance of reaching capacity, closure costs for the entire site will be incurred over a few years. Although without inflationary impacts, the actual expenditure for closure and post-closure care will not change based on when closure occurs, delaying the expenditure reduces the present value of the expense.

Table 4-3 shows the anticipated closure schedule and costs (not adjusted for inflation and not discounted) for the Vancouver Landfill if the site is filled to capacity. In the event that the Vancouver Landfill is closed in 2012, all of the remaining area of the site (approximately 2/3 of the total site area) would be closed in that year. This scenario is shown in Table 4-4. The total expenditure in 2012 would therefore be approximately $64,000,000. Expenditures in Table 4-3 and Table 4-4 are not adjusted for inflation or discounted to show the proportions of the site that will require closure at each instance in time. Closure costs are discounted to allow comparison of the two alternatives in Chapter 5.

Table 4-3 and Table 4-4 also show the expected annual leachate generation following closure of each phase. Prior to closure, all rainwater that is not evapotranspired from the site becomes leachate. Following closure, only approximately 10% of rainwater becomes leachate, 25-35% of rainwater evapotranspires and 55-65% runs off into local agricultural ditches.

Leachate generation volumes are of interest because Vancouver pays Delta for leachate management based on total leachate discharged to sewer. Leachate management costs in the future are uncertain, and may affect future landfill operational costs. Chapter 5 contains a sensitivity analysis of the impacts of increasing leachate management costs.

Table 4-3: Final Cover and Leachate Costs Full Capacity Model

Vancouver Landfill Final Cover and Leachate Costs
Fill to Full Capacity Model

Total Precipiation	1179	mm/year
Pre-Closure Leachate/Precip Volume	75%	
Post-Closure Leachate/Precip Volume	10%	
Final Cover Cost	55.00	$/m^2
Leachate Management Cost	0.71	$/m^3

Closure Area	Year	Closure Area (m^2)	Closure Cost ($)	Leachate Volume (m^3)	Leachate Cost ($/year)
	2003	0		1,658,282	1,169,089
Phase 1	2006	192,862	10,607,410	1,510,482	1,064,890
Phase 2	2008	113,156	6,223,580	1,423,765	1,003,754
40 Ha	2010	400,000	22,000,000	1,117,225	787,644
Phase 3	2012	175,718	9,664,490	982,563	692,707
Phase 4	2017	122,755	6,751,525	888,490	626,386
Phase 5	2020	105,875	5,823,125	807,353	569,184
Phase 6	2023	105,791	5,818,505	726,280	512,027
Phase 7	2028	157,045	8,637,475	605,928	427,180
Phase 8	2032	144,022	7,921,210	495,557	349,368
Phase 9	2041	358,130	19,697,150	221,104	155,878
		1,875,354	$103,144,470		

Notes: All costs are not adjusted for inflation and not discounted

Table 4-4: Final Cover and Leachate Costs 2012 Closure Model

Vancouver Landfill Final Cover Costs and Leachate Generation Close in 2012 Model		
Total Precipiation	1179	mm/year
Pre-Closure Leachate/Precip Volume	75%	
Post-Closure Leachate/Precip Volume	10%	
Final Cover Cost	55.00	$/m^2$
Leachate Management Cost	0.71	$/m^3$

Closure Area	Year	Closure Area (m^2)	Closure Cost ($)	Leachate Volume (m^3)	Leachate Cost ($/year)
	2003	0		1,658,282	1,169,089
Phase 1	2006	192,862	10,607,410	1,510,482	1,064,890
Phase 2	2008	113,156	6,223,580	1,423,765	1,003,754
40 Ha	2010	400,000	22,000,000	1,117,225	787,644
Remainder	2012	1,169,336	64,313,480	221,104	155,878
		1,875,354	$103,144,470		

Notes: All costs are not adjusted for inflation and not discounted

4.4 Landfill Gas Utilization

Landfill gas from the Vancouver Landfill is used to generate electricity and heat at the CanAgro Greenhouse adjacent to the Landfill. Maxim Power Corporation developed the project in 2003 with a $10,000,000 investment. Maxim sells electricity to B.C. Hydro and heat to CanAgro. The heat is a by-product of generating electricity and is sold to CanAgro at a significant savings compared to natural gas. If the Vancouver Landfill closes in 2012, landfill gas production from the site will decrease gradually over time making less gas available for electrical and heat generation. The anticipated landfill gas production for either closure at capacity or in 2012 is shown in Figure 4-2.

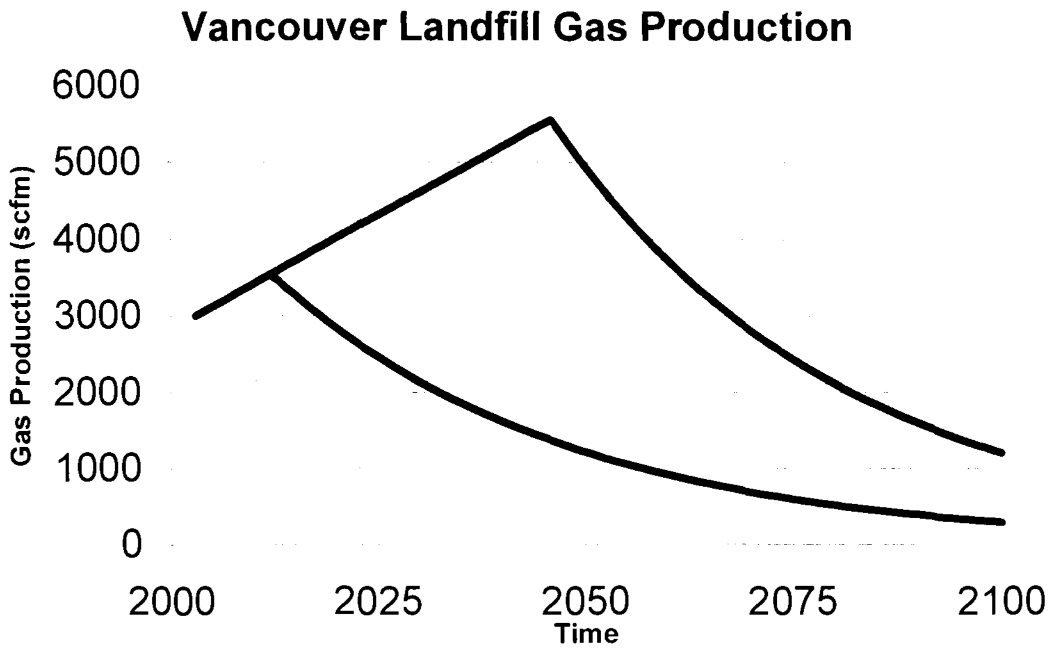

Figure 4-2: Vancouver Landfill Gas Production

The Vancouver Landfill gas beneficial use system captures approximately 500,000 GJ/year of energy from the Landfill. The total energy available is sufficient to meet the heat and electrical needs of 3,000 to 4,000 homes. Of the 500,000 GJ/year of energy, approximately 100,000 GJ/year is available to the greenhouse. The remainder is either captured as electricity or lost as heat. CanAgro pays less than $2 per GJ for the heat. Current market price is approximately $6 per GJ ($M^3$ & W Inc., 2004) (as of May 2004). On this basis, CanAgro receives a benefit of approximately $400,000 per year from the project. In the event that the Vancouver Landfill closes in 2012, the benefit to CanAgro will diminish over time when gas production tapers off as shown in Figure 4-2. In the event that the Vancouver Landfill continues to operate to capacity, the benefit to CanAgro will continue to grow with increasing gas production.

Many large landfills utilize landfill gas. The Vancouver Landfill gas utilization system is the only system in Canada that includes both electrical and heat generation through a cogeneration process. The heat can only be captured because of the proximity of the Vancouver Landfill to the CanAgro Greenhouse. Based on the operation of the Cache Creek Landfill (where no landfill gas is utilized currently), and the operation of other remote landfills across North America, it is unlikely that a cogeneration system could be employed at Ashcroft Ranch. On this basis, the heat energy captured through the cogeneration system would be lost if the Vancouver Landfill closed.

Although reduced heating costs are real benefit to CanAgro, since not all of the owners of CanAgro reside in the GVRD, it is difficult to conclude what portion of the benefit should be allocated to GVRD residents. On this basis, the increased costs to CanAgro will not be counted in the analysis as a cost of closing the Vancouver Landfill.

4.5 System Flexibility

With a solid waste disposal system including a local landfill, the GVRD solid waste management system is flexible allowing waste flows to be reallocated within the system as required. In the event of a storm, labour disruption, back-haul disruption, mechanical failure etc. waste can be redirected to the Vancouver Landfill within hours at minimal cost.

Adding waste to the Vancouver Landfill can be accomplished easily due to the short haul from the transfer stations to the Vancouver Landfill, and the ability to increase the daily waste processed at a landfill by simply adding mobile equipment and staff. If either the Waste-to-Energy Facility or the Cache Creek Landfill are closed or operating at limited capacity, waste can be immediately reallocated to the Vancouver Landfill. If no local landfill existed, reallocation of waste would be more challenging because of the long haul to Cache Creek. Round-trip to Cache Creek from the GVRD's transfer stations takes more than 8 hours compared to 2 hours to the Vancouver Landfill. Therefore, to shift the same amount of waste, three times the fleet size would be required if the waste were going to Cache Creek compared to the Vancouver Landfill (a walking floor load is approximately 24 tonnes compared to 36 tonnes for a B-train travelling to Cache Creek).

