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Our file: 2490

March 12, 2003

Regional District of Nanaimo
Environmental Services
P.O. Box 40
Lantzville, B.C.
V2P 1S6

Attention: Mr. Dennis Trudeau, Manager - Liquid Waste

Dear Sirs:

Re: Hydrogeological Assessment of Land Application of Biosolids
Malaspina University-College Forest, Nanaimo, B.C.

As requested, Piteau Associates Engineering Ltd. (Piteau) conducted an assessment of the potential impact that land application of biosolids would have on local groundwater supplies, with particular reference to the impact on Lantzville's Harby Road well-field.

PROPOSED WORK PLAN

As set out in a letter dated February 5, 2003 this assessment was carried out by Allan Dakin, P.Eng., (the writer) a senior hydrogeologist with Piteau, and involved the following:

1. Review of reports on local area hydrogeology and surface drainage network (see list of references).

2. Review of information on the test plot applications and details of the proposed biosolids land application project.

3. A visit to the site to examine: representative land application areas, geologic exposures, existing vegetation, shallow soils and surface drainage features.

4. Review of information on existing biosolids land application projects in other areas, particularly those located in British Columbia.

5. Preparation of a summary report for the Regional District of Nanaimo (RDN).

PROPOSED BIOSOLIDS APPLICATION SITE

The Malaspina University-College (Malaspina) proposes to discharge biosolids onto two areas located in the Malcolm Knapp Research Forest (the Forest) near Nanaimo. This forest is located on an elevated plateau in rolling hill country, about 4 km west of Nanaimo and 4.5 km south of the industrial area of Lantzville. The two proposed biosolids application areas are indicated as Units 1 and 2 (yellow areas) on Figs. 1 and 2 (Application Units). According to the two Land Application Plans (see Appendix A), both 7.8 ha units have second growth forest cover, with mixes of Douglas fir, Red Cedar and Lodgepole pine. Units 2 and 1 have trees ranging up to 6 and 41 years old, respectively. The understory vegetation includes salal, Oregon-grape and blackberry

The topography within the Application Units has been classified as gently undulating, and elevations range from about 350 to 380m above sea level (m-asl). The Application Units are located just east of a north-south oriented watershed divide (see red line on Fig. 2) and hence runoff from the Application Units flows eastwards, and discharges into Stump, Repair and Flynnfall Creeks, which discharge into Benson Creek and then into Brannen Lake. There are no perennial stream channels located within the Application Units. The nearest reach of perennial stream is located in Benson Creek, just east of the Flynnfall Creek confluence, which is about 2km from the nearest Unit. As set out in the BC Organic Matter Recycling Regulation (OMRR) (BC Government, 2002), no application of biosolids will be permitted within a 30m distance from any drainage channels, including ephemeral channels. As set out in Appendix A, the proposed application areas within each Unit allow for this constraint.

REGIONAL GEOLOGY AND SOILS

The regional bedrock geology was mapped by Muller (1977) as a combination of Nanaimo Group sedimentary rocks of Cretaceous age and Karmutsen volcanic rocks of middle to upper Triassic age. As indicated on Fig. 1, the bedrock located under the Application Units is Haslam Formation (Unit uKh), which consists of shale, siltstone and fine sandstone. Outcrops of this type of rock are visible in road cuts along Weigles Road and in the quarry located I km southeast of the Application Units.

Northwest-southeast trending faults are mapped along creek valleys located northeast and southwest of the Application Units. Southwest of the Application Units two northeast/southwest trending faults are mapped through the Brannen Lake lowlands. Similar faults are mapped throughout many parts of Vancouver Island and the Gulf Islands. The coal bearing unit is the Comox Formation (Unit uKc), which is located south and east of the biosolids Application Units. According to Gartner Lee (1999) the Composite Plan of the Nanaimo Coal Field Workings are located west of any historical underground coal mine workings.

The regional surficial geology mapping (Halstead, 1963) shows that the sediments below the Application Units are mapped as a thin (less than 1.5m thick) veneer of ground moraine deposits, consisting of glacial till, lenses of gravel, sand and silt overlying bedrock.

The glacial till was deposited during the last major ice sheet advance. During the retreat of the glacial ice the sea level rose 150m higher than its present level, and glaciomarine deposits were deposited in the areas located below this elevation, north and east of the Application Units. These are represented as the multi-coloured units mapped on Fig. 1. A typical profile of this geologic sequence along the east coast of Vancouver Island, is indicated on right side of Fig. 3.

Bedrock and soil conditions were assessed as part of a terrain analysis for a proposed municipal landfill site (Gartner Lee, 1999). This included both air photo interpretation and digging test pits. Approximate locations of nine test pits that were dug under Gartner Lee's supervision are indicated on Fig. 2. The logs of these test pits and observations on site confirm that sediments located under the Application Units typically consists of a thin veneer (less than 1.5m thick) of loose weathered glacial till consisting of silt sand and gravel. A similar result was observed in two test pits that were dug in the two Application Units, under the supervision of Malaspina College (see Photos 3 and 4). While on site the writer observed that there were relatively few bedrock outcrops in the area. The lack of bedrock outcrops is likely a result of the combined effects of erosion resistant soil, moderate soil drainage capacity and subdued topographic relief.

Soils testing carried out by Malaspina indicated that local soils consisted of an ortho dystric brunisol which had a thin (less than 20mm thick) organic surface layer, consisting mostly of coniferous twigs and leaves. From a forestry point of view, the soils are of low productivity, as they are nutritionally impoverished, thin and well drained.

REGIONAL HYDROGEOLOGY AND GROUNDWATER RESOURCES

Whole detailed hydrogeologic assessments involving drilling and hydraulic testing have not been conducted at the site, the conditions below the two Application Units and surrounding areas can reliably be postulated from available published information and experience at sites with similar geology and terrain.

Groundwater flows from areas of high hydraulic potential head (upland recharge areas) to areas of low potential hydraulic head (lowland discharge areas). The Application Units are located in an uplands recharge area, and infiltrating precipitation will recharge the groundwater flow system during wet weather in the late fall and winter periods. As indicated by Gartner Lee (1999) the groundwater table generally rises during the winter and gradually declines though the summer, until the rains begin again in October or November. Generally the lowest groundwater levels occur in September. Relatively dry conditions were observed by the author during a site visit in February 2003 (see Photos 1 to 4).

Once it has seeped below the plant and tree root zone, groundwater typically flows along the surface of the bedrock until it reaches interconnected fractures in the bedrock. Some of the water may discharge in nearby stream channels, but most will likely seep into fractured bedrock below. Permeable fracture and bedding planes are moderately frequent in sedimentary formations, but less so in the underlying Karmutsen volcanic bedrock.

