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PIT TO PARK: GRAVEL MINE RECLAMATION USING BIOSOLIDS

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ABSTRACT

In an innovative recycling and mine reclamation project Valley Gravel Sales Ltd., GVRD Parks, GVRD Biosolids Recycling and Sylvis Environmental worked together in the reclamation of a gravel pit located in one of GVRD's regional parks. In the transformation from "Pit to Park" the use of Nutrifor™ (GVRD's biosolids) and Nutrifor compost was proposed as a soil amendment to assist in the establishment of vegetation over the site.

Extensive public consultation was conducted in both final land use planning and the use of organic amendments in achieving mutual objectives. As the gravel pit and park are located over the sensitive Abbotsford Sumas aquifer, there was concern that the addition of organic amendments would further compromise aquifer quality. Local area residents, some on shallow well water, were also concerned about the possible impact of the application on their drinking water source.

Local area wells were included in the monitoring program and stakeholders were involved in the decision-making and progress of the reclamation activities through public meetings, tours, direct mail-outs and newspaper advertisements. A lysimeter study was completed to quantify the environmental effects of the proposed applications on the groundwater, soil and vegetation prior to reclamation. This study assisted in refining and verifying amendment application rates that are protective of the environment.

Upon receiving a BC Ministry of Environment, Lands and Parks Approval, approximately 12 hectares of the re-contoured pit were reclaimed with 930 bulk tonnes (235 dry tonnes) of biosolids and 3918 bulk tonnes (1884 dry tonnes) of biosolids compost as a 1:1:4 by volume mix (compost:biosolids:native soil) in September, 1999. After the removal of the last sand stockpile expected in Summer 2000, final applications will be made in the late summer to the remaining areas.

Environmental monitoring showed a post application increase in soil nutrients. No effect on groundwater or surface water was observed. The gravel pit within Aldergrove Lake Regional Park will soon be a parkland green space, complete with picnic area, concert bowl, and a canoeing lake with three islands.

INTRODUCTION

In 1969, the Greater Vancouver Regional District (GVRD) purchased land for inclusion within the Aldergrove Lake Regional Park located on the Aldergrove/Abbotsford border in the Fraser Valley. The original land purchase did not include the rights to extract gravel, which was later acquired by a local aggregate producer -Valley Gravel Sales,

Valley Gravel Sales has conducted its aggregate (sand and gravel) operation for over 25 years from a property adjacent to the GVRD park, primarily supplying high quality concrete aggregates. The proximity of Valley Gravel Sales' operations to the park site allowed for the use of an overland conveyor belt to transport the aggregate from the GVRD site to Valley Gravel Sales. The conveyor allowed for the minimal use of machinery on the GVRD site. Before gravel extraction began, the GVRD and Valley Gravel Sales agreed to modify the extraction area to accommodate more suitable long-term park use.

The replaced overburden requires additional nutrients produce favourable growth. To assist in the establishment of a self-sustaining cover of vegetation suitable for parkland use, the use of organic amendments were proposed. Nutrifor biosolids and biosolids compost from the GVRD were the amendments used in the pit to park transformation.

Valley Gravel Sales, GVRD Parks and the GVRD Biosolids Recycling Program agreed to work together to reclaim this gravel pit after the final extraction. Valley Gravel Sales' responsibilities included restoring the site to the desired grade and placing the stockpiled native soil across the site. GVRD coordinated the park planning process, supplied the biosolids and biosolids compost and retained Sylvis Environmental. Sylvis Environmental provided technical support throughout the project on the use of soil amendments, the environmental monitoring program and on obtaining the authorization from Ministry of Environment, Lands and Parks.

WHY ORGANIC AMENDMENTS?

The closure of a mine often involves the establishment of a self-sustaining community of vegetation. Typically, stockpiled overburden remaining after aggregate extraction is unable to support healthy vegetation as a result of a lack of nutrients and organic matter. Nutrients are required for healthy and vigorous vegetation growth, while organic matter is required to retain the nutrients and moderate their release. The organic matter retains moisture for plant uptake and improves soil tilth, which is important for proper root growth and soil stability.