Redirecting waste from GVRD transfer stations to the Vancouver Landfill during peak seasons reduces GVRD fleet requirements. Figure 4-3 shows weekly waste transfer tonnage from the GVRD system into the Vancouver Landfill for 2003. In total, 105,000 tonnes of waste were transferred into the Vancouver Landfill from GVRD transfer stations in 2003. Weekly waste flows varied from 20 tonnes in the last week of February to 5,000 tonnes in mid May. The variation shown in Figure 4-3 is a result of seasonal variation of waste flow into the GVRD system, as well as system disruptions such as a spring shutdown of portions of the Burnaby Waste-to-Energy Facility. May and June have the highest waste flows with January and February the lowest waste flows. By transferring into the Vancouver Landfill, the GVRD can keep waste flows to Cache Creek constant. All of the system variation is handled through transfers to the Vancouver Landfill. If the Vancouver Landfill closed, the GVRD would need sufficient equipment to allow for peak garbage transport to Cache Creek. The tractors used by the GVRD are ubiquitous and could be rented or hired during peak months. The trailers on the other hand are specialized and would need to be kept on-hand to manage peak waste flows.

With a peak weekly waste flow of approximately 5,000 tonnes, an extra six B-train trailer units would be required to meet peak demand. The estimated cost of the units is $900,000 based on $150,000 per unit (Carrusca, 2004). The annual capital cost of the trailers is therefore estimated at $160,000 per year based on a seven year lifespan. One hundred and sixty thousand dollars is the annual payment required to pay the full initial capital cost of the units over seven years at a nominal interest rate of 6%. No operating costs are included as the operating costs for the units would be paid as part of the cost of transferring the waste to Ashcroft Ranch. Capital costs are additional as six additional units would be required to haul the same amount of waste due to the seasonal peaks.

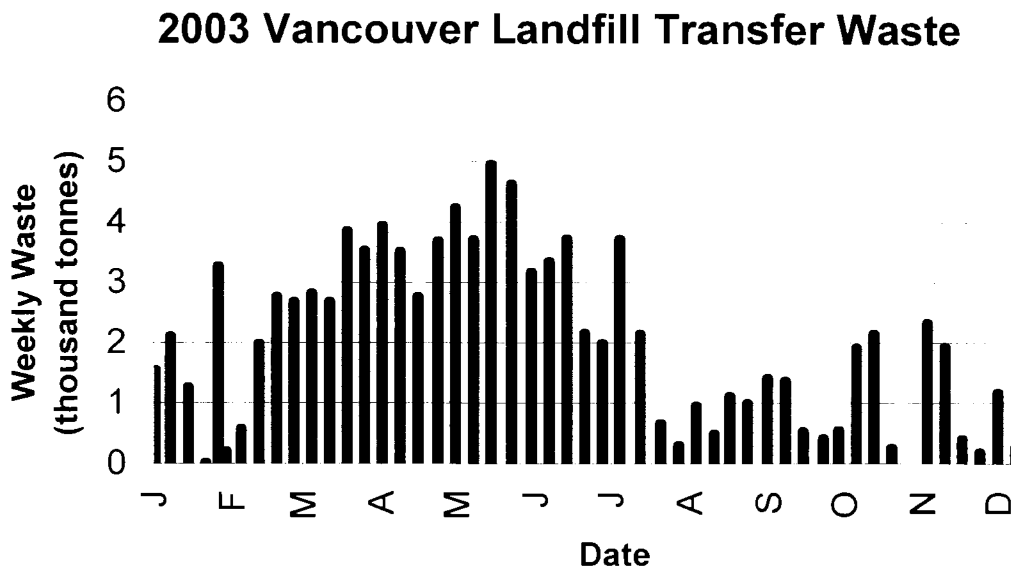

Figure 4-3: 2003 Vancouver Landfill Transfer Waste

4.6 Property Values

In a May 21, 2004 article on the GVRD's hot real estate prices, Wyng Chow (Chow, 2004) suggests that one way to avoid paying high real estate prices is to buy in a location that others shun. He cites railway tracks, industrial zones, highways, landfills and graveyards as locations where nearby real estate may be priced much lower than comparable properties. According to Boardman et. al. (2001), increases or decreases in property value can be used as a way to estimate the benefits or costs of a project. Using changes in property values as an indication of costs and benefits is called the asset valuation method. Limitations of this method would be encountered in situations where hidden variables are impacting property prices, or in situations where individuals attach varying values to particular attributes. In the case of the Vancouver Landfill, the asset valuation method would suggest that if there are negative impacts on surrounding properties due to noise, odour and birds, the cost of those impacts can be estimated by the lower property values for properties close to the Vancouver Landfill. If such was the case, closing the Vancouver Landfill would increase surrounding property values creating a community benefit.

The nearest residential properties to the Vancouver Landfill are located approximately 1 kilometre to the south west of the Vancouver Landfill. To gauge the impact of the Vancouver Landfill on residential property values, all 2003 and January to May 2004 sales within approximately 5 kilometres of the entrance of the Vancouver Landfill were analysed based on:

- sales price
- sales date
- age
- total developed floor space
- distance from the Vancouver Landfill entrance

Lot size data were not available and were therefore not used in the analysis. Given that the areas adjacent to the Vancouver Landfill are relatively homogenous, it is unlikely that other variables such as views, school catchment, traffic and security are impacting property prices.

A total of more than 90 sales, ranging in price from $250,000 to $380,000 were included in the analysis. The sales data are from the Multiple Listing Service (MLS) database and are provided in Appendix 1.

The relationship between floor space and sales price is shown in Figure 4-4. As indicated in Figure 4-4, there appears to be a relationship between the total floor space and price. Increasing floor space corresponds to increasing price.

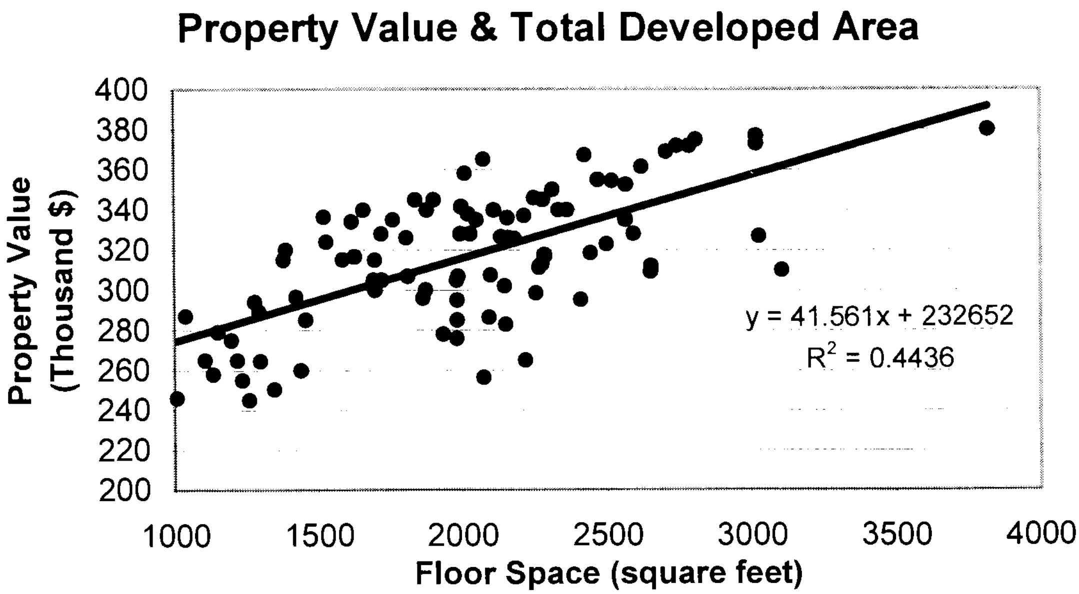

Figure 4-4:Property Value and Total Developed Area

Figure 4-5 shows the relationship between building age and sales price. For old-timers with no known construction date, a default value of 50 years is used. A similar relationship is shown except that increasing age results in decreasing price.

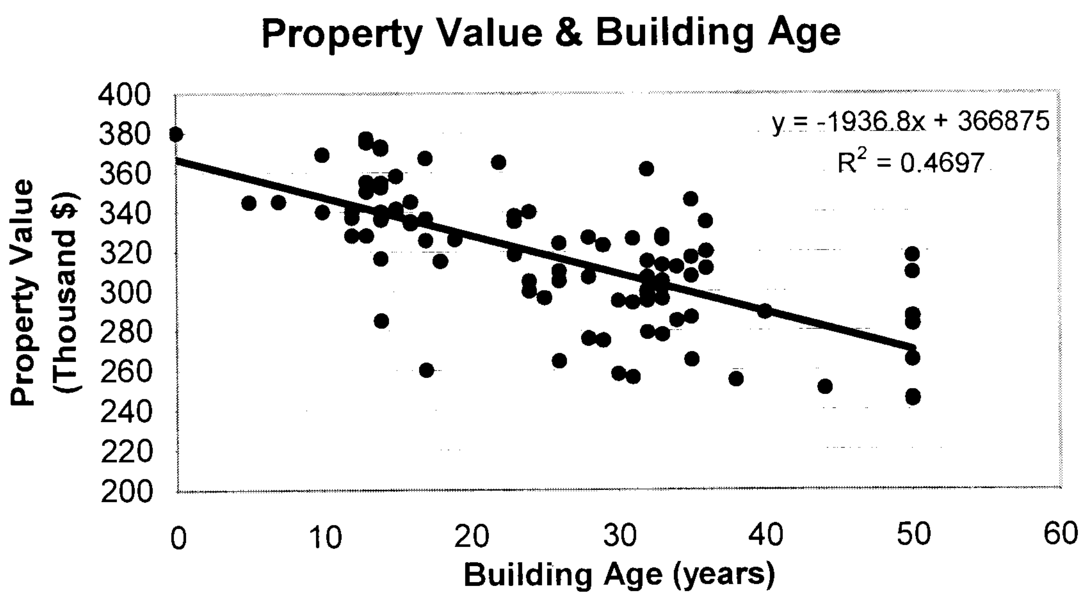

Figure 4-5: Property Value and Building Age

Figure 4-6 shows the relationship between property value and sales date.