Regional groundwater flow systems generally reflect and coincide with surface watersheds, with groundwater recharge occurring in the upland areas and discharges occurring in the lowland areas that have perennial creeks and rivers. The writer agrees with Gartner Lee's (1999) conclusion that in this area, it is reasonable to assume that groundwater flow from the upland area, where the Application Units are located, will be eastwards toward the ephemeral reaches of Benson and possibly Caillet Creeks. These both discharge into Brannen Lake.

A piped municipal water service is available within the City of Nanaimo City Limits, about 3.5 km to the east of the two Application Units. The Lantzville improvement District, north and east of the site, is partially serviced with a water system that relies on groundwater wells. The system includes five production wells (Harby Road Well Field) that tap the Quadra Sand Aquifer and have a combined rated capacity of about 1,600m^3/day (EBA, 2002). This system services 920 of the 1480 properties in the Lantzville Improvement District. The remaining 560 properties are on private wells. The properties located along the west, and southwest side of Brannen Lake are the closest properties to the Application Units (2.5 km away). However, these properties and their wells lie just outside the Lantzville District boundary (see Fig. 2).

Quadra Sand (Unit Qgls on Fig 1) and associated coarse-grained sediments are considered to be the principal aquifer in Lantzville and the surrounding area. As indicated in EBA (2002), while there is some groundwater discharge from bedrock into this aquifer, most of the recharge comes from either infiltration from direct precipitation, or seepage from overlying streams.

Based on a review of BC Ministry of Water, Land and Air Protection well records, there are 12 domestic wells in the vicinity of Brannen Lake. Of these, about 50% are completed in shallow surficial aquifers (likely Quadra Sand) and the rest in fractured bedrock. However, it should be noted that the BC Government water well record is based on information provided on a voluntary basis, and hence is never complete.

PREPARATION OF BIOSOLIDS

Biosolids are a municipal sewage sludge that has been sufficiently treated through stabilization processes to reduce pathogen densities, smell, and vector attraction, such that it meets the requirements of the OMRR and can be beneficially recycled as a fertilizer or soil amendment.

The treatment processes used include: anaerobic digestion, aerobic digestion, chemical stabilization, composting, heat treatment, disinfection, and lagooning. Anaerobic digestion is the most common method used in BC and is the method used at the RDN's waste water treatment plant. This method involves the biological degradation of organic matter in the absence of free oxygen. This process results in the conversion of readily degradable organic matter into carbon dioxide, methane, hydrogen sulphide and water, leaving a biologically stable residue. A considerable reduction in the number of bacteria occurs during the digestion process.

The process involves removing sludge from the sedimentation tanks and pumping it into a closed vessel called a digester. Within the digester the sludge is mixed, heated and held for 20 to 60 days. After digestion the biosolids are dewatered to transform them from a fluid sludge to a damp solid, or dewatered 'cake' (see Photo 5).

LAND APPLICATION OF BIOSOLIDS

Land application of biosolids of various types has been practiced for thousands of years. Problems started to develop with this type of land fertilization in the middle of the last century when agronomic application rates were exceeded and/or large portions of the waste water came from industries discharging metal wastes. The present day source control measures that have been implemented in cities such as Nanaimo have significantly reduced toxic compounds in the sludge, and scientifically-backed guidelines are now used to ensure agronomic application rates and methodologies.

Some scientists once hypothesized that as organic matter that grew up on biosolids decomposed, trace elements that it had absorbed would be released into more soluble forms and would result in increased uptake by plants from biosolids. Recent results of new long term studies do not show that this is occurring.

In the northwest states of the USA, biosolids are typically either applied to land or placed in a municipal landfill. With high landfill discharge fees, about 90% of this material is now being applied to land. A similar trend is happening in many parts of Canada, including British Columbia. Research has shown that forestry reclamation and nonfood chain crops (cotton, hay, etc.) are excellent uses for biosolids. Research conducted in the Malaspina Forest and in many other parts of the world has shown that the application of biosolids results in improved tree growth, and if properly applied, it will not have an impact on local area water quality.

According to McDougall et. al. (2002), when biosolids are applied at the agronomic rate at the appropriate time of year, there should not be any impact on groundwater quality. This statement is consistent with the conclusion that Epstein (2003) reached after reviewing many hundreds of project studies and carrying out some of his own research. He states that "Trace elements from land-applied biosolids do not appear to move through the soil profile and essentially remain in the top 30 cm. This greatly reduces the potential heavy metals to move through the soil into groundwater".

MALASPINA RESEARCH BIOSOLIDS RESEARCH PROJECT

During the period August 13, 1992 and October 31, 1992 about 600 dry tonnes of biosolids were transported to the research site, mixed with water to make a slurry and then sprayed in selected areas of the Research Forest. The biosolids that were applied in 1992 came from both Greater Vancouver Regional District's Annacis Island treatment plants (83%) and from the RDN's Water Pollution Control Center. The biosolids typically left the treatment plant in a semi-solid form (see Photo 5) where the weight percent of solid organic matter was about 25%. One-third of the biosolids (200 dry tonnes) was mixed at the site and applied as a slurry with a 10% solids content and the remaining two-thirds was applied directly to the forest.

The monitoring program included:

- Water quality sampling in ephemeral creeks.
- Collection samples of mineral soils and analyzing metals and nutrient content.
- Periphyton sampling from one ephemeral creek station.
- Water quality in five local area water supply wells (four of which are named on Fig. 2).

The results confirmed an increase in tree growth with no impact on the local surface and groundwater quality.

CONCLUSIONS

1. The soils located below the two Application Unit areas consist of relatively well drained sediments with a moderate silt content that is typically covered by a thin organic layer. These factors, coupled with the known characteristics of biosolids leachate, lead to the conclusion that most (99.9%) of the contaminants that potentially could leach from the biosolids would be removed while flowing through the first few centimeters of the soil profile.

2. As the depth to the water table in the fractured sedimentary bedrock below the Application Units is likely several tens of metres below ground surface, there is an opportunity for further renovation as the water percolates through this unsaturated zone.

3. Once in the fractured bedrock below the Application Units, groundwater will likely migrate towards one of the two northwest to southeast oriented fault zones, and/or related fractures. From there it is judged that the groundwater will flow towards, and discharge into, the ephemeral portion of Benson Creek.