Inorganic fertilizers provide a flush of nutrients quickly and little, if any, organic matter. Consequently, nutrients are quickly washed from coarse-textured soils by rainfall; little moisture is retained and soil tilth remains poor. Even with repeated applications of inorganic fertilizers, the establishment of vegetation may not be successful.

The properties of organic soil amendments complement those of mineral soils. Furthermore, different organic soil amendments have different properties; this allows for the creation of mixes tailored to site-specific requirements. The majority of organic soil amendments have high concentrations of essential plant nutrients and high organic matter content. Through understanding the physical, chemical and biological properties of biosolids and biosolids compost, these amendments will supply necessary nutrients, increase the water holding capacity and provide the medium to sustain vegetation while promoting soil development.

PROJECT CONCEPT

Land reclamation utilizing biosolids and other organic soil amendments is not new. Organic reclamation projects in the US date back approximately 25 years. Many gravel pit reclamation programs using organic amendment exist in BC, with the most comprehensive program at Construction Aggregates Limited, Sechelt. This reclamation program uses biosolids from the local Gibsons and Sechelt wastewater treatment plants (WWTP) and pulp sludge from Howe Sound Pulp and Paper to improve the quality of soils for the establishment of vegetation.

The use of biosolids in gravel pit reclamation was a logical progression from the GVRD's successful organic reclamation of ore mines, including Similco Mines in Princeton and Highland Valley Copper, Logan Lake. In 1996, the GVRD completed its first biosolids application to a gravel pit operated by the BC Ministry of Transportation and Highways (MoTH), near Logan Lake. GVRD biosolids have been used in the reclamation of two additional MoTH gravel mines prior to use at Aldergrove Lake Regional Park.

LOCATION AND SITE DESCRIPTION

The pit to park transformation (Figure 1) occurred at Valley Gravel's gravel mining operations located in the GVRD's Aldergrove Lake Regional Park, located between 272nd Street and Lefeuvre Road and O and 8th Avenue on the Aldergrove/Abbotsford border. The gravel formation that exists in the park is a result of a geologically recent melt water channel scouring into outwash glacial fluvial deposits laid down previously. The resulting sand and gravel deposits range to 40 m in depth, with periodic lenses of silt and clay resulting from glaciomarine sedimentation.

Groundwater in the park flows from south to southeast, and is recharged through the vertical infiltration of winter precipitation. The park is located over the western extent of the Abbotsford-Sumas aquifer (Figure 2). An Environment Canada report (Hii, *et. al,* 1999), studying 31 piezometers at 13 sites in the aquifer from 1991 to 1999 noted that 20 of the 31 piezometers had nitrate concentrations over the drinking water guideline of 10 mg L"^{1}. The major source was hypothesized to be the inappropriate use of animal manure on agricultural lands. This report suggested recommendations to improve the aquifer water quality that included the appropriate use of fertilizers and organic residuals over and around the aquifer.