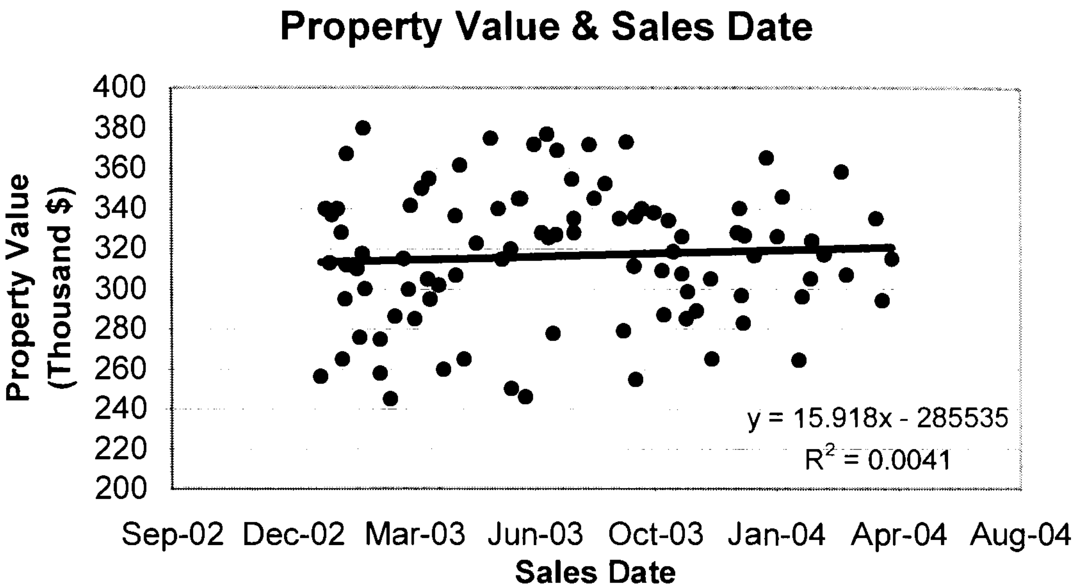

Figure 4-6: Property Value and Sales Date

Figure 4-6 shows that over the relatively short-run, property sales date is not a good predictor of property value. This conclusion would seem intuitively correct in that one would not expect to be able to accurately predict the value of a house based on the date it was sold unless there was a strong market trend towards higher or lower prices.

In spite of the low correlation between sales date and property value, there appears to be an increasing trend in price over the observation period. Therefore, over the very long term, when the influence of the date of sale is larger than the impact of other factors affecting sales value, the sales date could become an accurate predictor of property value. For instance, one could estimate the price of a house sold in 1960 using sales data spanning the period 1960 to today.

Figure 4-7 shows housing prices and distance in kilometres from the property to the Vancouver Landfill entrance (as the crow flies).

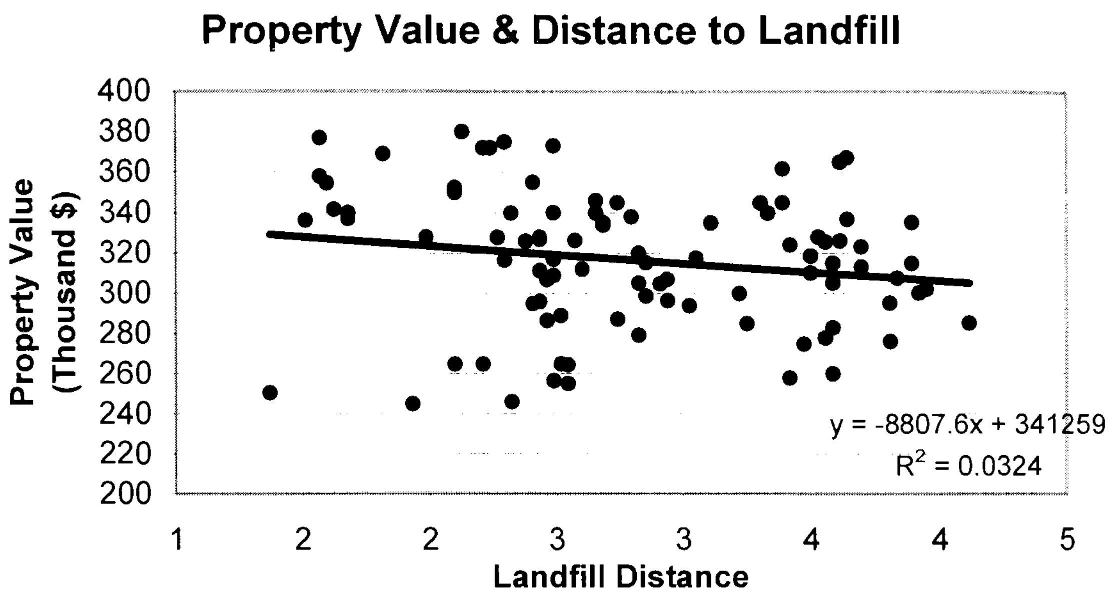

Figure 4-7: Property Value and Distance to Landfill

Figure 4-7 shows no relationship between distance to the Vancouver Landfill and property price. If anything, the trend-line would actually indicate prices dropping further away from the Vancouver Landfill.

To understand how floor space, property age, sales date and distance to the Vancouver Landfill work together, a multivariable analysis is required. For instance does price actually co-vary with both age and floor space? According to Boardman et. al. (2001), a multi-variable linear equation takes the following form:

$y = b + m_1x_1 + m_2x_2 + m_3x_3 \ldots\ldots\ldots\ldots + m_kx_k$

y = dependant variable (in this case property value)

b = the intercept parameter or constant

$x_1, x_2 \ldots x_k$ = independent variables (in this case floor space, age, sales date, etc.)

$m_1, m_2 \ldots\ldots m_k$ = coefficients

Multivariable linear regression estimates the value of each of the coefficients and determines whether individual coefficients are significant, thus adding predictive ability.

Developing a multivariable linear equation is normally done in a stepwise fashion. A regression using all of the potential independent variables is performed, and then independent variables that do not add predictive value are removed one at a time until an equation is left where each of the independent variables add predictive value.

One way to determine if an independent variable adds predictive value is using p-values. An independent variable either predicts the value of a dependent variable or not. P-value is the probability that the independent variable does not predict the value of the dependent variable given the observed data. Table 4-5 provides p-values for each of the independent variables analysed. As indicated in Table 4-5, of the four variables analysed, only distance to the Vancouver Landfill is insignificant in predicting property value. Therefore, it appears that the Vancouver Landfill does not reduce the value of surrounding residential property values.

Table 4-5: Property Value P-Value

Independent Variable	**P-value**
Sales Date	0.000581
Property Age	6.73E-13
Floor Space	1.47E-12
Distance to Landfill	0.792242

An analysis of the correlation between each of the independent variables indicates low correlation between independent variables. The highest R^2 value is between age and floor space at 0.13. On this basis, it appears that the independent variables are not highly correlated. The P-values in Table 4-5 therefore provide a reliable indication of the significance of each of the independent variables.

The best multivariable linear equation describing the value of a residential property adjacent to the Vancouver Landfill is thus:

$P = 60\ S - 1483\ A + 32\ F - 1987343$

P = Sales price in dollars

S = Sales date (January 1, 2003 is 37622)

F = Floor space in square feet

A = Property age in years

The adjusted R^2 for the equation is 0.71, an improvement over any of the single variable regressions. Full regression analysis statistics are provided in Appendix 2. Figure 4-8 shows the actual sales price and the estimated sales price for each property using the best fit multivariable linear equation. Figure 4-8 graphically demonstrates that the multivariable equation provides the best estimate of the actual value of a property.

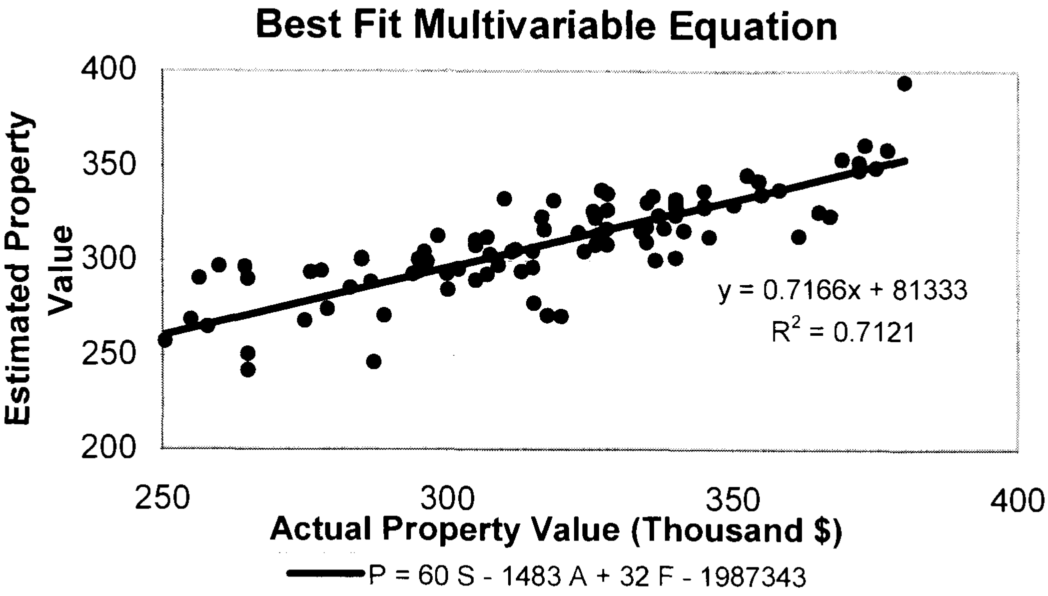

Figure 4-8: Best Fit Multivariable Equation

Land immediately adjacent to the Vancouver Landfill is primarily agricultural. It is unlikely that proximity to the Vancouver Landfill significantly impacts the value of the agricultural land. Boardman et al. (2001) suggest that adjacent land uses affect property values in the event that the land use creates nuisance impacts such as noise. One gauge of nuisance impacts of the Vancouver Landfill is complaints received at the site. Since the installation of an expanded landfill gas control system at the Vancouver Landfill in February 2001, the City of Vancouver has only received one odour complaint regarding the Landfill. No other nuisance related complaints have been received. On this basis, it is unlikely that property values are impacted by the operation of the Landfill.