4. The nearest known residence with a water supply well is located about 2.5 km east of the nearest Application Unit. Groundwater moves very slowly, with an estimated travel time of between 5 to 50 years for the 2.5 km distance in the local bedrock; hence there is a lot of time for natural biological and geochemical processes to remove all traces of any biosolids leachate that somehow seeped into the fractured bedrock.

5. Biosolids are an organic waste that has been subjected to a moderate degree of treatment, and as such the leachate generated from this material is relatively weak. In the writer's opinion, there is more likelihood of contamination of an aquifer from land application of animal manure, or from the discharge of a small subdivision with septic tanks, than from the application of biosolids.

6. It is concluded that the proposed application of biosolids at the two Application Units in the Malaspina Forest will not have any impact on groundwater quality in any of the wells located in the region. This includes the Harby Road well field that is located 4.5 km north of the nearest unit in another watershed, and any new wells located within 100m of the two Application Units.

I trust that this is sufficient for your present purposes.

Yours very truly,

PITEAU ASSOCIATES ENGINEERING LTD.

R. Allan Dakin, P.Eng.

MDM/jcw
Att.

RAD Mar/12/03

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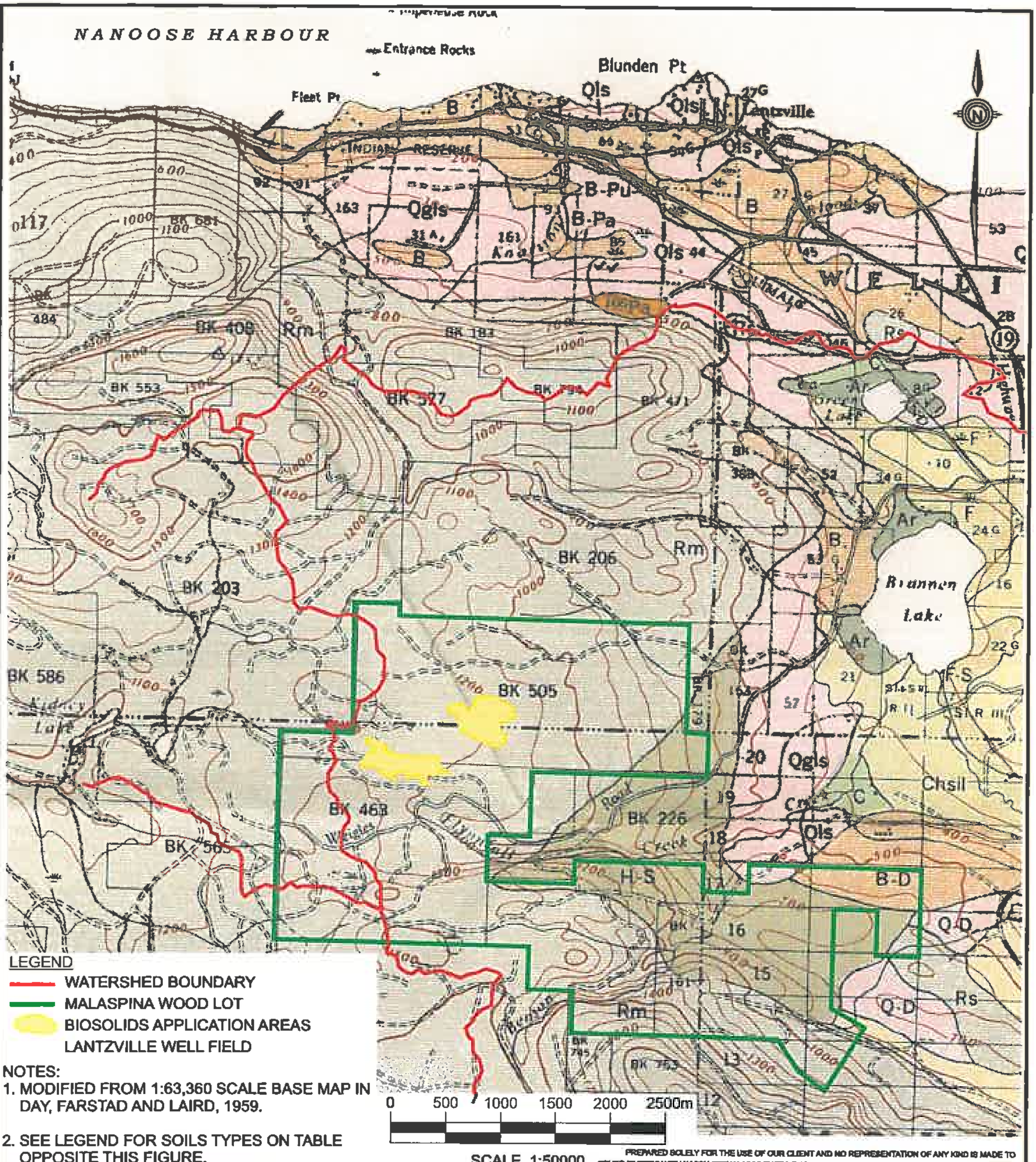
FIGURES



DWG NUMBER: 2490-002.CDR

NOTES:

1. MODIFIED FROM 1:63,360 SCALE BASE MAP IN DAY, FARSTAD AND LAIRD, 1959.
2. SEE LEGEND FOR SOILS TYPES ON TABLE OPPOSITE THIS FIGURE.

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REGIONAL DISTRICT OF NANAIMO