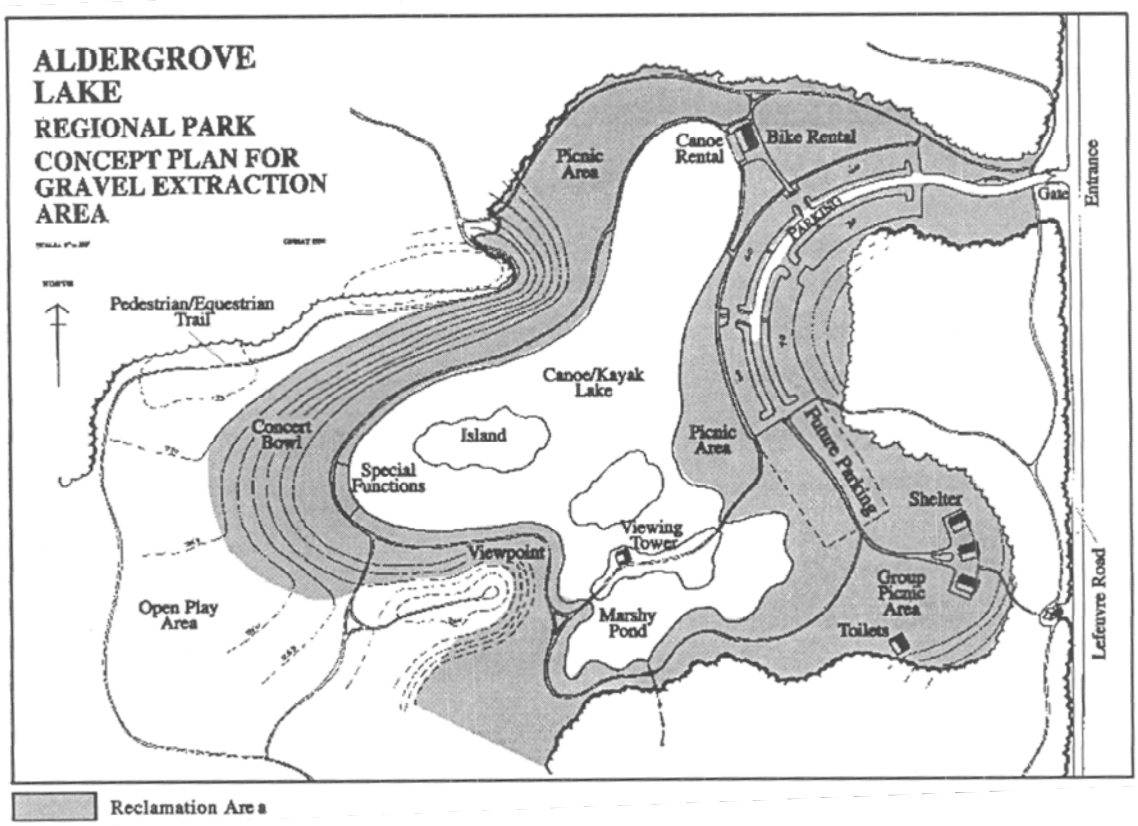


Figure 1: Site plan of the total area designated for reclamation.

PUBLIC CONSULTATION

Stakeholder input into establishing the objectives for the pit reclamation from a park perspective plus input on the means and methods of achieving the defined objectives are of paramount importance. This includes the use of biosolids and biosolids compost as organic amendments to establish vegetation.

A comprehensive public information program was undertaken in November 1996 and will continue until project completion to inform and involve the community of the reclamation project. At inception, the program objectives were to familiarize stakeholders with the project and relevant science, and actively involve them in the decision-making process.

The public consultation program began by identifying key stakeholders. Among them were elected officials, Abbotsford-Sumas Aquifer International Task Force, residents within a one kilometer radius of the park and local and US interest groups. Information regarding the project was presented through an open house, meetings, telephone conversations and letters.

Throughout the process, the participants were encouraged to voice their ideas or issues about the project. Generally, their comments were supportive of the reclamation project. Two main concerns raised were the possible effects on the Abbotsford-Sumas Aquifer and the possible odours from the soil amendments. The first concern was addressed by the lysimeter study as described below. During a subsequent open house stakeholders were given the opportunity to smell stockpiles of biosolids and biosolids compost that were brought to the site. Through active stakeholder input into the project, most stakeholders supported the reclamation plan.

LYSIMETER STUDY

Concerns were expressed by Ministry of Environment, Lands and Parks, Ministry of Health and local residents on the possible adverse environmental impacts the application could have on the already compromised Abbotsford-Sumas aquifer (Figure 2). To address their concerns and to further refine and validate application rates, a research trial was initiated to assess the efficacy of a series of soil amendments on the establishment and growth of vegetation and on nutrient and trace element leaching. Three replicates of six treatments were randomly applied to monolith lysimeters constructed and installed at the gravel pit. The six treatments were:

1. Thermophilic anaerobically digested secondary biosolids from the GVRD's Annacis Island WWTP *(Nutrifor™)*
2. Biosolids Compost *(Compost)*
3. Nutrifor NT, a product composed of waste paper fibre and biosolids *(NutriforNT)*
4. Biosolids with Biosolids Compost *(Nutrifor with Compost)*
5. Inorganic Chemical Fertilizer *(Chemical Fertilizer)*
6. Control *(Control)*

