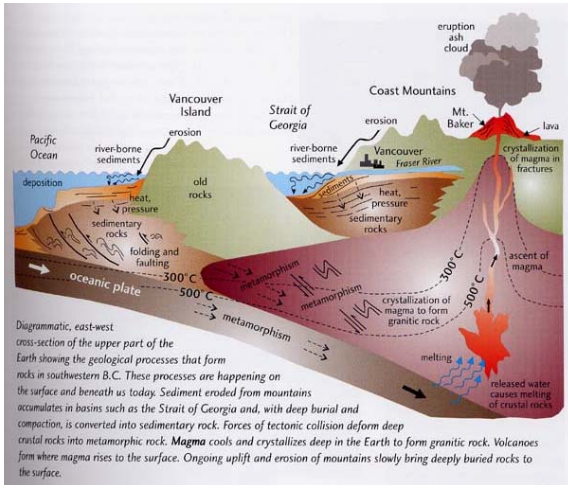
PART ONE – COMMUNITY ANALYSIS

A.1 GEOLOGY, TOPOGRAPHY AND SOIL Beryl Allen Dick

A.1.1 Geology[1]

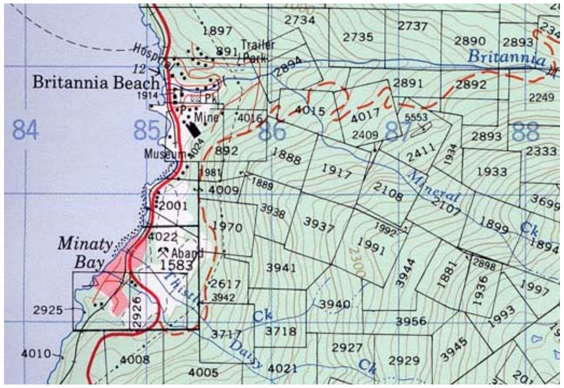
Britannia Beach is located in the Coast Mountains, 48 km. north of Vancouver, British Columbia on the shore of the fjord of Howe Sound. The Coast Mountains originated when the North American plate, floating on the Earth's mantle over-rode and collided with oceanic plates. Some crustal fragments or terranes of the oceanic plates became attached to North America. The Coast Mountains were formed by the compression folding and faulting of crustal rocks during the collision process and are a complex mosaic of terranes. Rivers, glaciers and gravity then eroded the Coast Mountains exposing granitic and metamorphic rocks. The rocks exposed at Britannia Beach are predominantly metamorphosed sedimentary and volcanic rocks. During the Pleistocene Epoch (2 million to 10,000 years ago) ice sheets covered much of British Columbia during a number of glacial cycles. During the last glaciation the Cordilleran ice sheet covered Howe Sound. The original steep-walled river valley was deepened and widened by this glacier, then flooded by the ocean when the glacier retreated. Howe Sound is a typical B.C. fjord. Britannia Beach is the site of the Britannia Mine, which operated from 1902 to 1974. The orebody lies within rock formed by volcanic eruptions on the ancient seafloor, part of an oceanic plate. The orebody of sulphide rich lenses of rock extends over 2 km. from the top of Britannia Mountain to below sea level and over 4 km. in an east-west direction. The sulphide rich rock contains copper, zinc, lead, cadmium, silver and gold.



Geologic processes forming the Coast Mountains (Clague and Turner, 2003)

A.1.2 Topography

The Britannia Beach area lies within a rugged section of the Coast Mountains with steep slopes rising to elevations of 1400 meters within a horizontal distance of 2 km.[2] Slopes adjacent to the development area average 45%. The adjacent mountains are composed primarily of fractured, metamorphosed volcanic rocks. Much of the mountainous area bordering the proposed development area is catacombed with tunnels. During the operation of Britannia Mine, a small community, Jane Camp, was built near the top of Britannia Mountain adjacent to the underground tunnels of the mine. In 1915 a rockslide slid down the steep mountainside above Jane Camp and destroyed homes and bunkhouses, killing 56 people. Geologists believe that the use of explosives for underground tunnelling contributed to the deterioration in slope stability. Geotechnical