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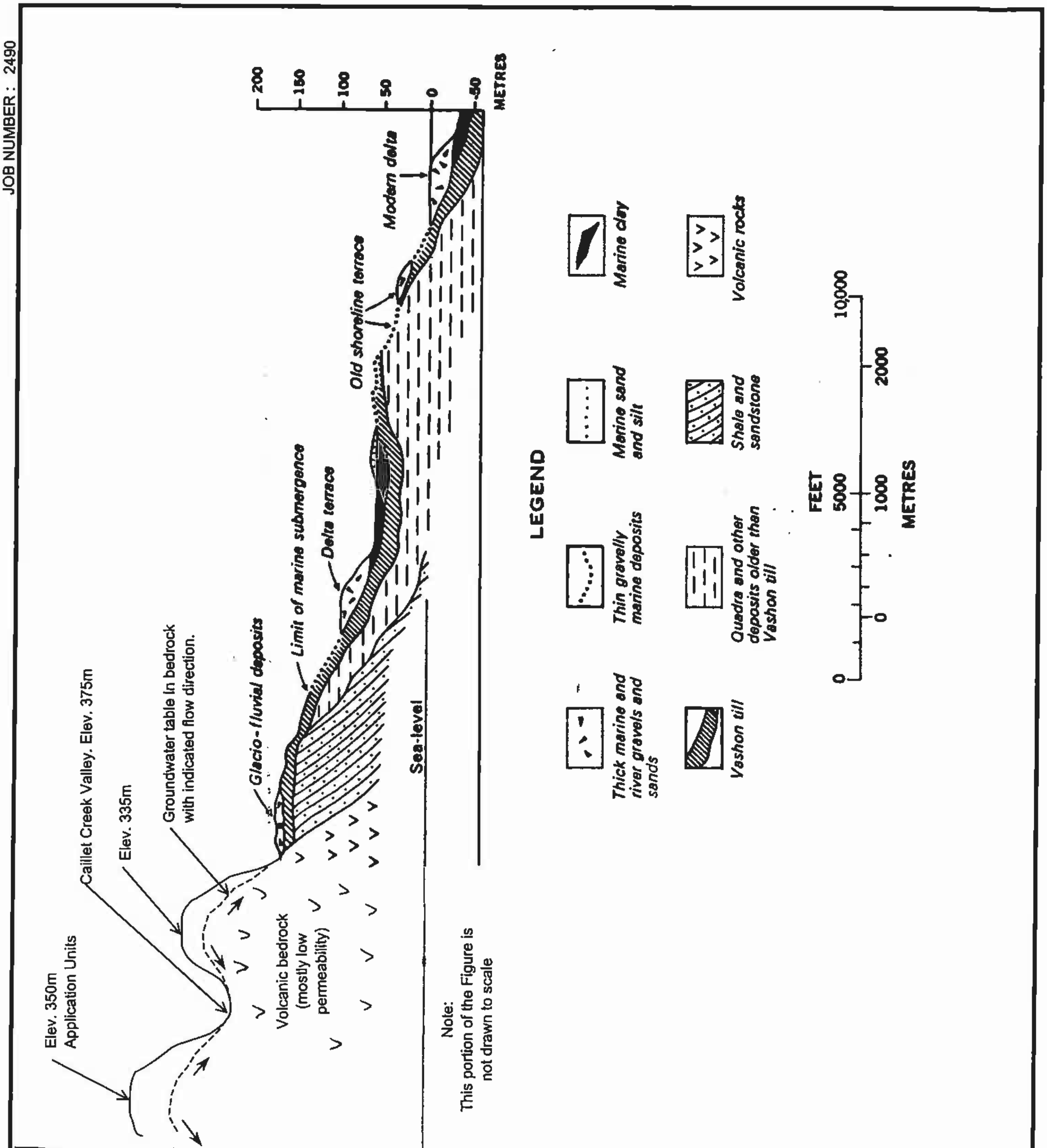
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

HYDROGEOLOGIC ASSESSMENT OF IMPACT OF PROPOSED MALASPINA BIOSOLIDS PROJECT NANAIMO, B.C.	AREA SOILS MAP	BY: RAD/cz	DATE: FEB. 03
		APPROVED:	FIG: 1



NOTES
1) Modified from Halstead & Treichel, 1966

REGIONAL DISTRICT OF NANAIMO

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HYDROGEOLOGIC ASSESSMENT OF POTENTIAL IMPACT OF PROPOSED MALASPINA BIOSOLIDS PROJECT, NANAIMO, B.C.

TYPICAL GEOLOGIC PROFILE ALONG THE EAST COAST OF VANCOUVER ISLAND

Drawn:	Date Feb. 2003
Approved:	Fig. 3

File.2009 2490-Figs.xls Fig. 1 11-03-03 9.16 AM

APPENDIX A

BIOSOLIDS LAND APPLICATION PLANS

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit One

DRAFT

Date:	November 1, 2002
Biosolids production facility:	Regional District of Nanaimo Greater Nanaimo Water Pollution Control Centre 6300 Hammond Bay Road Nanaimo, British Columbia V9T 6N2 Attn: Sean De Pol Biosolids Project Manager Phone: (250) 390-6560 Fax: (250) 390-1542
Owner of proposed application site:	TimberWest Forest Corporation 3-4890 Rutherford Road Nanaimo, B.C. V9T 4Z4 Attn:Yvonne Deibert Propert Administrator Phone: (250) 729-3708 Fax: (250) 729-3763
Proposed start of application:	September 15, 2003
Time period of application:	30 days
Location and boundaries of application:	Polygon 219 Malaspina University-College Forest WL 020 Nanaimo, BC Block 463, Dunsmuir Land District
Plan prepared by:	Paul Lucas, RPF Malaspina University-College 900 Fifth Street V9R 5S5 Phone: (250) 753-3245 local 2232 Fax: (250) 740-6482

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit One

Summary

Malaspina University-College Forest (WL020) manages over 1,300 ha of forestlands, 12 kilometres northwest of Nanaimo, on the lower slopes of Mt Benson. As part of an operational fertilization program, Malaspina University-College Forest proposes to transport biosolids from the Regional District of Nanaimo's Hammond Bay Waste Water Treatment Plant (HBWWTP) and produce an Class B compost at on site facility. The compost will be used in an operational fertilization program on poor and low productivity forest stands. The use of biosolids as fertilizer was done in a 1992 forest fertilization project and is a stated objective in Malaspina's Management Plan # 2 1994-1998 and Management Plan #3 2001-2005. The site vegetation and soils were assessed, and samples of the soil collected and analyzed for fertility and trace element concentration. Concentrations of nitrogen and phosphorus were very low. The soils have a low organic matter content. Class B compost are to be surface applied in mid-September, 2003 to forest stand by high speed side throw discharge spreader. The calculated application rate is 17.1 dry tonne/ha, providing 855 kg N/ha. Special site management considerations have been identified with respect to biosolids stockpiles, transportation and application. Calculation of the trace element concentrations in the soil suggests that no element will exceed the standards set out in the Organic Matter Recycling Regulation. No post application environmental monitoring program is to be conducted.

Objective

Unit One, a stand management unit located about 1.1 kilometers from the end of pavement on Weigles Road. The stand, bisected by Cavey Road, is proposed to be fertilized with an agronomic application rate of biosolids to provide the nitrogen that the trees and understory vegetation require to optimize growth, while ensuring no adverse environmental impacts.

Site Characteristics

Unit One is a 7.8 hectare mixed Douglas fir/Lodgepole pine stand approximately 41 years old. year old year old saplings. This stand was juvenile spaced in 1999 favouring the largest , best spaced Douglas fir as leave trees. A map of the application area is found in Appendix 1. No portion of the site is located within 30 m of a surface water body. This management polygon is completely enclosed within other stand management polygons and is located behind locked gate, thereby restricting public access.