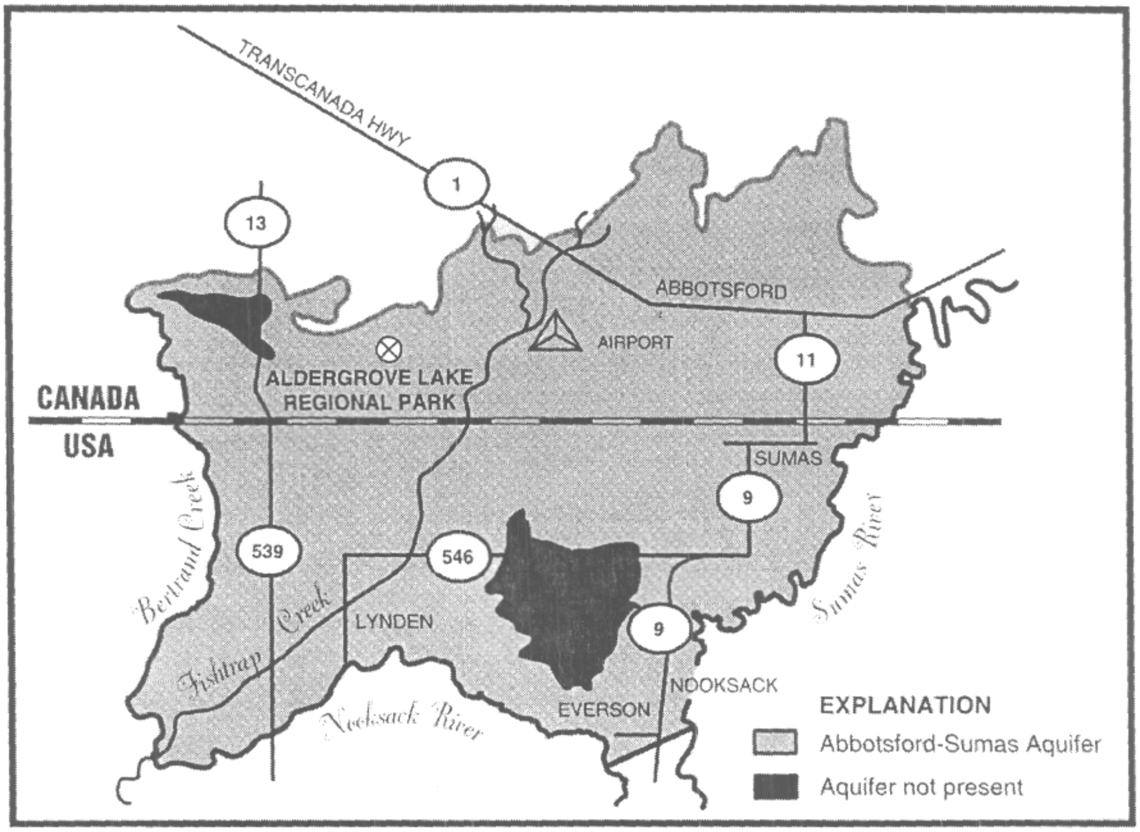


Figure 2: Site plan of Abbotsford-Sumas Aquifer.

Lysimeters are devices for sampling soil water, and allow for the collection of water moving down through the soil profile following a specific management practice such as the application of a fertilizer. Lysimeters are used in a multitude of research applications for soil water sampling.

These treatments were based upon the GVRD proposed amendment application rate of 1 part Nutrifor with 1 part compost with 4 parts native soil on a volume basis. The objective of this trial was to compare the rehabilitation treatments of leaving the area alone *(Control),* applying inorganic fertilizer *(Chemical Fertilizer),* or the treatment proposed by the GVRD *(Nutrifor with Compost).* The biosolids alone *(Nutrifor)* and compost alone *(Compost)* treatments were included so that the effects of the biosolids and compost applications applied together could be assessed separately. The application rates calculated for *the Nutrifor with Compost* treatment reflect these rates. The *Nutrifor with Compost* treatment was a combination of the *Compost* alone application rate and the *Nutrifor* alone application rate. The application rate of *chemical fertilizer* matched the nitrogen calculated to be available from the *Nutrifor with Compost* treatment.

