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DEMONSTRATING SELF-SUSTAINING VEGETATION: GRANBY TAILINGS, PRINCETON, B.C.

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ABSTRACT

The Granby Tailings, located immediately east of the Town of Princeton, are a highly visible reminder of the original Granby Copper and Consolidated Company that operated in the Princeton area between 1922 and 1956. This seventy eight hectare tailings pile lay barren, void of vegetative cover for almost forty years, creating aesthetic, wind erosion, and chronic dust problems for the local citizens. Low annual precipitation (35 cm), combined with the poor moisture and nutrient retention of the inert tailings, had frustrated the efforts of both man and nature to revegetate the tailings site.

In 1992, the Greater Vancouver Regional District in partnership with the Town of Princeton established four demonstration plots on the Granby Tailings, to show how mine spoils can be successfully reclaimed using biosolids (treated sewage sludge). The tailings were enriched with biosolids, seeded, and monitored over the past five years. Extensive soil, water, and vegetation sampling in and around the plots, before and following the applications, confirmed that biosolids is a safe and effective soil amendment. The biosolids provided organic matter and essential plant nutrients that helped establish a healthy, mixed grass and legume cover, which in turn eliminated the dust and wind erosion problems, and reclaimed the area for recreation, cattle, and wildlife use.

Based on the results from the initial demonstration plots, Princeton Town Council and the Economic Development Commission supported the GVRD's proposal in 1994 to landscape the entire Granby Tailings site using biosolids. A total of fifty six hectares of flat pond surfaces and twenty hectares of steep slide slopes were reclaimed over two years. The vigorous growth has provided increased opportunities for forage production, seasonal cattle grazing, and wildlife habitat. Even more exciting is the Town's plans to expand the local golf course onto the tailings site. The results of the monitoring program associated with the demonstration plots, as well as a brief overview of the full scale reclamation operation are presented.

INTRODUCTION

The Granby Tailings in Princeton are a reminder of the rich history of mining in British Columbia as a driving force of economic development which helped open up the interior of the province. They are also a monument to another era of mining powered by sweat and steam. From underground workings on Copper Mountain, 16 km to the south and the site of the present day Similco Mine, ore was hauled by steam locomotive to the concentrator mill located at the once thriving Allenby town site. Tailings from the Allenby mill were then conveyed down a 6 km wooden flume to the Granby Tailings site. The ponds, now referred to as benches, were constructed by hydraulically placing coarse tailings against batter boards around the periphery of the pond to form the dam and allowing the fines to settle out towards the center.

The climate in Princeton is typified by warm, dry summers and cold cloudy winters with an annual precipitation of approximately 350 mm, of which one third is snowfall. Situated in the valley bottom adjacent to the Similkameen river, the Granby Tailings lie exposed to the strong valley winds. Sand storms were common on the tailings during the summer drought periods, and frequently carried dust into the town nearby.

In 1992, the GVRD was invited to explore the potential use of biosolids as a reclamation aid for the Granby Tailings site. Biosolids had the essential properties of an effective soil amendment to meet the challenges posed by the tailings site. Reclamation success achieved with biosolids is primary due to three factors related to its organic matter content: 1) nitrogen in biosolids is in a slowly available organic form; 2) the high organic carbon content provides an immediate energy source for soil microbes; 3) the organic matter improves the poor spoil physical conditions resulting from the absence of top soil and compaction (Sopper 1992). Furthermore biosolids improves the moisture holding capacity of the soil, which is important in low rainfall areas.

The use of biosolids as a soil amendment in mine reclamation has proven to accelerate plant growth and soil forming processes in dozens of projects across North America (Sopper 1993). Biosolids have also been used in mine reclamation projects in Australia, South Africa, and Europe. Based on these successes and GVRD's own experience with biosolids, a reclamation plan for the Granby Tailings was developed, beginning with a demonstration phase and ultimately the operational reclamation of the whole site.