The trees are spaced to a density of 1,560 stems per hectare and when combined with roadside pruning provides ease of access to the stand for fertilization. The topography is described as gently undulating. There is no appreciable slope to the land in any specific direction. The understory vegetation is described in detail below Previous stand records indicate that the stand has not been fertilized. Due to the size of the trees, a fertilization regime in this system will be designed to significantly increase the rate of diameter growth and reduce rotation age. The reduced rotation age will see a complimentary reduction in risk of catastrophic loss due to forest fire

Vegetation

The vegetation of the area is dominated by the overstory of Douglas fir (*Pseudotsuga menzesii*) and lodgepole pine.(*Pinus contorta*) with an average height of 12.7 metres.. Significant components of the understory vegetation include:

Salal (*Gaultheria shallon*): an shade intolerant, evergreen shrub that has been shown to compete for moisture and nutrients, effectively reducing growth of crop (Douglas fir) trees. With an average height of 75 centimeters salal forms a uniformly continuous dense mat of competitive vegetation throughout Polygon 219. This shrub is indicative of disturbed and early seral or secondary succession. Previous experience gained from the 1992 biosolids fertilization project shows that salal growth is not enhanced as a results of nitrogen input from biosolids. It appears that the increased shade from the crowns of fertilized crop trees is reducing the vigour and growth rate of salal.

Oregon-Grape *(Mahonia aquifolium)*: a shade tolerant to intolerant evergreen shrub that occurs on dry, low to medium productivity soils. This shrub is present throughout the forest stand in scattered associations with salal.

Trailing Blackberry *(Rubus ursinus)*: again, a shade tolerant to intolerant deciduous shrub that occurs on dry, medium productivity soils. This shrub is common on open forests at low elevations.

Other species include the oval leafed mitrewort *(Mitela ovalis*), red huckleberry (*Vaaccinium parvifolium*) and bear berry (*Actostaphylos uva-ursi*)

Soils

The bedrock within this polygon is of sedimentary origin, varying sequences of conglomerate, shale and sandstone overlying volcanics. A thin, (often less than 1 m) veneer of morainal deposits, including till and lenses of gravel silts exist. Soil type is ortho dystric brunisol having a a very thin organic surface layer (less than 2 cm thick) consisting of mostly coniferous leaves and twigs. Soils are of low productivity, being impoverished nutritionally, thin and well drained.

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit One

Average nutrient concentrations in the soils in Unit One are found in the table below. The * indicates that this is an estimate to be confirmed by lab tests at a later date.

Mineral Soil Analysis

Nutrient	Concentration (ug/g)
Ammonium	<1
Nitrate	<.4
Phosphate	69
Potassium	114
Arsenic	<10
Cadmium	<1
Chromium	20
Cobalt	12
Copper	16
Lead	32
Mercury	.05
Molybdenum	<4
Nickel	<2
Selenium	<3
Zinc	78
pH	4.4

Concentrations of nitrogen in the forms of ammonium and nitrate are very, severly deficient. Unit T soils are also low in organic matter.

Biosolids Information

The biosolids from Hammond Bay WWTP are produced from a anaerobic digestion facility. The pathogen reduction process employed at this WWTP produces a Class B biosolids with fecal coliform levels greater than 1000 MPN per gram biosolids. The moving average of biosolids quality as determined from monthly sampling (n=8) for eight months is found in the table below.

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit One

Biosolids/Compost Analysis

Trace elements, Nutrients, and Bacteriology (mg/kg except where noted)	Mean (n=8)
Arsenic	3.02
Cadmium	4.0
Chromium	55.7
Cobalt	5.12
Copper	983
Lead	116
Mercury	7.88
Molybdenum	9.5
Nickel	33
Selenium	3.95
Zinc	747
Total Solids (%)	27.8
TKN (%)	3.03
Total-Phosphorous	15,875
Ammonia distillation	6.937*
Total Potassium	29.000*
Fecal Coliform (MPN method/g dry weight)	1.134*

* Figures are estimates.

Reviewing the monthly analysis, there is little variation in biosolids quality, and the average the mean values in the table above are used in the determination of trace element additions and the application rate.

Proposed Application Rate

Design values used in the calculation of the biosolids application rate reflect the nitrogen demand by the crop trees and minor vegetation. The estimated nitrogen uptake and transformations are found in the table below.

Application Rate Data

Nitrogen Uptake - Trees (kg/ha)	110
Nitrogen Uptake - Understory (kg/ha	45
Volatilization (%)	20
Denitrification (%)	10
Immobilization (kg/ha)	175
Mineralization Rate (%)	30
Total Nitrogen Required (kg/ha)	855
Application Rate (Dry Tonnes/ha)	17.1
Application Rate (Bulk Tonnes per ha)	68.4

The mineralization rate of the compost was determined from research and experience gained in Malaspina University-College Forests' 1992 biosolids project and from the Best Management Practices Guidelines for Land Application Of Managed Organic Material (June 2002).

Application Method and Timing

Biosolids from Hammond Bay WWTP will be transported and stored/composted on Malaspina University-College Forest site. Storage/composting sites will be located on high ground a minimum of 400 m from any surface water body. Application of compost will be completed utilizing a truck/forwarder mounted side discharge aero-spreader in mid-September, 2003. Compost will be surface applied and not incorporated, due to the existing root structure of the trees. Applications will be completed and all equipment removed from the stand prior to October 15, 2003.

Special Site Management Considerations

The application is scheduled to occur in the fall, when the roots of the Douglas fir will be actively growing . The roots will take up and store nutrients for upcoming spring budbreak. This result was confirmed during the 1992 biosolids project which took place during the same time period.

The active portion of the root network (the area of the root biomass that will contribute the most to nutrient uptake) in these coniferous stands occurs around the canopy drip line. As the stand is close to crown closure the application of compost will be made in a relatively uniform manner as the crop tree roots exist throughout entire stand. If a truck is utilized as the prime mover than the application will be made uniformly for 30 metres on either side of Cavey Road which bisects the forest stand.

Prior to compost application area will be surveyed for mountain bike and hiking trails. While no significant adverse environmental impact will occur from the application of compost to these areas. best management practices suggest no application be made to these areas. Mountain bike and hiking trails will be identified prior to application and all trails leading into Unit One will have appropriate signage erected.

Access to Unit One is via Weigles Road. Malaspina University-College Forest has received the necessary approval from Ministry of Forests for the composting facility and for the fertilization of Unit One. Composting facility plans and the Land Application Plan have been reviewed by Fisheries and Oceans Canada staff and they have indicated that they expect no impacts on streams.. Truck/forwarder transporting and applying compost from the composting facility will be do so on private roads behind gates. There are no creeks or open bodies of water along the route between compost site and Unit One.