The lysimeter construction allowed for quantification and characterization of soil water moving down through the soil profile. The lysimeters were constructed and treatments applied in August 1997 and water was collected every two weeks from September 14th, 1997 through April 26th, 1998 from each lysimeter. At each sampling event, the water volume moving out of the lysimeters was measured and analyzed for forms of nitrogen, phosphorus, and carbon. An additional sample was collected every four weeks and analyzed for trace metals. Assessments were made of the germination and growth of the vegetation at each sampling interval. At the end of the lysimeter water collection, the vegetation established in the lysimeters was removed, dried, weighed, and analyzed for essential plant nutrients.

Vegetation germination was rapid on the *Control* and *Chemical Fertilizer* treatments. A delay in germination was noted in the organic amendment treatments. Upon germination, the *Nutrifor* and *Nutrifor with Compost* treatments resulted in the most vigorous growth and the largest quantity of vegetation. The *Control* treatment, while germinating first, grew slowly and became chlorotic as compared to the other treatments. The vegetation growth on the *Nutrifor NT treatment* was poor.

Vegetation biomass at the end of the study was the greatest in the *Nutrifor* and *Nutrifor with Compost* treatments. These treatments produced more than 13 times the above ground vegetation as produced by the *Control* treatment. The *Compost* and *Chemical Fertilizer* treatments resulted in a marginal increase in vegetation biomass. The *Nutrifor NT* treatment resulted in a reduction in biomass as compared to the *Control* treatment.

In assessing the quality of vegetation determined through foliar nutrient analysis, the *Nutrifor* and *Nutrifor with Compost* amendments were the only treatments to significantly increase the foliar nitrogen concentration above that of the *Control.* The control treatment, as well as what existing vegetation was present, were severely nitrogen deficient. Adequate foliar nitrogen concentration is important in the growth and survival of the established vegetation. The *Nutrifor* and *Nutrifor with Compost* treatments increased the concentrations of all deficient plant essential nutrients tested, and reduced one micronutrient found in excess in the *Control* treatment.

Nitrate nitrogen comprised the largest component of the total nitrogen lost in all treatments except the *Control.* The application of *Chemical Fertilizer* resulted in nitrogen losses greater than that of the *Compost,* and *Nutrifor with Compost* treatments. The *Nutrifor with Compost* treatment, composed of the same amount of both *Nutrifor* and *Compost* as applied in the respective individual treatments did not result in an additive nitrogen loss. A significant reduction in the amount of water moving down and out of the *Nutrifor with Compost* treatment was observed. This can be attributed to the establishment of a dense community of vegetation resulting in both increased evapotranspiration losses and water storage in this treatment.

The *Nutrifor with Compost* treatments resulted in less phosphorus in the lysimeter water as compared to all the other treatments, including the *Control.* As phosphorus plays an important role in the promotion of eutrophication, treatments that reduce the movement of phosphorus out of the soil profile and into subsurface receiving water bodies are preferable. *The Control* and *Compost* alone treatments resulted in the largest total phosphorus concentrations in the lysimeter water.

In assessing the trace metals in the lysimeter water, the concentrations of arsenic, cadmium, chromium, cobalt, lead, mercury, molybdenum, nickel, selenium and silver, were all below detection limits in all treatments at all sampling intervals. While soil water is not drinking water, the concentrations of the remaining trace metals in the *Nutrifor with Compost* treatment lysimeter water were well below levels specified in Health Canada's Guidelines for Canadian Drinking Water Quality (1996).

The *Nutrifor with Compost* amendment, applied at the appropriate rates, resulted in the best establishment of vegetation with the lowest potential impact on waterbodies receiving soil water from this treatment. The *Nutrifor with Compost* treatment increased the soil water storage capacity, and buffered the flow of water through the soil profile. The vegetation growing on this treatment resulted in a higher rate of evapotranspiration of water back into the atmosphere.

ORGANIC RECLAMATION - 1999

The biosolids and compost were hauled and stockpiled on site shortly before the application work began. Prior to application, the biosolids and biosolids compost were mixed together on-site using a front-end loader against the active face of the stockpile. The loader operator mixed the two amendments as uniformly as possible and then loaded the application equipment. A total of five rear-discharge manure spreaders pulled by tractors and one CAT Challenger tractor applied the material over a ten-day period. The depth was continually measured to ensure the correct amounts of amendments were being applied and that buffer zones were maintained to the canoeing lake established in the middle of the reclamation area. In 1999, 12 hectares were reclaimed with 930 bulk tonnes (235 dry tonnes) of biosolids and 3918 bulk tonnes (1884 dry tonnes) of compost at a volume ratio of 1:1:4 (compost:biosolids:native soil).