4.7 Greenhouse Gas Emissions

Greenhouse gas emissions associated with landfill disposal of municipal solid waste are primarily from transportation of the waste, as well as landfill gas emissions. Greenhouse gas emissions can only be counted in this analysis if costs and benefits accrue to residents of the GVRD, because only GVRD residents have standing in the analysis. The actual benefits and costs of changes to emissions would be realized globally and therefore would be insignificant to GVRD residents. However, emission reductions can be counted if reducing those emissions avoids GVRD residents being required to pay for emission reductions by some other means.

In December 2002, Canada ratified the Kyoto Accord committing to reduce greenhouse gas emissions by 6% compared to 1990 levels (Paraskevas, 2002). Although an implementation plan for the country is not yet in place, various municipalities and regional districts across Canada are committed to reducing both municipal operations' emissions and community emissions through a program called Partners for Climate Protection.

The GVRD is a member of Partners for Climate Protection, but has not yet set emission reduction goals. Individual municipalities within the GVRD, such as Vancouver, have set emission reduction goals. Vancouver has set a 20% corporate emissions reduction goal (City of Vancouver, 2003b), and developed a draft action plan to achieve 6% community emissions reduction (City of Vancouver, 2004). The GVRD is in the process of developing an inventory of greenhouse gas emissions and will also set emission reduction targets. It is reasonable to count emission reduction benefits and costs from solid waste operations as being realized by GVRD residents, because it appears that in the future, GVRD residents will collectively be required to achieve emission reduction targets. Increased emissions from solid waste operations would need to be offset by other emission reductions to achieve a net reduction in GVRD emissions.

In the event that the Vancouver Landfill is closed in 2012, transporting the waste to Ashcroft Ranch would increase greenhouse gas emissions. Based on the fuel consumption of City of Vancouver trucks transporting waste to the Vancouver Landfill, the greenhouse gas emissions resulting from waste transport are approximately 0.077 kg CO_2/km/tonne of waste. Walker, Hilburne and Colman (1999) estimate the greenhouse gas emissions for freight transport at 0.115 kg CO_2/km/tonne. The Walker, Hilburne and Colman (1999) estimate may be higher than the City of Vancouver calculation because the City of Vancouver calculation uses total trip emissions to calculate emissions per travelled kilometre. Emissions per kilometre tonne are then calculated based on the loaded kilometres traveled (in the case of Vancouver 50% of the total distance travelled). This mimics the GVRD situation where emissions for the back-haul should be allocated to the woodchip transport rather than the waste transport. The Walker, Hilburne and Colman estimate may allocate empty return trip emissions to the distance the freight is shipped.

If the wood chips hauled from Cache Creek to the coast were hauled regardless of whether garbage is hauled to Cache Creek, one could argue that all emissions should be attributed to the wood chip transport. Emissions would stay approximately the same if garbage was no longer transported to Cache Creek. In the case of Cache Creek, a wood chip facility was built immediately adjacent to the Cache Creek Landfill to take advantage of the back-haul opportunity. In theory, locating the wood chip facility adjacent to Cache Creek Landfill allows wood chips that could not otherwise be economically harvested to be transported to the coast. In addition, without a back-haul, it may not be economical to transport waste to Cache Creek (or

Ashcroft Ranch in the future). Some other disposal option, such as waste incineration or barge transport to another remote landfill, might be the most economic option. On this basis, it is reasonable to allocate a portion of the emissions to each of wood chips and garbage transport.

Based on a 300 km trip to Cache Creek and the lower of the two emission estimates, the total CO_2 emissions associated with transporting all of the waste disposed of at the Vancouver Landfill to Cache Creek is approximately 10,000 tonnes per year of CO_2 equivalents. This is equivalent to the emissions of approximately 2,000 automobiles. The calculation assumes that backhaul material is available for all loads, so that backhaul emissions do not need to be allocated to transporting the waste.

Additional emission reductions are achieved through cogeneration using landfill gas. Heat provided to the greenhouse reduces natural gas consumption and greenhouse gas emissions. As described in Section 4.4, cogeneration results in the capture of approximately 100,000 GJ/year of energy to heat the CanAgro Greenhouse. This results in a CO_2 emission reduction of approximately 5,000 tonnes per year. In the event that the Vancouver Landfill operates to capacity, the emission reductions will increase over time. In the event the site closes in 2012, the emission reductions will decrease with decreasing gas production as shown in Figure 4-2.

The value of greenhouse gas emission reductions is difficult to estimate as markets for emission reductions are just being established. The government of Canada through the Pilot Emission Removals, Reductions and Learnings (PERRL) Initiative has recently purchased emission reduction for up to $6.90 per tonne (PERRL, 2004). In comparison, as of spring 2004, voluntary emission reductions are trading on the Chicago Climate Exchange for approximately $1 per tonne (Chicago Climate Exchange, 2004).

Using $1 per tonne, the cost of additional emission reductions resulting from closing the Vancouver Landfill in 2012 would peak at approximately $15,000 per year. The cost of the emissions may increase in the future if emission reductions are indeed mandated and emission trading is formalized.

4.8 Water Quality and Leachate Management

Leachate is any water that has come into contact with garbage. In the case of the Vancouver Landfill, at present, there is no separation between surface water and leachate. Therefore, all rainwater that falls onto the Vancouver Landfill either evapotranspires or becomes leachate. As indicated in Section 4.3, the Vancouver Landfill currently generates approximately 1.7 million cubic metres per year of leachate. Leachate from the Vancouver Landfill is pumped to the Annacis Island wastewater treatment plant (WWTP) where it is treated along with municipal sewage. Leachate from the Vancouver Landfill could negatively affect the environment in two ways: 1.) it could directly migrate into the environment at the Landfill or 2.) it could impact the environment when it is discharged along with other treated municipal sewage into the Fraser River.

In 2000, Gartner Lee conducted an extensive review of the impacts of the Vancouver Landfill on surrounding ground and surface water systems (Gartner Lee, 2000). A similar review was conducted in 1995. Gartner Lee (2000) concluded that "the current Vancouver Landfill leachate collection and containment system is approximately twice as effective in containing leachate as an engineered liner system that meets the requirements of the BC Environment Landfill Criteria for Municipal Solid Waste". Gartner Lee (2000) also concluded that less that ½ of one percent of precipitation that falls onto the Landfill begins to flow down through the compressed peat and silty clay layer under the Landfill. Garter Lee's modelling showed that even after 150 years, leachate is still contained within the Landfill footprint. Gartner Lee (2000) also installed monitoring wells and reviewed historic groundwater monitoring results. Gartner Lee did not find landfill related impacts in either the surface or groundwater systems surrounding the Vancouver Landfill. Annual reviews of the Vancouver Landfill's water quality monitoring program by third party consultants in the years 1999, 2000, 2001, 2002 and 2003 confirm that the Vancouver Landfill is not impacting surrounding ground and surface water resources.

Leachate from the Vancouver Landfill makes up approximately 1% of all of the wastewater treated at the Annacis Island WWTP (GVRD Quality Control Division, 2003). Annacis Island WWTP was upgraded from primary treatment (the wastewater is settled in retention tanks) to secondary treatment (biological treatment) in 1997. Annacis operates under a Ministry of Water Land and Air Protection waste discharge permit. In 2002, Annacis effluent did not exceed permit levels for maximum flow, biochemical oxygen demand (BOD) or total suspended solids (TSS). Although not a specific authorized discharge parameter, toxicity must be tested against a standard on a monthly basis. In the event that the toxicity exceeds the standard, toxicity must be tested on a weekly basis until three consecutive tests do not exceed the standard. In 2002, 8 of the 12 monthly tests exceeded the standard. Toxicity is strongly linked to effluent ammonia concentration.

The GVRD attributes the exceedence to the test procedure, specifically the test involves aerating a sample containing rainbow trout fry for a 24 hour period. The toxicity of the effluent is determined by the portion of the fish that survive at varying portions of effluent. To pass the test, all of the fish must survive at 100% effluent. Aerating the water increases the pH of the water by stripping carbon dioxide out of the water. As a result, more free ammonia is created compared to the inert ammonium ion. Free ammonia is toxic to aquatic life. The GVRD contends that the actual toxicity of the effluent is much lower than indicated by the test. For instance in 2002, the GVRD parallel tested all samples with a pH controlled sample. In total, 22 samples (weekly and monthly) failed the toxicity test. Of these, 21 passed with pH control (GVRD Quality Control Division, 2003). The GVRD contends that effluent from the Annacis Island WWTP is not negatively impacting the environment (GVRD Quality Control Division, 2003). On this basis, the Vancouver Landfill is not impacting the environment due to leachate conveyed to the Annacis Island WWTP.

In 2003, the federal government added ammonia to the list of toxic substances in the Canadian Environmental Protection Act (CEPA) (Government of Canada, 2003). The federal government may in the future require that ammonia be removed from municipal wastewater treatment plant effluent. Ammonia removal requirements for WWTPs are important to a cost-benefit analysis of early closure of the Vancouver Landfill because, although leachate from the Vancouver Landfill is only 1% of Annacis WWTP flow, the Vancouver Landfill contributes approximately 5% of Annacis ammonia mass loading because the leachate ammonia concentration is higher than municipal sewage ammonia concentration. Leachate management costs paid by Vancouver to Delta are a combination of charges based on total flow discharged to sewer as well as surcharges for BOD and TSS. No surcharges are currently levied for ammonia. If surcharges were levied for ammonia, leachate discharge fees would go up substantially. Alternatively, Vancouver would be required to pre-treat leachate to remove ammonia. A 1994 study estimated leachate treatment for ammonia removal at the Vancouver Landfill would have a capital cost of $20,000,000 (in 1994 dollars) and approximately $500,000 dollars per year in operating costs (Associated Engineering, 1994). Early closure of the Vancouver Landfill would substantially reduce leachate flows thereby reducing treatment requirements and costs.