Water Resource

The nearest creek, Flynnfall Creek, is located 150 metres to the south of Unit One. Unit One is located in the Brannen Lake watershed. This watershed is not used as a community water supply under the Safe Drinking Water Regulation, BC Reg 230/92. The nearest residential water well 3.1 kilometres to the east at 6292 Duomont Road.

Application Rate Data

Criteria	Units	Value		Calculation	Comments
Initial Ammonia/Ammonium	%	1		n/a	Obtained from compost analysis
Initial Nitrate Nitrite	%	0		n/a	Obtained from compost analysis
Organic Nitrogen	%	4		n/a	Obtained from compost analysis
Solids	%	25		n/a	Obtained from compost analysis
Nitrogen Transformations					
Mineralization Rate	%	10		n/a	Obtained from compost analysis
Volatilization Losses	%	50		n/a	(Best Management Practices)
Denitrification Losses	%	10		n/a	(Best Management Practices)
Nitrogen Uptake/Storage					
Tree Uptake	kg N ha^{-1} yr^{-1}	110		n/a	Professional knowledge - 1992 project
Understory Uptake	kg N ha^{-1} yr^{-1}	45		n/a	Professional knowledge - 1992 project
Soil Immobilization	kg N ha^{-1} yr^{-1}	175		n/a	Professional knowledge - 1992 project
Available N required	**kg N ha^{-1}**		**325**		Sum of nitrogen uptake and storage
Nitrogen Transformations					
Initial Ammonia/Ammonium	kg dt^{-1}	10		(1/100)*1000 kg dt^{-1}	Calculate initial concentration per tonne
Volatilization Losses	kg dt^{-1}	-2		(20/100)*10 kg dt^{-1}	Calculate volatile nitrogen losses
Mineralization Additions	kg dt^{-1}	12		(4/100)*(30/100)*1000 kg dt^{-1}	Calculate mineral additions
Ammonia/Ammonium Total:	kg dt^{-1}		20		Sum of ammonia/ammonium transformations
Denitrification Losses	kg dt^{-1}	1		(10/100)*10 kg dt^{-1}	Calculate volatile nitrogen losses
Net Available N	**kg dt^{-1}**		19		Calculate net N available per tonne applied
Application Rate	**dt ha^{-1}**		**17.1**	325/19	Tonnes required to meet nitrogen needs
Application Rate	**wt ha^{-1}**		**68.4**	17.1/(25/100)	Convert dry tonnes to wet tonnes
Application Rate	**kg ha^{-1}**		**855**	17.1(1+0+4)*10	Application rate by nitrogen content

Calculation of compostagronomic application rate for forest fertilization

The adjacent property owner's to the east of Malaspina University-College Forest, Mr. Tom Gibson from Dunsmuir Quarries, Mr. Bryan Gregson owner of Lot 179 and Mr Eric Heikaala owner of WL 012 have expressed written support for the project.

Post Application Site Monitoring

No environmental post application site monitoring is proposed. Following the biosolids application the polygon boundary will be walked to ensure the application has not extended into any adjacent polygons. Trees will be measured periodically to insure optimum growth rates are maintained and to evaluate if forest stand requires additional treatments. Signs will be posted and maintained at key access points to Unit One, informing any visitors of the biosolids fertilization activities.

Estimated Trace Element Concentrations

The following table gives the pre-application amounts of trace elements in soil and biosolids in mg/kg and kg/hectare. The trace elements in the soil following application meet standards set out in the Organic Matter Recycling Regulation.

Trace Element Data

Trace Element	Concentration in Biolsolids (mg/kg)	Addition to Soil (kg/ha)	Pre-Application Soil Concentration (mg/kg)	Pre-Application Soil Concentration (kg/ha)	Estimated Post Soil Concentration (kg/ha)	Estimated Post Soil Concentration (mg/kg)
Arsenic	3.02	.0516	<10	<21	<21.051	<10.02
Cadmium	4.0	.0684	<1	<2.1	<2.1684	<1.032
Chromium	55.7	.9524	20	42	42..952	20.453
Cobalt	5.12	.0875	12	25.2	25.287	12.041
Copper	983	16.80	16	70.5	87.30	41.571
Lead	116	1.983	32	67.2	69.183	32.944
Mercury	7.88	0.134	0.05	.105	.1847	.0879
Molybdenum	9.5	.162	<4	<8.4	<8.562	<4.077
Nickel	33	.564	<2	<4.2	<4.764	<2.268
Selenium	3.95	.067	<3	<6.3	<6.367	<3.031
Zinc	747	12.773	78	163.8	176.57	84.080

Application Rate: 17.1 dt/ha

Soil Bulk Density: 1400 kg/m^3

Soil Depth: 0.15 m

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit One

The estimated post soil concentrations are calculated based on the assumption there is no change in bulk density following application, and that the biosolids are incorporated into the top 15 cm of the soil. In the application proposed in this Land Application Plan, the compost will not be incorporated, but remain on the surface.

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MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit Two

DRAFT

Date:	November 1, 2002
Biosolids production facility:	Regional District of Nanaimo Greater Nanaimo Water Pollution Control Centre 6300 Hammond Bay Road Nanaimo, British Columbia V9T 6N2 Attn: Sean De Pol Biosolids Project Manager Phone: (250) 390-6560 Fax: (250) 390-1542
Owner of proposed application site:	TimberWest Forest Corporation 3-4890 Rutherford Road Nanaimo, B.C. V9T 4Z4 Attn: Yvonne Deibert Propert Administrator Phone: (250) 729-3708 Fax: (250) 729-3763
Proposed start of application:	September 15, 2003
Time period of application:	30 days
Location and boundaries of application:	Polygon 218 Malaspina University-College Forest WL 020 Nanaimo, BC Block 463, Dunsmuir Land District
Plan prepared by:	Paul Lucas, RPF Malaspina University-College 900 Fifth Street V9R 5S5 Phone: (250) 753-3245 local 2232 Fax: (250) 740-6482

MALASPINA UNIVERSITY-COLLEGE (WL 020)
LAND APPLICATION PLAN
Unit Two

Summary

Malaspina University-College Forest (WL020) manages over 1,300 ha of forestlands, 12 kilometres northwest of Nanaimo, on the lower slopes of Mt Benson. As part of an operational fertilization program, Malaspina University-College Forest proposes to transport biosolids from the Regional District of Nanaimo's Hammond Bay Waste Water Treatment Plant (HBWWTP) and produce an Class B compost at on site facility. The compost will be used in an operational fertilization program on poor and low productivity forest stands. The use of biosolids as fertilizer was done in a 1992 forest fertilization project and is a stated objective in Malaspina's Management Plan # 2 1994-1998 and Management Plan #3 2001-2005. The site vegetation and soils were assessed, and samples of the soil collected and analyzed for fertility and trace element concentration. Concentrations of nitrogen and phosphorus were very low. The soils have a low organic matter content. Class B compost are to be surface applied in mid-September, 2003 to forest stand by high speed side throw discharge spreader. The calculated application rate is 17.1 dry tonne/ha, providing 855 kg N/ha. Special site management considerations have been identified with respect to biosolids stockpiles, transportation and application. Calculation of the trace element concentrations in the soil suggests that no element will exceed the standards set out in the Organic Matter Recycling Regulation. No post application environmental monitoring program is to be conducted.