Once spreading was complete, the biosolids were incorporated by disc into the top 15-30 centimeters of native topsoil (overburden), which had been placed across the reclamation area approximately 60 centimeters deep. Following incorporation, the site was broadcast seeded with a general sportsturf seed mixture and then lightly incorporated and compacted with a culti-packer.

AMENDMENT MONITORING

All of the biosolids used in this project originated from the GVRD's Annacis Island WWTP (AIWWTP). The biosolids compost was manufactured by composting AIWWTP biosolids with yard waste. Analysis of the biosolids and biosolids compost is provided in Table 1.

Constituent		Biosolids 31-Aug-99	Compost 16-Sep-99	Mixture[1] 22-Jul-99	MoELP Limits[2]	Units
Arsenic ***Total***	**As**	7.6	9.0	10	75	mg/kg-dry
Cadmium ***Total***	**Cd**	3.6	2.9	3.0	20	mg/kg-dry
Chromium ***Total***	**Cr**	58	100	85	1060	mg/kg-dry
Cobalt ***Total***	**Co**	4.1	6.0	5.7	150	mg/kg-dry
Copper ***Total***	**Cu**	1570	868	1019	2200	mg/kg-dry
Lead ***Total***	**Pb**	165	121	139	500	mg/kg-dry
Mercury ***Total***	**Hg**	1.1	4.7	3.3	15	mg/kg-dry
Molybdenum ***Total***	**Mo**	13	6.4	8.1	20	mg/kg-dry
Nickel ***Total***	**Ni**	17	40	37	180	mg/kg-dry
Selenium ***Total***	**Se**	4.6	3.7	3.2	14	mg/kg-dry
Zinc ***Total***	**Zn**	1152	666	723	1850	mg/kg-dry
Fecal Coliform		-	-	33	1000	MPN/g
Salmonella		-	-	0.7	3	MPN/4g

1 Mixture of biosolids and biosolids compost on a 1:1 by volume basis.
2 Limits from MoELP Approval dictating product quality.

The concentrations of trace metals and biological parameters for the ingredients and mixture of biosolids and compost were well below the approval limits.

SOIL MONITORING

The site soils were sampled once pre- and once post- application with three composite samples formed from eight sub-samples per interval. A summary table of these results is provided in Table 2. The application resulted in an increase in plant nutrients (i.e. ammonia, total kjeldahl nitrogen (TKN), phosphorus, potassium and boron). No increase was seen in soil nitrate nitrogen due to plant uptake. A beneficial change in pH was noted.

Constituent		Pre-Application(1) 9-Dec-98	Post-Application(1) 14-Dec-99	Limits(2)	Detection Limit	Units
Water Soluble Nitrite	N	1	1		1	mg/g
Ammonia Nitrogen	N	5	11		5	mg/g
Nitrate Nitrogen	N	4	5.2		4	mg/g
Total Kjeldahl Nitrogen	N	0.15	0.24		0.02	%
Moisture		19.8	31.5		0.1	%
pH		5.8	6.2		0.1	pH Units
Boron	B	4	12		1	mg/g
Phosphorous	P	2923	4810		20	mg/g
Available Phosphorous	P	49	98		1	mg/g
Potassium	K	430	611		1	mg/g
Arsenic	As	10	10	15	10	mg/g
Cadmium	Cd	0.3	0.3	1.5	0.3	mg/g
Chromium	Cr	35	15	60	2	mg/g
Cobalt	Co	9	10	50	1	mg/g
Copper	Cu	19	91	150	1	mg/g
Lead	Pb	30	30	200	30	mg/g
Mercury	Hg	0.04	0.37	2	0.001	mg/g
Molybdenum	Mo	4	4	10	4	mg/g
Nickel	Ni	31	32	100	2	mg/g
Selenium	Se	0.5	0.5	3	0.5	mg/g
Zinc	Zn	57	111	200	1	mg/g

1 Average of three samples. Mean concentrations are running averages of total values. Analytical results returning values of less than detection limits are assumed to have a normal distribution. Concentration means for constituents with less than detection limits are calculated from half the detection limit.