THE DEMONSTRATION PHASE

In September of 1992, four one-hectare demonstration plots were established on the Granby Tailings site, distributed across three pond elevations, or benches (Figure 1). Plot 1, which is no longer monitored, was a previously established alfalfa-grass forage field which was regularly irrigated and fertilized with effluent from the Town's adjacent sewage lagoons. Plots 2 and 3 were located on the middle bench, and in 1993 were subdivided to monitor the growth on re-seeded plots re-applied with biosolids. The fourth plot received biosolids combined with an equal volume of wood chips.

Vegetation was established within one growing season on all sites without irrigation (Renken 1994). Compared to the sparse natural vegetation of the previous 40 years and the productivity of the surrounding grassland, the growth rate was remarkable and continues to maintain excellent biomass productivity (Table 1) in spite of annual deer, elk and cattle grazing. In both 1994 and 1995, vegetation sampling indicated no micro nutrient or metal toxicity problems for plant health or cattle consumption as a result of the biosolids applications (Gould Gizikoff 1995).

For more detailed information on the soil and vegetation monitoring at Granby tailings, refer to papers previously presented to this symposium: Salahub, Sahlstrom, & Wilson (1992), Duthie, Peddie, & Salahub (1994), Renken, Peddie, & Chieng, (1995).

THE OPERATIONAL PHASE

<u>Project Design</u>

The success of the Granby tailings demonstration plots initiated full scale reclamation efforts in 1995. The goal was to establish a vegetation cover, to improve the aesthetics of the site, and eliminate severe dust problems. The reclamation plan was implemented over a two year period. In total 35,000 dry tonnes of well-aged land dried biosolids from the Annacis Island Wastewater Treatment Plant in Delta, BC, was used to re-vegetate 76 hectares of copper mine tailings. The land dried biosolids was used to avoid odour concerns, but it also had lower nitrogen levels and organic carbon content than freshly dewatered biosolids. Therefore an application rate of 526 dry tonnes per hectare was used, instead of the standard 100-200 dry tonnes per hectare. Even at this higher application rate the land dried biosolids had lower fertility than the material used on the demonstration plots.

In anticipation that Granby Tailings could be used for extending nine holes of the local golf course, the GVRD consulted with a landscape architect to help design the final contouring plan for the tailings. The project included sloped areas, flat benches and an irrigated hayfield. Recontouring began in mid-August of 1995 and application of biosolids was completed through August, September and October in both years. By 1997 dust storms that once plagued the Town of Princeton have been alleviated and the majority of the tailings area has a healthy forage cover.