Objective

Unit Two, a stand management unit located about 1.1 kilometers from the end of pavement on Weigles Road. The stand, accessed via Cavey Road, is proposed to be fertilized with an agronomic application rate of biosolids to provide the nitrogen that the trees and understory vegetation require to optimize growth, while ensuring no adverse environmental impacts.

Site Characteristics

Unit Two is a 7.8 hectare mixed Douglas fir/red cedar plantation containing 6 year old year old saplings. This site was harvested in 1996 and planted in 1997. A map of the application area is found in Appendix 1. No portion of the site is located within 30 m of a surface water body. This management polygon is completely enclosed within other stand management polygons and is located behind locked gate, thereby restricting public access.

The trees are planted to a density of 1,442 stems per hectare and are an average of 1.7 metres in height allowing ease of access to the stand for fertilization. The topography is described as gently undulating. There is no appreciable slope to the land in any specific direction. The understory vegetation is described in detail below The seedlings were fertilized at time of planting with 10 gram 20-10-5 tablets. Due to the size of the trees, a fertilization regime in this system will be designed to significantly increase the rate of diameter growth and reduce rotation age. The reduced rotation age will see a complimentary reduction in risk of catastrophic loss due to forest fire

Vegetation

The vegetation of the area is dominated by six year old plantation of Douglas fir (*Pseudotsuga menzesii*) and red cedar.(*Thuja plicata*) with an average height of 1.7 metres.. Significant components of the understory vegetation include:

> Salal (*Gaultheria shallon*): an shade intolerant, evergreen shrub that has been shown to compete for moisture and nutrients, effectively reducing growth of crop (Douglas fir) trees. With an average height of 75 centimeters salal forms a uniformly continuous dense mat of competitive vegetation throughout Polygon 219. This shrub is indicative of disturbed and early seral or secondary succession. Previous experience gained from the 1992 biosolids fertilization project shows that salal growth is not enhanced as a results of nitrogen input from biosolids. It appears that the increased shade from the crowns of fertilized crop trees is reducing the vigour and growth rate of salal.
>
> Oregon-Grape *(Mahonia aquifolium)*: a shade tolerant to intolerant evergreen shrub that occurs on dry, low to medium productivity soils. This shrub is present throughout the forest stand in scattered associations with salal.
>
> Trailing Blackberry *(Rubus ursinus)*: again, a shade tolerant to intolerant deciduous shrub that occurs on dry, medium productivity soils. This shrub is common on open forests at low elevations.

The understory described above is sparse in nature, and occurs primarily around openings created through the presence of windrows or gaps. Although usually indicative of a nitrogen rich ecosystem, the spatial distribution and density do not represent the true nature of the nutrient status of the site.

Soils

The bedrock within this polygon is of sedimentary origin, varying sequences of conglomerate, shale and sandstone overlying volcanics. A veneer of morainal deposits, (approximately 1 m in depth) , including till and lenses of gravel silts exist. Soil type is ortho dystric brunisol having a a very thin organic surface layer (less than 2 cm thick) consisting of mostly coniferous leaves and twigs. Soils are of low productivity, being impoverished nutritionally, thin and well drained.

Average nutrient concentrations in the mineral soils in Unit Two are found in the table below.

Mineral Soil Analysis –

Nutrient	Concentration (ug/g)
Ammonium	<1
Nitrate	<.4
Phosphate	1820
Potassium	367
Arsenic	<10
Cadmium	<1
Chromium	25
Cobalt	13
Copper	31
Lead	28
Mercury	.04
Molybdenum	<4
Nickel	<2
Selenium	<3
Zinc	65
pH	4.5

Concentrations of nitrogen in the forms of ammonium and nitrate are very, severly deficient. Unit Two soils are also low in organic matter.

Biosolids Information

The biosolids from Hammond Bay WWTP are produced from a anaerobic digestion facility. The pathogen reduction process employed at this WWTP produces a Class B biosolids. The moving average of biosolids quality as determined from monthly sampling (n=8) for eight months is found in the table below.

Biosolids/Compost Analysis

Trace elements, Nutrients, and Bacteriology (mg/kg except where noted)	Mean (n=8)
Arsenic	3.02
Cadmium	4.0
Chromium	55.7
Cobalt	5.12
Copper	983
Lead	116
Mercury	7.88
Molybdenum	9.5
Nickel	33
Selenium	3.95
Zinc	747
Total Solids (%)	27.8
TKN (%)	3.03
Total-Phosphorous	15.875
Ammonia distillation	6.937*
Total Potassium	29,000*
Fecal Coliform (MPN method/g dry weight)	1,134*

* Figures are estimates.

Reviewing the monthly analysis, there is little variation in biosolids quality, and the average the mean values in the table above are used in the determination of trace element additions and the application rate.

Proposed Application Rate

Design values used in the calculation of the biosolids application rate reflect the nitrogen demand by the crop trees and minor vegetation. The estimated nitrogen uptake and transformations are found in the table below.

Application Rate Data

Nitrogen Uptake - Trees (kg/ha)	57
Nitrogen Uptake - Understory (kg/ha	35
Volatilization (%)	30
Denitrification (%)	10
Immobilization (kg/ha)	175
Mineralization Rate (%)	30
Total Nitrogen Required (kg/ha)	855
Application Rate (Dry Tonnes/ha)	17.1
Application Rate (Bulk Tonnes per ha)	68.4

The mineralization rate of the compost was determined from research and experience gained in Malaspina University-College Forests' 1992 biosolids project and from the Best Management Practices Guidelines for Land Application Of Managed Organic Material (June 2002).