2 Most stringent applicable soil standards for Urban Parkland in BC Contaminated Sites Regulation, April 1, 1997.

Table 2: Pre and post application soil analysis.

No trace metal concentration exceeded the Approval limits, which are the criteria for Urban Parkland in the BC Contaminated Sites Regulation. Copper, mercury and zinc increased slightly as expected, but were well below the Approval limits. Interestingly, the pre-existing chromium concentration in the soil was diluted due to the addition of the soil amendment.

WATER MONITORING

In conjunction with discussions with the area residents, and based on hydrogeological flow patterns in the aquifer, five neighbouring domestic drinking water wells were identified for monitoring. One well is within the boundaries of the pit, three others are private wells for nearby residences and one at a nearby solid waste transfer station. Water samples are also collected from the canoeing lake established within the gravel pit boundaries.

Following application, water samples are collected every three months for the first year and then once every six months for the second year. The results for the analysis completed to date are seen below in Table 3.

Constituent	Concentration Mean[1,2]					Drinking Water Limits[3]	Units	Detection Limit
	Park Mon Well	ResWell No. 1	ResWell No. 2	ResWell No. 3	Pond Outlet			
pH	8.4	7.4	6.5	6.5	8.3	6.5 - 8.5	pH	-
Hardness $CaCO_3$	29.5	100	61.9	39.8	50.2	80 - 100	mg/L	0.1
Chloride Cl	36	6.9	5.4	1.6	27.8	250 (dissolved)	mg/L	0.1
Ammonia N	0.07	0.01	0.01	0.01	0.01	n/a	mg/L	0.01
Nitrate/Nitrite N	0.02	1.1	5.7	2.3	0.04	10	mg/L	0.01
Fecal Coliform	0.78	0.6	0.6	0.6	24	varies	MPN/100ml	1.1
Arsenic As	0.005	0.004	0.001	0.001	0.004	0.025	mg/L	0.001
Cadmium Cd	0.01	0.01	0.01	0.01	0.01	0.005	mg/L	0.01
Chromium Cr	0.01	0.01	0.01	0.01	0.01	0.05	mg/L	0.01
Cobalt Co	0.01	0.01	0.01	0.01	0.01	n/a	mg/L	0.02
Copper Cu	0.01	0.01	0.06	0.03	0.01	0.5	mg/L	0.02
Lead Pb	0.03	0.03	0.03	0.03	0.03	0.01	mg/L	0.06
Mercury Hg	0.0001	0.0002	0.0002	0.0002	0.0002	0.001	mg/L	0.0002
Molybdenum Mo	0.02	0.02	0.02	0.02	0.02	0.25	mg/L	0.03
Nickel Ni	0.01	0.01	0.01	0.01	0.01	n/a	mg/L	0.02
Selenium Se	0.001	0.002	0.001	0.001	0.001	0.01	mg/L	0.001
Zinc Zn	0.01	0.01	0.01	0.02	0.01	5	mg/L	0.01

1 n=3 except for Park Mon. Well where n=2. Mean concentrations are running averages of total values. Analytical results returning values of less than detection limits are assumed to have a normal distribution. Concentration means for constituents with less than detection limits are calculated from half the detection limit.

2 Most stringent applicable guidelines/criteria in British Columbia Water Quality Guidelines (Criteria) for Drinking Water: 1998 Edition, updated January 2000.

Table 3: Analysis of groundwater and pond water.

In both the groundwater and surface waters, the results reported for cadmium and lead are above the respective drinking water limit due to a high detection limit for these trace elements (compare the sample detection limit to the quality criteria). The actual levels are anticipated to be below the drinking water limits, as with all of the other trace metals. The hardness levels for all but one residential well and the canoeing lake are below the range listed for drinking water. However, this range is based upon aesthetics, not a health-based concentration, and is typical of water in the Fraser Valley.