Depending on the timing of ammonia removal requirements, the most likely scenario would be that a leachate treatment system would be constructed to manage leachate generated following closure of the Western 40 Hectares and Phase 3 in approximately 2012 (see Table 4-3). Sizing for leachate flows following closure of the Western 40 Hectares is likely because the Western 40 Hectares accounts for approximately 20% of the landfill footprint and consequently 20% of leachate flows. As discussed in Section 4.3, leachate flows are approximately 75% of precipitation in advance of closure and 10% following closure. If ammonia removal was required in advance of 2012, paying a surcharge for the interim period where leachate volumes were higher than the design volume would be more economical than overbuilding a leachate treatment system. Designing the leachate treatment system for leachate flows following closure of the Western 40 Hectares would allow the plant to be designed for approximately 70% of current leachate flows.

Based on designing a leachate treatment system for post Western 40 Hectares and Phase 3 closure, leachate flows would be similar to the flows used by Associated Engineering (1994) to size a leachate treatment system. On this basis, the expected cost of a treatment plant constructed in 2012 discounted using a real discount rate of 4% to 2004 would be approximately $17,000,000 and the annual operating costs would be approximately $450,000. Leachate treatment costs are in addition to leachate discharge to sewer costs currently paid to Delta because it is expected that the leachate would continue to be discharged to sewer following pre-treatment at the Landfill. A sensitivity analysis in Chapter 5 analyses the impacts on the cost of the operation of the Vancouver Landfill of pre-treating leachate for ammonia removal.

Even under a scenario where leachate management costs do not increase relative to other costs, closure in 2012 would result in reduced leachate management costs. Comparing Table 4-3 to Table 4-4, leachate management costs in 2012 would decrease from $692,000 based filling to full capacity to $155,000 based on closing in 2012.

4.9 Impact on Burns Bog

Burns Bog is a globally unique bog located immediately north of the Vancouver Landfill. The remaining bog area is approximately 2800 hectares, of which 2018 hectares was purchased from private landowners by the Provincial, Federal, GVRD and Delta governments in March 2004 for $73 million (Gulyas, 2004). The land on which the Vancouver Landfill exists was originally part of Burns Bog. Some people suggest that the operation of the Vancouver Landfill negatively impacts Burns Bog due to the proximity of the Vancouver Landfill to the Bog.

In 1999, the Provincial Government conducted an extensive ecosystem review of the significance of Burns Bog and the factors important to sustaining the bog. The conclusions of that review are in a document published by the B.C. Environmental Assessment Office titled Burns Bog Ecosystem Review: Synthesis Report (Hebda et. al, 2000), as well as a summary document prepared by Greg McDade, a special advisor to the Minister of the Environment on the ecosystem review (McDade, 2000). The factors critical to maintaining the integrity of Burns Bog include:

- preserving approximately 2450 hectares of the remaining 2800 hectares
- blocking ditches draining the water mound zone, particularly those running into the centre of the mound

The Synthesis Report (Hebda et al., 2000) identified the following specific threats to the viability of Burns Bog:

- Changes to the hydrology of the Bog caused by increased drainage
- Fire resulting from a combination of increased development within and adjacent to the Bog and drying caused by increased drainage
- Habitat loss caused by fire and drying. In particular, as the Bog dries out, trees and shrubs are encroaching on traditional bog communities
- Cranberry farming/peat mining because the zoning of the Bog allows these activities which effectively destroy bog habitat

The Synthesis Report (Hebda et. al., 2000) refers specifically to the role of landfills. Hebda et al. suggest that landfill affecting Burns Bog include areas covered by municipal solid waste, demolition and construction waste, roads and abandoned railways and other fill sites. Hebda suggests that water shed from landfills has different composition than bog water impacting bog water chemistry. Compression of the peat under the fill affects the bog hydrology. Different soil characteristics on the surface of the fill affect vegetation types and wildlife habitat, and municipal landfills in particular encourage scavenging wildlife such as crows, gulls coyotes and bears. Linear fill corridors into the bog (roads and rail beds) provide pathways for invasive species as well as easy access for humans into the bog.

In the case of the Vancouver Landfill, the impacts identified by Hebda et al. (2000) are independent of whether the landfill is operating. The exception to this is impacts of scavenging wildlife. Staff at the Vancouver Landfill do not observe bears or coyotes scavenging at the Landfill. The Vancouver Landfill has an active bird control program using hawks and other deterrents to scare scavenging birds such as gulls and crows. In 2004, the City of Vancouver plans to extend the bird control program to include suspended mono-filament lines to further deter birds. Mono-filament lines are used successfully at the Hartland Landfill in Victoria. There is no evidence that birds scavenging at the Vancouver Landfill negatively affect Burns Bog or surrounding communities.

In conclusion, there is no evidence that closing the Vancouver Landfill in 2012 would reduce the Vancouver Landfill's impact on Burns Bog. Any current impacts are not the critical impacts identified in the 1999 Ecosystem Review (Hebda et al., 2000).

4.10 Chapter Summary

Table 4-6 provides a summary of the costs and benefits of early closure of the Vancouver Landfill under the base case scenario. Chapter 5 completes the analysis of the costs and benefits of early closure of the Vancouver Landfill. Chapter 5 calculates the net present value of the costs and benefits, determines which residents of the GVRD would be impacted by closing the Vancouver Landfill, and conducts a sensitivity analysis to determine the impact of changing the most important variables.

Table 4-6: Vancouver Landfill Early Closure Cost-Benefit Summary

Early Closure Cost-Benefit Summary

Item	Cost	Benefit	Neutral
Transfer & Disposal	■		
Secondary Material Disposal	■		
Landfill Closure	■		
Landfill Gas Utilization[1]			■
System Flexibility	■		
Property Values			■
Greenhouse Gas Emissions	■		
Water Quality and Leachate Management		■	
Impact on Burns Bog			■

Notes:

1. Although there is a financial cost associated with landfill gas utilization, the cost may impact other individuals than GVRD residents. On this basis the impact is assumed neutral.

5 COST BENEFIT ANALYSIS: NET PRESENT VALUE, DISTRIBUTION AND SENSITIVITY

The estimated costs and benefits of closing the Vancouver Landfill in 2012 and disposing of all of the GVRD's waste (with the exception of waste disposed of at the Waste-to-Energy Facility) at the new Ashcroft Ranch Landfill are presented in Table 5-1. Costs of early closure are shown as positive numbers, and benefits are shown as negative numbers. All costs and benefits are discounted using a 4% real interest rate to a 2004 base year. The expected cost to GVRD residents in 2004 dollars of closing the Vancouver Landfill in 2012 rather than when it reaches capacity around 2041 is $81,200,000. This is the expected net present value of the cost under the most likely scenario.

For each of transfer & disposal, secondary materials and system flexibility, each year's annual value is calculated by discounting the initial value presented in Chapter 4. For closure costs, the values are derived based on the area that would require closure in each year. These values are from Table 4-3 and Table 4-4. Leachate management costs are derived from the same tables based on the amount of leachate discharged to sewer as the landfill is progressively closed. As final cover is installed on the landfill, less precipitation infiltrates into the landfill reducing the amount of leachate generated.

The value of greenhouse gas emissions is based on the additional 10,000 tonnes per year of transportation emissions plus increased emissions resulting from a gradual reduction in the amount of landfill gas available for beneficial use. The value for greenhouse gas emissions in the final year of operation of the full capacity scenario (2041) is the terminal value of future emission reductions based on the expectation that the landfill gas will continue to be utilized after the landfill is closed. The quantity of emission reductions is calculated based on the information presented in Figure 4-2.

Table 5-1: Vancouver Landfill Early Closure Cost -Benefit Net Present Value

Vancouver Landfill Early Closure Net Present Value Calculation

Discount Rate	4%
Base Year	2004

Year	Transfer & Disposal	Secondary Materials	Landfill Closure	System Flexibility	Greenhouse Gas Emissions	Water Quality and Leachate Management
2012	2,123,262	1,471,026	39,931,482	109,604	7,307	-392,255
2013	2,041,598	1,414,448		105,388	7,151	-377,169
2014	1,963,075	1,360,046		101,335	7,023	-362,662
2015	1,887,572	1,307,736		97,437	6,893	-348,714
2016	1,814,973	1,257,439		93,690	6,760	-335,302
2017	1,745,167	1,209,076	-4,054,791	90,086	6,625	-282,574
2018	1,678,045	1,162,573		86,621	6,488	-271,706
2019	1,613,505	1,117,858		83,290	6,350	-261,256
2020	1,551,447	1,074,864	-3,109,014	80,086	6,211	-220,667
2021	1,491,776	1,033,523		77,006	6,072	-212,180
2022	1,434,400	993,772		74,044	5,933	-204,019
2023	1,379,231	955,550	-2,761,709	71,196	5,794	-169,043
2024	1,326,183	918,798		68,458	5,656	-162,542
2025	1,275,176	883,460		65,825	5,519	-156,290
2026	1,226,131	849,481		63,293	5,382	-150,279
2027	1,178,972	816,808		60,859	5,247	-144,499
2028	1,133,627	785,393	-3,369,664	58,518	5,114	-105,840
2029	1,090,026	755,185		56,268	4,981	-101,770
2030	1,048,102	726,140		54,103	4,851	-97,855
2031	1,007,790	698,211		52,022	4,722	-94,092
2032	969,029	671,357	-2,641,545	50,022	4,596	-64,524
2033	931,759	645,535		48,098	4,471	-62,043
2034	895,922	620,707		46,248	4,348	-59,656
2035	861,463	596,834		44,469	4,228	-57,362
2036	828,330	573,879		42,759	4,110	-55,156
2037	796,471	551,806		41,114	3,994	-53,034
2038	765,838	530,583		39,533	3,880	-50,995
2039	736,382	510,176		38,012	3,769	-49,033
2040	708,060	490,554		36,550	3,660	-47,147
2041	680,827	471,686	-4,614,980	35,145	22,766	0
Totals	$38,184,138	$26,454,503	$19,379,778	$1,971,079	$179,905	-$4,949,664
Net Cost		$81,219,738				