Figure 1: Map of the Granby Tailings Reclamation Plan

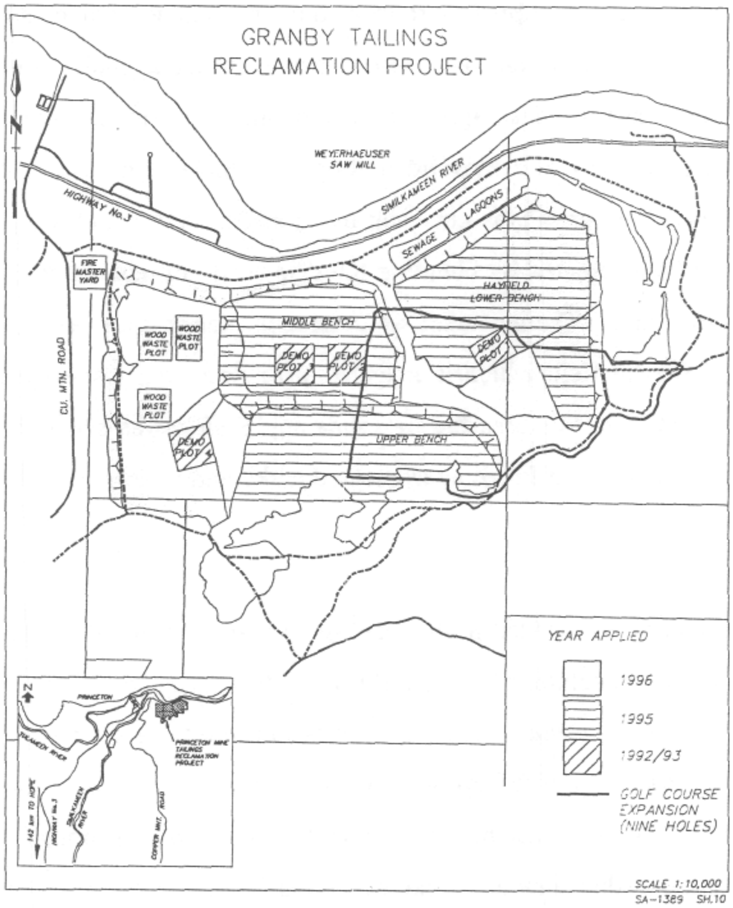

Table 1: Average Biomass Yields on Granby Demonstration Plots.

Note: Surrounding grassland yields = 600-900 kg/ha.

Plot	BiosolidsTreatment	Treatment Date	Yield (kg/ha) Sept 1993[a]	Yield (kg/ha) July 1994	Yield (kg/ha) July 1995	Yield (kg/ha) July 1997
2C	Control (no biosolids)	Oct-92	100	144	63	n/a [b]
2A	77 dt/ha	Oct-92	4900	3574	2792	n/a [c]
2B	62 dt/ha	Oct-92	4500	1792	1753	2674
2B-S	fertilized with 52 dt/ha	Sep-93		3191	2657	4435
2B-TS	rototilled, reseeded + 52 dt/ha	Sep-93		4676	3380	5752
3A	179 dt/ha	Oct-92	1700	5050	4384	4846
3B-S	fertilized with 106 dt/ha	Sep-93		2414	2423	5332
3B	77 dt/ha	Oct-92	5800	2753	2333	4662
3A-TS	rototilled, reseeded only	Sep-93		5873	2780	3003
3B-TS	rototilled, reseeded + 106 dt/ha	Sep-93		2638	3171	5188
4	1:1 biosolids/woodwaste	Oct-92	3100	669	615	1298

a - first year of growth includes fall rye
b - amended with biosolids in 1995
c - harvested for hay before sampling

Application Methods

Biosolids were delivered by truck and stockpiles were located on the benches, adjacent to the slopes and on the hayfield. On the flat areas the material was then spread evenly using a grader and a D4 Caterpillar and incorporated 15 cm into the tailings using an agricultural rotovator. The sloped portions of the tailings were recontoured to facilitate the placement of a biosolids/tailings soil blend and construction of the golf course expansion. One meter of the slope crest was cut back using an excavator and a bulldozer to decrease the incline of the slopes. Top soil was created by blending the displaced tailings material with biosolids using a grader and an agricultural rotavator. The amended soil was then placed onto the slope with a grader and a small wide-track bulldozer. The hayfield which is irrigated with Princeton's sewage effluent was vegetated before the biosolids application. On this area the biosolids application was scheduled to coincide with the 1995 crop rotation where the existing alfalfa crop was plowed under and re-seeded.

Vegetation Monitoring

In both years the reclaimed areas were seeded in the late fall so that the seed could take full advantage of the spring moisture. All applied areas, excluding the hayfield, were drill seeded with a reclamation seed mix at 50 kg/ha consisting of smooth brome, crested wheatgrass, pubescent wheatgrass, hard fescue, orchardgrass and Russian wild rye. In 1995 a nurse crop of fall rye was also seeded to these areas for rapid establishment at 30 kg/ha. The following year the fall rye was removed from the seed mix. Although fall rye is effective at establishing plant cover quickly, this annual cereal can contribute to low grass yields through moisture competition, especially in the first year of growth.

In July of 1996, an assessment of the vegetation response from the previous years seeding on the tailings was conducted. Although germination was generally consistent over the area, the middle bench proved to be more productive than the upper bench and the interior sloped areas. The first year of vegetation cover varied, ranging from 5 to 40%. Crested wheatgrass was the most successful of all the seeded grass species. The upper bench and slopes yielded 1,000 kg/ha fall rye and 500 kg/ha grasses while the middle bench produced 2,000 kg/ha and 1,000 kg/ha respectively (Gould Gizikoff 1996). The lower yields on the upper bench and slopes is attributed to lower soil moisture levels relative to the middle bench.