COMPLETING THE TRANSFORMATION - 2000

As Valley Gravel completes their mining operation in the park this summer, reclamation of the remaining area will be completed afterwards, again using biosolids and biosolids compost as soil amendments. The remaining area requires grading to final contour, including the placement of overburden, before soil amendments may be applied. With gravel extraction completed and vegetation established by fall 2000 the park will have completed its metamorphosis from its previous open pit "moonscape". GVRD Parks has already received a tentative booking for use of the park prior to the complete transformation - a good indication of the success achieved in the development of this park space.

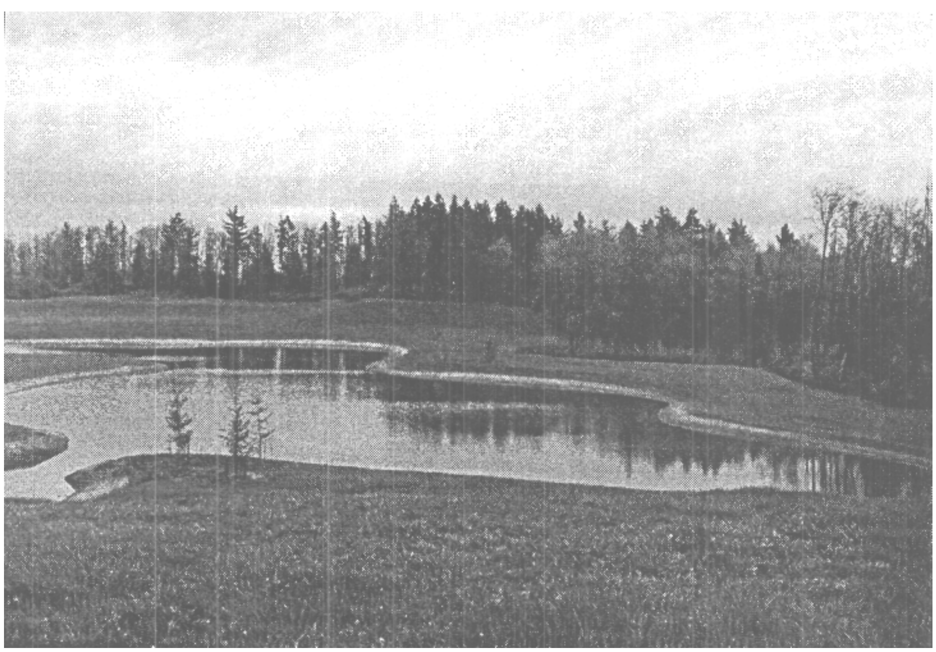
CONCLUSION

Reclamation of the Aldergrove Lake Regional Park gravel mine has resulted in a benefit to the environment, the local community, Valley Gravel and the GVRD. Valley Gravel has been able to enhance and expedite their reclamation efforts through the use of organic soil amendments and have access to technical expertise in the use of the materials. The GVRD Parks Department has a re-contoured and vegetated extension to its previous park space and GVRD Biosolids Recycling Program has another successful biosolids recycling project. Research and monitoring performed by Sylvis Environmental in conjunction with the GVRD have increased the knowledge surrounding the use of biosolids in reclamation activities. The GVRD and Valley Gravel have benefited from an increased, positive public profile. The local homeowners and general public will soon enjoy an expanded park that will provide a lake for kayaking and canoeing, a venue for outdoor concerts, picnic areas and additional walking trails.

The application of biosolids and biosolids compost in the reclamation of the Aldergrove Lake Regional Park pit has provided the opportunity to mitigate and potentially improve the quality of the Abbotsford-Sumas aquifer. The establishment of self-sustaining community of vegetation has resulted in a reduction in both nitrogen and phosphorus movement into the aquifer as compared to areas un-reclaimed or areas reclaimed using traditional inorganic fertilizers.

Numerous abandoned and nearly completed gravel extraction operations exist in the Fraser River Valley and elsewhere in BC. Establishing a self-sustaining healthy community of vegetation on these sites is important for both site rehabilitation and protection of water quality. The use of organic amendments in the reclamation of these mines is a simple, effective and cost-effective method for achieving final land use objectives - should they be public park, agricultural land, forests or a combination.

Photograph 1: Final excavation and pre site contouring.



Photograph 2: Canoeing lake and established vegetation two months following soil amendment application.

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