So far this paper has looked at the costs and benefits of closing the Vancouver Landfill in 2012 to GVRD residents in general. Those costs and benefits are not evenly distributed among GVRD residents. Table 5-2 combines information from several tables to determine the overall distribution of the increased cost of transfer and disposal in the event the Vancouver Landfill is closed in 2012. The first two data columns show the distribution of the total annual GVRD system costs with and without the Vancouver Landfill from Table 3-1 and Table 4-1. The costs in the first two columns of Table 5-2 are annual costs to each of Vancouver, Delta and other GVRD residents for each of the two alternative systems. As indicated in Table 5-2, costs are distributed such that if the Vancouver Landfill is filled to capacity, Delta receives a net annual benefit. This is because in addition to receiving free disposal of residential waste, Delta receives royalties on all Vancouver and other GVRD municipal waste disposed of at the Vancouver Landfill. The final data column shows the distribution of the net present value of the increased transfer & disposal costs in the event the Vancouver Landfill is closed in 2012 from Table 5-1. Positive numbers indicate increased costs; negative numbers indicate decreased costs.

As indicated in Table 5-2, GVRD residents other than Vancouver and Delta residents would see a reduction in transfer & disposal costs in the event the Vancouver Landfill closed whereas both Vancouver and Delta residents would see an increase in costs. Decreased costs to GVRD residents other than Vancouver and Delta residents is a result of the expected decrease in operating costs at Ashcroft Ranch in the event that all of the GVRD's waste is disposed of at Ashcroft Ranch.

Table 5-2: Transfer & Disposal Cost Distribution

Transfer & Disposal Cost Distribution

	Vancouver Landfill Annual Cost	No Vancouver Landfill Annual Cost	Change	Total Net Present Value
Vancouver	10,369,890	12,293,050	1,923,160	$25,271,423
Delta	-870,000	1,321,754	2,191,754	$28,800,902
Other GVRD	54,813,110	53,604,016	-1,209,094	-$15,888,187
Total	$64,313,000	$67,218,820	$2,905,820	$38,184,138

Under the Tri-Partite Agreement (City of Vancouver, Corporation of Delta and GVRD, 1989), closure and post closure care costs at the Vancouver Landfill are shared between Vancouver and the GVRD based on the GVRD's portion of waste in the Vancouver Landfill. The GVRD's portion of waste is the amount of waste in the Vancouver Landfill from municipalities other than Vancouver and Delta. By 2012, the estimated GVRD portion of the Vancouver Landfill waste will be 20%. Therefore if the Vancouver Landfill closed in 2012, Vancouver would incur 80% of closure and post closure costs and the GVRD would incur 20% of costs. Closure and post closure costs include closure costs as well as leachate management costs. The remainder of the costs and benefits of early closure of the Vancouver Landfill are shared proportionally by all GVRD residents.

As indicated in Table 5-3, although Vancouver and Delta would incur the majority of the costs of early closure, other GVRD residents would also incur a net cost if the Vancouver Landfill closed in 2012. The additional costs to other GVRD residents would be due to increased disposal costs for secondary materials including sewage treatment plant residuals, ash from the Waste-to-Energy Facility and asbestos.

A secondary equity issue that is relevant in considering the costs and benefits of closing the Vancouver Landfill is the distribution of operating savings at Ashcroft Ranch due to additional waste disposal. Ideally, any benefits would be transferred to all GVRD residents through reduced solid waste disposal costs. In the event that the Vancouver Landfill closed, the GVRD would be served by only two facilities with Ashcroft Ranch receiving approximately 80% of the GVRD's waste. Ashcroft Ranch will likely be operated by Wastech or another contractor with a long term operating contract. There is a risk that the contractor may be able to earn monopoly rents as the primary solid waste disposal facility for the GVRD. On this basis, GVRD municipalities and commercial waste generators may not realize all or any of the savings achieved through reduced operating costs at Ashcroft Ranch.

Table 5-3: Vancouver Landfill Early Closure Cost-Benefit Distribution

Overall Cost-Benefit Distribution

	Vancouver	Delta	GVRD
Transfer & Disposal	25,271,423	28,800,902	-15,888,187
Secondary Materials	7,070,626	1,250,963	18,132,914
Landfill Closure	15,503,822		3,875,956
System Flexibility	526,820	93,207	1,351,052
Greenhouse Gas Emissions	48,084	8,507	123,314
Water Quality and Leachate Management	-3,959,731		-989,933
Total Cost Distribution	$44,461,044	$30,153,579	$6,605,114

Boardman et al. (2001) indicate that a key step in conducting a cost-benefit analysis is undertaking a sensitivity analysis of factors that could impact the outcome of the cost-benefit analysis. Boardman et al. suggest that discount rates are uncertain and therefore good candidates for sensitivity analysis. In this analysis, due to the magnitude of the costs associated with early closure of the Vancouver Landfill, and also due to the fact that the scenario is not based on large capital expenditures with downstream benefits, interest rates are not a significant factor in determining the outcome of the analysis. For instance, a 10% real discount rate changes the cost of early closure from $81,000,000 to $40,000,000. Most people would consider a 10% real discount rate unreasonably high.

Of more interest are impacts of two other factors: Ashcroft Ranch operating costs and Vancouver Landfill leachate management costs. Both of these factors are relatively uncertain. The base case scenario presented in Table 5-1 uses a decrease in operating costs at Aschroft Ranch of 18% as a result of increased garbage disposal at Ashcroft Ranch.

A sensitivity analysis of the reduction in operating cost per tonne for Ashcroft Ranch compared to Cache Creek's current operating costs is shown in Table 5-4. The most optimistic scenario is a 25% reduction in cost at Ashcroft Ranch compared to Cache Creek. This scenario could occur if Ashcroft Ranch becomes the primary garbage disposal facility in B.C. and thus receives more garbage than just the GVRD's waste, or potentially if more significant economies of scale than anticipated could be realized. It is unlikely that unit cost reductions in excess of 25% could be achieved. The least optimistic scenario is a 10% reduction in cost at Ashcroft Ranch compared to Cache Creek. This scenario would occur if limited economies of scale could be realized at Ashcroft Ranch. Ten per cent reduction in costs should be the minimum expected scenario as long as all of the GVRD's waste is disposed of at Ashcroft Ranch. If, for instance, Vancouver entered into a third party agreement to dispose of Vancouver's garbage at some other landfill, a cost reduction at Ashcroft Ranch of less than 10% could occur. As indicated in Table 5-4, under all of the scenarios there would be a significant cost to GVRD residents if the Vancouver Landfill is closed in 2012. The total cost over the life of the Vancouver Landfill ranges from $63,000,000 to $101,000,000.

Table 5-4: Ashcroft Ranch Operating Cost Sensitivity Analysis

Ashcroft Ranch Operating Cost Sensitivity Analysis

	Base Case 18% Cost Reduction	25% Cost Reduction	10% Cost Reduction
Ashcroft Ranch Cost ($/tonne)	19.04	17.35	20.82
GVRD System Cost ($/tonne)	61.77	60.49	63.11
Increased Transfer & Disposal Cost ($/year)	$2,905,831	$1,513,443	$4,372,369
Net Present Value Early Closure Cost	$81,200,000	$63,015,019	$100,582,806

As discussed in Section 4.8, the other significant source of uncertainty is cost of managing leachate from the Vancouver Landfill. If ammonia must be removed from the leachate prior to discharge to sewer, a leachate treatment system would be required at the Landfill. The cost of treating the leachate would be in addition to the cost of discharging the leachate to sewer as the treatment would likely have little impact on parameters other than ammonia. The treated leachate would still require final treatment prior to discharge to a receiving water body such as the Fraser River. As shown in Table 4-3, assuming the Vancouver Landfill is filled to capacity, the estimated leachate volume in 2012 would be approximately 983,000 cubic metres per year. In comparison, if the Vancouver Landfill is closed in 2012 the estimated leachate volume would be 221,000 cubic metres per year. The present value of the cost of constructing a leachate treatment plant in 2012 to manage 983,000 cubic metres per year of leachate is approximately $17,000,000. The present value of the operating cost is approximately $450,000 per year.

In the event that the Landfill is closed in 2012, leachate treatment would still be required, but a much smaller treatment plant would be needed. The reduction in capital expenditure to construct a leachate treatment system to manage the post-closure leachate volume is estimated at $13,000,000 (discounted to 2004) compared to the cost of the facility if the Landfill operates to capacity. The reduction in operating costs is estimated at $350,000 per year (discounted to 2004). Table 5-5 has the same information as Table 5-1 with the addition of the impacts of leachate treatment on the net present value of closing the Vancouver Landfill in 2012. As indicated in Table 5-5, requiring leachate treatment in order to continue to operate the Vancouver Landfill does not significantly impact the costs of early closure of the facility. Table 5-5 indicates that even with leachate treatment, the cost of early closure would still be approximately $62,000,000. The actual cost may exceed $62,000,000 because one would expect that as leachate flows decrease leachate ammonia concentration will increase. Increasing leachate ammonia concentration would increase treatment plant requirements because treatment plant design is based on both hydraulic loading as well as contaminant mass loading. More detailed analysis would be required to determine actual treatment plant requirements.