The middle bench resulted in consistent growth over the applied area, though it proved higher in weed composition. The invasion of weeds is believed to have spread from the demonstration plots, which are also located on the middle bench. The upper bench was less impacted by weeds, but produced a more variable cover than the lower bench. These less productive patches corresponded with areas where sawdust had been placed on the tailings to improve traction for trucks; hauling to the biosolids stockpiles. The resulting increase in C:N ratios led to thin plant cover and the chlorotic appearance of the fall rye in these areas. The upper bench and slopes were also heavily impacted by cattle grazing.

The results of the vegetative analysis for foliage quality are consistent with the past successes of reclamation with biosolids. The vegetation monitoring program shows that the concentrations of macro-nutrients and trace elements in the vegetation do not exceed target levels for plant and cattle health, except for some elevated foliage nitrate levels (Table 2 and Table 3). Elevated plant nitrate levels tend to be seasonal and are most pronounced in the first year. Appropriate management of cattle grazing may be necessary to avoid nitrate toxicity problems on newly seeded areas.

Visual assessment of the second year of growth is as promising as the demonstration plots. In spite of heavy cattle *glazing* and trampling, the plant cover remains lush and extensive. The fall 1996 seeding also shows promising signs of yielding a diverse and healthy grass legume forage.

Table 2: Macronutrient levels in Foliage from Granby Tailings (Gould Gizikoff 1996).

			TOTAL NUTRIENTS (%)						
Species	Site Description	Transect	N	NO^3	P	K	Ca	Mg	S
Fall Rye	Upper Bench	1	5.02	0.12	0.56	3.86	0.64	0.22	0.46
	Slope	2	4.32	0.04	0.46	3.39	0.57	0.18	0.46
	Middle Bench	3	6.21	0.59	0.52	4.02	0.70	0.21	0.46
Mixed Grasses	Upper Bench	1	4.55	0.23	0.30	2.82	0.48	0.12	0.37
	Slope	2	3.26	0.05	0.26	2.28	0.49	0.10	0.36
	Middle Bench	3	4.68	0.20	0.35	3.05	0.55	0.13	0.44
Target Levels for Plant and Cattle Health			**>1.55**	**<0.10**	**>0.14**	**0.5-3.0**	**1.0-4.0**	**.05-.50**	**<4.00**

Table 3: Trace metal levels in Foliage from Granby Tailings (Gould Gizikoff 1996).

			TOTAL METALS (mg/kg)									
Species	Site Description	Transect	As	B	Cd	Cu	Fe	Hg	Mn	Mo	Pb	Se
Fall Rye	Upper Bench	1	<1.0	4.0	<0.2	27	205	<0.7	36	5.0	<2.1	<4.2
	Slope	2	<1.0	4.0	<0.2	28	155	<0.7	55	2.0	<2.1	<4.2
	Middle Bench	3	<1.0	4.0	<0.2	23	174	<0.7	51	3.0	<2.1	<4.2
					<0.2							
Mixed Grasses	Upper Bench	1	<1.0	5.0	<0.2	24	174	<0.7	32	<0.3	<2.1	<4.2
	Slope	2	<1.0	7.0	<0.2	25	206	<0.7	42	1.0	<2.1	<4.2
	Middle Bench	3	<1.0	5.0	<0.2	23	130	<0.7	36	<0.3	<2.1	<4.2
Target Levels for Plant and Cattle Health			**<50**	**5-100**	**<1.0**	**5-100**	**20-500**	**<1.0**	**20-500**	**0.1-5.0**	**<30**	**<5.0**

Soil and Water Monitoring

Biosolids and soil sampling are routinely done prior to any site reclamation and after biosolids incorporation. The organic matter and nutrient status of the tailing improved substantially after the biosolids were applied to the tailings (Table 4). Composite soil samples collected on Granby Tailing before and after biosolids applications also indicate that total metals concentrations showed little or no change following biosolids applications. All samples were well below the Canadian Council of Ministers to the Environment (CCME) Soil Criteria for Residential/Parkland metal levels, except for copper. The high copper content are a result of the natural levels in the tailings in combination *with* the elevated levels found in biosolids (Table 5).