Application Method and Timing

Biosolids from Hammond Bay WWTP will be transported and stored/composted on Malaspina University-College Forest site. Storage/composting sites will be located on level ground a minimum of 400 m from any surface water body. Application of compost will be completed utilizing a truck/forwarder mounted side discharge aero-spreader in mid-September. 2003. Compost will be surface applied and not incorporated, due to the existing root structure of the trees. Applications will be completed and all equipment removed from the stand prior to October 15, 2003.

Special Site Management Considerations

The application is scheduled to occur in the fall, when the roots of the Douglas fir will be actively growing . The roots will take up and store nutrients for upcoming spring budbreak. This result was confirmed during the 1992 biosolids project which took place during the same time period.

The active portion of the root network (the area of the root biomass that will contribute the most to nutrient uptake) in these coniferous stands occurs around the canopy drip line. If a truck is utilized as the prime mover than the application will be made uniformly for 30 metres on either side of Cavey Road which bisects the forest stand.

Prior to compost application area will be surveyed for mountain bike and hiking trails. While no significant adverse environmental impact will occur from the application of compost to these areas, best management practices suggest no application be made to these areas. Mountain bike and hiking trails will be identified prior to application and all trails leading into Unit One will have appropriate signage erected.

Access to Unit One is via Weigles Road. Malaspina University-College Forest has received the necessary approval from Ministry of Forests for the composting facility and for the fertilization of Unit Two. Composting facility plans and the Land Application Plan have been reviewed by Fisheries and Oceans Canada staff and they have indicated that they expect no impacts on streams. Truck/forwarder transporting and applying compost from the composting facility will be do so on private roads behind gates. There are no creeks or open bodies of water along the route between compost site and Unit Two.

Water Resource

The nearest creek, Flynnfall Creek, is located 165 metres to the south of Unit Two. Unit Two is located in the Brannen Lake watershed. This watershed is not used as a community water supply under the Safe Drinking Water Regulation, BC Reg 230/92. The nearest residential water well 2.7 kilometres to the east at 6292 Duomont Road.

Application Rate Data

Criteria	Units	Value		Calculation	Comments
Initial Ammonia/Ammonium	%	1		n/a	Obtained from compost analysis
Initial Nitrate Nitrite	%	0		n/a	Obtained from compost analysis
Organic Nitrogen	%	4		n/a	Obtained from compost analysis
Solids	%	25		n/a	Obtained from compost analysis
Nitrogen Transformations					
Mineralization Rate	%	10		n/a	Obtained from compost analysis
Volatilization Losses	%	50		n/a	(Best Management Practices)
Denitrification Losses	%	10		n/a	(Best Management Practices)
Nitrogen Uptake/Storage					
Tree Uptake	kg N ha^{-1} yr^{-1}	57		n/a	Professional knowledge - 1992 project
Understory Uptake	kg N ha^{-1} yr^{-1}	35		n/a	Professional knowledge - 1992 project
Soil Immobilization	kg N ha^{-1} yr^{-1}	175		n/a	Professional knowledge - 1992 project
Available N required	**kg N ha^{-1}**		**267**		Sum of nitrogen uptake and storage
Nitrogen Transformations					
Initial Ammonia/Ammonium	kg dt^{-1}	10		(1/100)*1000 kg dt^{-1}	Calculate initial concentration per tonne
Volatilization Losses	kg dt^{-1}	-3		(20/100)*10 kg dt^{-1}	Calculate volatile nitrogen losses
Mineralization Additions	kg dt^{-1}	12		(4/100)*(30/100)*1000 kg dt^{-1}	Calculate mineral additions
Ammonia/Ammonium Total:	kg dt^{-1}		19		Sum of ammonia/ammonium transformations
Denitrification Losses	kg dt^{-1}	1		(10/100)*10 kg dt^{-1}	Calculate volatile nitrogen losses
Net Available N	**kg dt^{-1}**		**18**		Calculate net N available per tonne applied
Application Rate	**dt ha^{-1}**		**14.8**	267/18	Tonnes required to meet nitrogen needs
Application Rate	**wt ha^{-1}**		**59.3**	14.8/(25/100)	Convert dry tonnes to wet tonnes
Application Rate	**kg ha^{-1}**		**740**	14.8(1+0+4)*10	Application rate by nitrogen content

Calculation of compostagronomic application rate for forest fertilization

The adjacent property owner's to the east of Malaspina University-College Forest, Mr. Tom Gibson from Dunsmuir Quarries, Mr. Bryan Gregson owner of Lot 179 and Mr Eric Heikaala owner of WL 012 have expressed written support for the project.

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The following table gives the pre-application amounts of trace elements in soil and biosolids in mg/kg and kg/hectare. The trace elements in the soil following application meet standards set out in the Organic Matter Recycling Regulation.

Trace Element Data

Trace Element	Concentration in Biosolids (mg/kg)	Addition to Soil (kg/ha)	Pre-Application Soil Concentration (mg/kg)	Pre-Application Soil Concentration (kg/ha)	Estimated Post Soil Concentration (kg/ha)	Estimated Post Soil Concentration (mg/kg)
Arsenic	3.02	.045	<10	<21	<21.045	<10.02
Cadmium	4.0	.059	<1	<2.1	<2.159	<10.28
Chromium	55.7	.824	25	52.5	53.324	25.39
Cobalt	5.12	.076	13	27.3	27.376	13.04
Copper	983	14.55	31	65.1	79.65	37.92
Lead	116	1.717	28	58.8	60.517	28.81
Mercury	7.88	0.117	0.04	.08	.197	.094
Molybdenum	9.5	.141	<4	<8.4	<8.541	<4.07
Nickel	33	.488	<2	<4.2	<4.688	<2.23
Selenium	3.95	.058	<3	<6.3	<6.358	<3.03
Zinc	747	11.06	65	136.5	147.556	70.26

Application Rate: 14.8 dt/ha

Soil Bulk Density: 1400 kg/m^3

Soil Depth: 0.15 m

The estimated post soil concentrations are calculated based on the assumption there is no change in bulk density following application, and that the biosolids are incorporated into the top 15 cm of the soil. In the application proposed in this Land Application Plan, the compost will not be incorporated, but remain on the surface.

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PHOTOS

Photo 1.
View of a typical forested area where Biosoilds will applied.

Photo 2.
Another view of a typical forested area where biosolids will be applied.

Photo 3.
Silty soils exposed in test pit, which overlie weather shale and siltstone bedrock (Haslam Formation).

Photo 4.
Dry silty soils excavated from test pit located in proposed biosolids application area.

Photo 5.
Close-up view of typical biosolids.