Table 5-5: Vancouver Landfill Early Closure Leachate Treatment Impacts

Vancouver Landfill Early Closure Leachate Treatment Impacts

Discount Rate	4%
Base Year	2004

Year	Transfer & Disposal	Secondary Materials	Landfill Closure	System Flexibility	Greenhouse Gas Emissions	Water Quality and Leachate Management	Leachate Treatment
2012	2,123,262	1,471,026	39,931,482	109,604	7,307	-392,255	-13,350,000
2013	2,041,598	1,414,448		105,388	7,151	-377,169	-336,538
2014	1,963,075	1,360,046		101,335	7,023	-362,662	-323,595
2015	1,887,572	1,307,736		97,437	6,893	-348,714	-311,149
2016	1,814,973	1,257,439		93,690	6,760	-335,302	-299,181
2017	1,745,167	1,209,076	-4,054,791	90,086	6,625	-282,574	-287,674
2018	1,678,045	1,162,573		86,621	6,488	-271,706	-276,610
2019	1,613,505	1,117,858		83,290	6,350	-261,256	-265,971
2020	1,551,447	1,074,864	-3,109,014	80,086	6,211	-220,667	-255,742
2021	1,491,776	1,033,523		77,006	6,072	-212,180	-245,905
2022	1,434,400	993,772		74,044	5,933	-204,019	-236,447
2023	1,379,231	955,550	-2,761,709	71,196	5,794	-169,043	-227,353
2024	1,326,183	918,798		68,458	5,656	-162,542	-218,609
2025	1,275,176	883,460		65,825	5,519	-156,290	-210,201
2026	1,226,131	849,481		63,293	5,382	-150,279	-202,116
2027	1,178,972	816,808		60,859	5,247	-144,499	-194,343
2028	1,133,627	785,393	-3,369,664	58,518	5,114	-105,840	-186,868
2029	1,090,026	755,185		56,268	4,981	-101,770	-179,681
2030	1,048,102	726,140		54,103	4,851	-97,855	-172,770
2031	1,007,790	698,211		52,022	4,722	-94,092	-166,125
2032	969,029	671,357	-2,641,545	50,022	4,596	-64,524	-159,735
2033	931,759	645,535		48,098	4,471	-62,043	-153,592
2034	895,922	620,707		46,248	4,348	-59,656	-147,684
2035	861,463	596,834		44,469	4,228	-57,362	-142,004
2036	828,330	573,879		42,759	4,110	-55,156	-136,543
2037	796,471	551,806		41,114	3,994	-53,034	-131,291
2038	765,838	530,583		39,533	3,880	-50,995	-126,241
2039	736,382	510,176		38,012	3,769	-49,033	-121,386
2040	708,060	490,554		36,550	3,660	-47,147	-116,717
2041	680,827	471,686	-4,614,980	35,145	22,766	0	-112,228
Totals	$38,184,138	$26,454,503	$19,379,778	$1,971,079	$179,905	-$4,949,664	-19,294,300
Net Cost		$61,925,438					

6 CONCLUSIONS AND RECOMMENDATIONS

The Vancouver Landfill is an important component of the GVRD solid waste management system. Based on the analysis presented in this paper, in the event that the Vancouver Landfill is closed in 2012, approximately 30 years in advance of reaching capacity, there is expected to be increased costs associated with:

- transfer & disposal of municipal solid waste
- disposal of secondary materials currently managed at the Vancouver Landfill such as asbestos, sewage treatment plant residuals and ash from the Burnaby Waste-to-Energy facility
- landfill closure
- system flexibility
- greenhouse gas emissions

Transfer & disposal of municipal solid waste would be more expensive in the event the Vancouver Landfill is closed because waste currently managed at the Vancouver Landfill would need to be shipped to Ashcroft Ranch for disposal. Increased transfer costs more than offset reduced operating costs at Ashcroft Ranch due to economies of scale. Managing secondary materials would be more expensive because these materials would need to be shipped to remote facilities for disposal. Increased landfill closure costs would be a result of the requirement to undertake closure activities earlier, which increases the cost of closure in present day dollars. Reduced system flexibility would increase costs because additional truck trailer capacity would be required to manage system flow variations from seasonal or other system disruptions. Reduced system flexibility also reduces the robustness of the system to withstand more catastrophic changes such as natural disasters, labour disruptions and the like. Greenhouse gas emissions are also expected to increase in the event that the Vancouver Landfill is closed in advance of reaching capacity. Transportation emissions would increase, and reduced fuel offsets would be achieved due to the lost opportunity for cogeneration. Cogeneration is much less likely at a remote landfill because there is typically no suitable industry in the vicinity of remote landfills. Increased emissions can be counted as a cost to GVRD residents because it is anticipated that in the future GVRD residents will be required to reduce greenhouse gas emissions. In the event that, the Vancouver Landfill is closed, any increased emissions would need to be offset by other emission reductions.

Although closing the Vancouver Landfill is expected to increase costs to the greenhouse that receives inexpensive heat from cogeneration, these costs cannot reasonably be attributed to the GVRD because the owners of the greenhouse are not necessarily GVRD residents.

An analysis of residential property sales in the vicinity of the Vancouver Landfill indicates that there is no impact on residential property values as a result of the operation of the Vancouver Landfill. Nonetheless, age, developed floor space and sales date can be used to develop a multivariable linear equation that reliably predicts the sales value of homes in the vicinity of the Vancouver Landfill.

Although landfill activities in the vicinity of Burns Bog have negatively impacted Burns Bog, there is no evidence that closing the Vancouver Landfill would reduce any impacts of the Landfill. In addition, any current impacts on Burns Bog by the Vancouver Landfill are minor and are not a significant threat to the Bog. The impact of the historic expansion of the Landfill within the Bog will not change whether or not the Landfill continues to operate. In the future, the Vancouver Landfill will not expand beyond the current landfill footprint.

The only benefit anticipated in the event the Vancouver Landfill is closed early would be reduced leachate management costs. Leachate management costs are expected to decrease because early closure will reduce the amount of leachate generated at the Landfill.

In total, the estimated net present value of the cost of closing the Vancouver Landfill in 2012 and sending all of the GVRD's waste to the new Ashcroft Ranch Landfill is approximately $81,000,000 in 2004 dollars. The cost is primarily a result of increased transfer & disposal costs, increased secondary material disposal costs, and increased landfill closure costs.

The cost of early closure is not evenly distributed among GVRD residents. Vancouver and Delta would pay approximately 90% of the costs. Other GVRD residents would be less impacted than Vancouver and Delta residents because, if expected economies of scale can be realized at Ashcroft Ranch, other GVRD residents would have lower costs than currently for transfer & disposal of municipal solid waste. A potential concern is that even if economies of scale can be achieved at Ashcroft Ranch, GVRD municipalities and commercial waste generators may not realize the resulting savings. If the contractor operating Ashcroft Ranch for the GVRD has monopoly power, the contractor may be able to realize some or all of the savings. For GVRD residents other than Vancouver and Delta residents, the primary cost of early closure of the Vancouver Landfill is expected to be additional disposal costs for secondary materials such as asbestos, sewage treatment plant residuals and ash from the Waste-to-Energy facility.

Sensitivity analysis indicates that the under any practical scenario, there would continue to be a large net cost to GVRD residents if the Vancouver Landfill was closed early. Assuming that the Ashcroft Ranch operating cost savings range from 10% to 25%, the cost of early closure ranges from $101,000,000 to $63,000,000. In the event that leachate treatment is required at the

Vancouver Landfill, the cost of early closure of the Landfill is reduced to approximately $62,000,000.

6.1 Recommendations

Based on the conclusions of the paper, the following recommendations are provided:

1. Operate the Vancouver Landfill to capacity

Given that the net present value of the cost of closing the Vancouver Landfill is estimated at approximately $81,000,000, cost-benefit analysis would suggest that it is appropriate to continue to operate the Vancouver Landfill to capacity in approximately 2041.

2. Maximize the benefit of the Vancouver Landfill to GVRD residents other than Vancouver and Delta

Given that for residents of the GVRD other than Vancouver and Delta there does not appear to be a significant cost in the event that the Vancouver Landfill is closed, Vancouver and Delta should take steps to increase the benefit to other GVRD residents where possible. If Vancouver and Delta fail to increase the benefit to other GVRD residents, the other GVRD residents will be indifferent to whether the Vancouver Landfill is closed and may not support long term operation of the facility. Increased benefit to other GVRD residents could be achieved by maximizing the extent that secondary materials are disposed of at the Vancouver Landfill, and potentially by increasing the amount of other GVRD municipal solid waste disposed of at the Vancouver Landfill. Increasing the amount of waste from municipalities other than Vancouver and Delta disposed of at the Vancouver Landfill would decrease the operating cost of the Vancouver Landfill through economies of scale, but might increase the disposal cost for other GVRD waste through reduced economies of scale at Cache Creek or the Waste-to-Energy facility. The implications of increasing the disposal of waste from other GVRD municipalities at the Vancouver Landfill would need to be studied in more detail.