Water samples were collected from six wells surrounding the tailing site. To date there have been no measurable increases in any parameters as a result of the biosolids applications, and future changes in water quality are not anticipated.

Wood Waste Research Trials

On the west side of the Granby Tailings Weyerhaeuser Canada has been depositing wood waste from their local mill operations to a depth of one meter. In 1996 GVRD began investigating three different reclamation treatments using dewatered biosolids incorporated into the wood waste. Substantial amounts of nitrogen are required to prevent nutrient deficiencies caused by the high carbon to nitrogen ratio in the wood waste (C:N - 105). Biosolids were applied at 140, 155 and 170 dry tonnes per hectare, then seeded with the Granby reclamation mix. The test plots will be monitored over the next two to three years. It is expected the entire wood waste area will be available for reclamation within the next five years.

CONCLUSION

The excellent results that have been demonstrated on the Granby Tailings are a testimonial to the beneficial characteristics of biosolids that make it so suitable to mine reclamation. The plant nutrients contained within this soil amendment allow for rapid vegetative establishment and sustained yields. More importantly, biosolids contribute vital organic matter to the soil which helps retain moisture, improves soil structure and provides carbon reserves to sustain ongoing microbial activity and nutrient recycling. Thorpe (1991) hypothesized that it could take 64 years to build up a sustainable nutrient supply purely through the degradation of newly established vegetation in the cool climatic regimes of Canada. In order to reduce the time for land rehabilitation he believed it was necessary to increase the organic matter of the soil, which in turn is essential for ongoing site fertility and nutrient cycling.

Table 4: Nutrient status of the Granby Tailings before and after biosolids applications.

Nutrient Analysis	Pre Application[a]	Post Application[b]	
		Sample #1	Sample #2
pH	8.2	7.4	7.6
Salinity (EC)	1.2	2.0	1.5
%Organic Matter	0.8	4.6	2.1
% Total Nitrogen (TKN)	73.0	1950.0	1178.0
Ammonium (mg/kg)	3.2	111.6	20.3
Nitrate (mg/kg)	2.6	116.6	99.3
Total Phosphate (mg/kg)	2.6	28.0	23.0
Total Potassium (mg/kg)	378.0	156.0	126.0
Sulfate (mg/kg)	350.0	261.0	198.0
Calicum (mg/kg)	3249.0	3166.0	3178.0
Magnesium (mg/kg)	183.6	149.0	123.0
Iron (mg/kg)	46.3	70.0	55.0
Copper (mg/kg)	101.0	83.0	87.0
Zinc (mg/kg)	0.6	19.0	14.0
Boron (mg/kg)	0.4	1.2	1.1
Manganese (mg/kg)	3.0	21.0	19.0

a - mean values from 3 samples collected October 1992
b - mean values from 3 samples collected August 1995

Table 5: Metal levels in the Granby Tailings before and after biosolids applications (Navratil 1996).

TOTAL METALS (mg/kg)	CCME Soil Criteria	Sample #1		Sample #2		Sample #3		Sample #4		Sample #5	
		Pre May-95	Post Oct-96	Pre May-95	Post Oct-96	Pre May-95	Post Oct-96	Pre May-95	Post Oct-96	Pre May-95	Post Oct-96
Arsenic	30	< 5	7.2	8.2	5.7	5.5	6.3	6.6	7.6	< 5	6.1
Cadmium	5	< 0.4	0.4	< 0.5	0.5	< 0.3	0.4	< 0.3	0.4	< 0.5	0.4
Chromium	250	27.0	32.3	29.0	28.4	27.2	29.3	32.7	26.0	41.0	27.0
Cobalt	50	23.0	11.7	7.7	9.8	9.0	10.9	11.0	11.0	19.0	11.0
Copper	100	1120	1680	2090	1300	1760	1680	2270	1740	1720	1700
Lead	500	14.0	14.8	8.5	20.1	< 2	18.0	< 2	14.9	19.0	14.7
Mercury	2	< 0.2	0.3	< 0.1	0.3	0.0	0.3	0.0	0.4	< 0.2	0.5
Molybdenum	10	< 2	1.2	1.3	1.1	< 2	1.1	< 2	1.1	< 2	1.3
Nickel	100	22.0	19.5	11.0	19.6	12.0	18.7	15.0	17.0	24.0	18.1
Selenium	3	0.5	0.6	0.3	0.7	0.2	0.7	0.2	1.0	0.5	0.6
Zinc	500	98.0	72.2	56.0	79.7	47.8	75.8	52.1	70.9	88.0	70.4
pH		7.8	7.3	8.5	7.3	8.4	7.3	8.4	7.1	8.2	7.5

Over time we are confident the newly established vegetation at Granby tailings will prove to be self sustaining. Vegetation on the demonstration plots has maintained highly productive yields for five seasons now, despite heavy annual spring cattle grazing and summer drought conditions. The successful reclamation of the Granby tailings has encouraged the Princeton Golf Course to lease the land from the Town and this once barren eyesore will soon become a valued piece of real estate (Figure 2).

The final operations on Granby tailings will be completed in the spring of 1998. This will involve reapplication of biosolids to areas of the tailings that were damaged by off road vehicles before vegetation establishment and implementation of a weed control program. A light topdress fertilizer application of biosolids is also planned to provide a final boost to the site's nutrients reserves.

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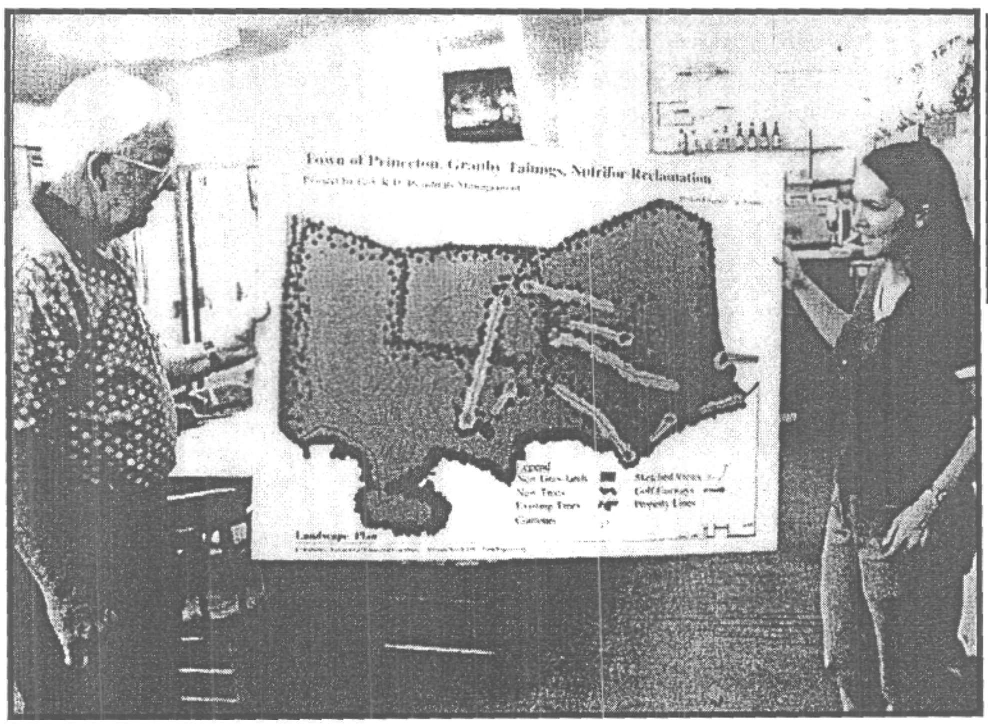
Figure 2: Newspaper photo from the Similkameen Spotlight, Wednesday July 23, 1997, Page B3.



Laurie Currie (R) shows Leah Taylor the design layout of the nine-hole expansion to the Princeton Golf Course.

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