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APPENDIX 1: PROPERTY SALES DATA

Address	Selling Price	Selling Date	Age	Total Sq Ft	Distance	Scale	Main Sq Ft	Estimate
6684 Ladner Trunk	250,500	6/8/03	44	1348	1.37	4.9	1348	257,341
6092 Ladner Trunk	255,000	9/20/03	38	1236	2.55	9.1	1236	268,895
4885 64th St	245,000	2/28/03	50	1261	1.93	6.9	1261	239,659
4796 Cedar Tree Ln	260,000	4/13/03	17	1440	3.58	12.8	1440	296,966
5226 Crescent Drive	246,000	6/20/03	50	1008	2.32	8.3	1008	238,283
5550 49th Av	258,000	2/20/03	30	1136	3.42	12.2	1136	264,839
4591 66th St	265,000	4/30/03	50	1219	2.10	7.5	925	241,975
5007 60 A St	256,500	1/2/03	31	2074	2.49	8.9	1060	290,432
4888 60 A St	265,000	1/20/03	35	2218	2.52	9	1030	290,188
4681 64th St	265,000	11/22/03	50	1107	2.21	7.9	1107	250,751
4623 55th St	275,000	2/20/03	29	1200	3.47	12.4	1200	268,370
4914 57 A St	279,000	9/10/03	32	1152	2.83	10.1	1152	274,505
4502 54 A St	276,000	2/3/03	28	1982	3.81	13.6	649	293,857
5626 48 B Av	285,000	3/20/03	14	1459	3.25	11.6	779	300,583
5626 45th Av	278,000	7/13/03	33	1936	3.56	12.7	1170	294,570
4476 61st St	264,500	2/1/04	26	1300	2.55	9.1	1300	296,779
5002 60 A St	286,600	3/4/03	35	2095	2.46	8.8	1237	288,832
4769 60 B St	289,000	11/9/03	40	1296	2.52	9	1296	270,849
4520 60 B St	287,000	10/13/03	50	1040	2.74	9.8	1040	246,207
6100 48 A Ave	296,000	2/4/04	33	1865	2.44	8.7	1140	304,658
5398 44th Ave	285,000	11/1/03	34	1984	4.12	14.7	1225	301,283
6049 49 B Ave	295,000	1/22/03	32	2409	2.41	8.6	1209	300,869
4460 54 A St	300,100	2/7/03	32	1875	3.92	14	1100	284,741
6044 Crescent Dr	298,500	11/2/03	32	2255	2.86	10.2	1148	312,981
5553 Maple Cr	307,500	10/28/03	35	2098	3.84	13.7	1198	303,208
4445 60 B St	305,000	2/11/04	26	1723	2.83	10.1	1064	310,915
4858 57 A St	294,000	4/9/04	31	1282	3.02	10.8	1282	292,868
5409 45th Avenue	302,000	4/9/03	33	2148	3.95	14.1	1248	295,654
4644 55 B St	283,000	12/18/03	50	2150	3.58	12.8	1970	285,687
5246 Crescent Dr	315,100	3/11/03	32	1588	2.86	10.2	800	277,477
5111 56th Street	300,000	3/15/03	24	1700	3.22	11.5	962	293,165
4462 Hawthorne Pl	305,000	11/21/03	24	1695	2.91	10.4	1695	308,065
5611 Maple Cres	305,000	3/31/03	33	1983	3.58	12.8	1266	289,834
4930 Linden Dr.	315,000	6/1/03	18	1381	3.58	12.8	1381	296,535
4875 Linden Dr.	325,500	7/10/03	17	2184	3.56	12.7	1237	326,054
6038 Brodie	311,350	9/19/03	36	2268	2.44	8.7	1134	304,825
5065 59 A St	312,000	1/23/03	34	2654	2.60	9.3	1351	305,803
5523 Chestnut Cr	313,000	1/9/03	33	2277	3.70	13.2	1253	294,382
5681 Green Pl	317,500	2/5/03	50	2286	3.05	10.9	1416	271,079
4982 56th Street	295000	4/2/03	30	1985	3.81	13.6	1985	294,467
4903 58th Street	307,000	4/23/03	32	1987	2.94	10.5	1150	292,825
4432 Hawthorne Pl	296,500	12/16/03	25	1426	2.94	10.5	1426	299,474
4720 Cedar Tree Ln	326,000	1/15/04	19	1809	3.61	12.9	863	322,428
5027 60 A St	307,000	3/11/04	28	1814	2.46	8.8	1197	312,601
6045 49th Aven	309,000	10/12/03	50	2652	2.49	8.9	1318	297,731
4611 56th St	310,000	2/1/03	26	3108	3.50	12.5	1732	332,735
4952 60 A St	317,000	2/22/04	35	2288	2.49	8.9	1144	316,308

Address	Selling Price	Selling Date	Age	Total Sq Ft	Distance	Scale	Main Sq Ft	Estimate
4602 56th St	318,500	10/21/03	23	2444	3.50	12.5	1344	331,656
5572 44th Av	315,000	4/17/04	32	1700	3.89	13.9	1700	305,241
6054 Crescent Dr	326,000	10/28/03	33	2161	2.38	8.5	1187	308,190
5422 Crescent Dr	327,900	7/31/03	33	2594	3.53	12.6	1354	316,706
4605 61st St	326,500	12/19/03	31	2137	2.58	9.2	2137	313,508
5612 47A Av	324,000	2/12/04	26	1530	3.42	12.2	1530	304,799
6308 45 B Av	316,500	12/27/03	14	1630	2.30	8.2	1630	322,975
5526 44th Av	335,000	4/4/04	36	2052	3.89	13.9	1237	309,793
4660 55 A St	336,500	4/23/03	17	1523	3.64	13	1523	300,222
5276 Crescent Dr	335,000	7/31/03	23	2567	3.11	11.1	1467	330,672
5020 Crescent Pl	328,000	1/19/03	12	1723	1.99	7.1	1723	308,397
5803 Crescent Dr	320,000	6/8/03	36	1390	2.83	10.1	1390	270,549
5012 60 A St	327,000	7/16/03	28	3029	2.44	8.7	1635	337,141
5962 49 A Av	334,000	10/17/03	16	1619	2.69	9.6	959	315,397
4865 59 A St	335,000	9/7/03	16	1761	2.69	9.6	936	317,541
4 4756 62 St	328,000	12/13/03	13	1996	2.27	8.1	1008	335,330
4467 63 St	328,000	7/4/03	13	2029	2.44	8.7	1208	326,666
4422 61 St	338,000	10/5/03	23	2023	2.80	10	1154	317,224
6675 London Lane	341,500	3/17/03	15	2000	1.62	5.8	1184	316,232
4628 London Mews	337,000	1/11/03	12	2215	1.68	6	1056	323,661
4707 London Cr	336,000	9/20/03	14	2159	1.51	5.4	1159	334,023
6360 Holly Park Dr	340,000	1/6/03	12	2365	2.32	8.3	1380	328,161
6389 Sunrise Lane	340,000	5/29/03	10	1880	2.49	8.9	1880	324,187
5626 48 B Av	340,000	1/16/03	15	1659	3.33	11.9	843	301,720
6790 London Dr	340,000	9/25/03	14	2111	1.68	6	1316	332,787
4678 55 St	323,000	5/11/03	29	2500	3.70	13.2	1390	314,770
5320 Crescent Dr	345,000	6/17/03	16	2280	3.30	11.8	1278	329,229
6406 Holly Park Dr	350,101	3/26/03	13	2315	2.10	7.5	1325	329,818
4531 60 B St	345,000	6/15/03	7	1840	2.74	9.8	1840	328,376
5679 47 A Av	345,000	8/17/03	5	1904	3.39	12.1	944	337,170
5021 59 St	346,000	1/19/04	35	2250	2.66	9.5	1200	313,052
6695 London Ct	354,500	7/29/03	14	2520	1.60	5.7	1108	342,395
6427 Holly Park Dr	352,500	8/26/03	14	2568	2.10	7.5	1342	345,611
4535 61 St	340,000	12/15/03	24	2335	2.66	9.5	1640	329,985
4762 London Green	358,000	3/7/04	15	2012	1.57	5.6	1287	337,976
6199 48 A Av	355,000	4/1/03	13	2471	2.41	8.6	1261	335,170
4604 56 A St	361,500	4/27/03	32	2622	3.39	12.1	1429	313,385
4657 55 A St	367,000	1/23/03	17	2427	3.64	13	1143	323,750
4895 64 St	369,000	7/17/03	10	2708	1.82	6.5	1573	353,623
4902 54 A St	365,000	1/6/04	22	2077	3.61	12.9	1141	326,015
6300 Holly Park Drive	372,000	6/28/03	14	2745	2.21	7.9	1385	347,735
6330 45 A Av	372,000	8/13/03	14	2788	2.24	8	1421	351,871
4520 Dawn Pl	373,000	9/13/03	14	3020	2.49	8.9	1920	361,155
4741 London Cr	377,000	7/9/03	13	3020	1.57	5.6	1608	358,678
6230 Holly Park Dr	375,000	5/23/03	13	2812	2.30	8.2	1327	349,202
6211 49 Ave	380,000	2/6/03	0	3820	2.13	7.6	1741	394,377

APPENDIX 2: REGRESSION ANALYSIS RESULTS

Regression Analysis Including Distance to Landfill

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.845
R Square	0.713
Adjusted R Square	0.700
Standard Error	18329
Observations	93

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	7.36E+10	1.84E+10	54.7607962	4.27429E-23
Residual	88	2.96E+10	3.36E+08		
Total	92	1.03E+11			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1660614	548525	-3.027	0.00323538	-2750691.08	-570536	-2750691	-570536
Sales Date	52	14	3.570	0.00058143	22.89198112	80	23	80
Property Age	-1473	175	-8.409	6.7324E-13	-1821.0718	-1125	-1821	-1125
Floor Space	32	4	8.243	1.4744E-12	24.18753543	40	24	40
Distance to Landfill	-753	2850	-0.264	0.79224229	-6416.35874	4911	-6416	4911

Regression Analysis without Vancouver Landfill

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.843
R Square	0.711
Adjusted R Square	0.701
Standard Error	18294
Observations	97

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	76496844316	2.55E+10	76.1893	5.80303E-25
Residual	93	31125132480	3.35E+08		
Total	96	1.07622E+11			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1987343	523388	-4	0.000261	-3026688	-947997	-3026688	-947997
Sales Date	60	14	4	3.38E-05	33	88	33	88
Property Age	-1483	172	-9	1.5E-13	-1824	-1143	-1824	-1143
Floor Space	32	4	8	3.51E-13	25	40	25	40