Topography of Britannia Beach area
Contour lines: 100 feet intervals
Distance across map: 3500 meters
Dept. Energy, Mines and Resources

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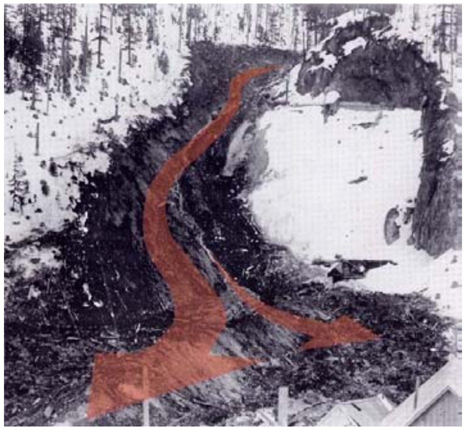
[1] geologic history from John Clague and Bob Turner, *Vancouver, City on the Edge*, Tricouni Press Ltd., Vancouver, 2003.
[2] *Britannia Mine Remediation-Structural Geology*, prepared by Steffen, Robertson and Kirsten (Canada), Inc., May 2002.

assessment of the steep slopes adjacent to the proposed development area should be conducted to determine slope stability before development begins.

A.1.3 Sediment and Soil

The last glacier that flowed down Howe Sound terminated near Porteau Cove. It deposited a ridge of gravel, sand and till called a moraine across Howe Sound. The uppermost layer of this moraine is composed of till, which is an impermeable layer of silt and clay. The morainal deposits flank the lower valley walls in this area. Fluvial deposits of gravel, sand and silt are also found. The extent of glacial deposits in the development area is not well documented and requires further study. The soils in the Howe Sound area are the residue from physical and chemical weathering of predominantly igneous and metamorphosed volcanic and sedimentary rocks. High precipitation in the area, moderate temperatures and a short dry period in the summer influences the type of soil found. The soil is a course textured acid material with high organic carbon and high iron and aluminum content called a humo-ferric podzol.[3] Marsh[4] recommends test pits in areas of proposed development to examine the suitability of sediments and soils for building and also the effects existing sediments will have on storm and rain water infiltration.

Complicating the existing sediment profile is the residue from the mining activities which took place in this area. The metal rich rock removed from Britannia Mountain by tunnelling and open pit mining was processed at the mill to extract the metallic minerals. Waste rock was pulverized and discharged into Britannia Creek and Howe Sound. Britannia creek has overflown its banks a number of times depositing this waste sediment during each flood event. The crushed waste rock is visible in many areas of the current town site. The sub-economic waste rock contains significant concentrations of copper and zinc minerals, and abundant pyrite, an iron sulphide mineral. Pyrite reacts with oxygen and water to form sulphuric acid, which acidifies rainwater and groundwater. This acidic water leaches metals from the metal rich rocks. The elevated levels of copper, zinc, cadmium and lead in the water are toxic. This acidified groundwater is called acid rock drainage. Acid rock drainage existed prior to mining and will continue despite closing of the mine.[5]



Jane Camp rockslide
Width of view at bottom: 150 meters
(Clague and Turner, 2003)

Metal rich waste rock adjacent to Howe Sound, Britannia Beach, September 2003.

[3] K.W.G. Valentine, P.N. Sprout, T.E. Baker and L.M. Kavkulich, editors, *The Soil Landscapes of British Columbia*, Ministry of the Environment, Victoria, 1978.
[4] William Marsh, *Landscape Planning, Environmental Applications*, John Wiley and Sons, New York, 1998.
[5] Chris Mills, "The Former Britannia Mine, Mount Sheer/Britannia Beach", British Columbia, http://technology.infomine.com/enviromine, (September, 2003)

The effect of disturbance of surficial contaminated sediments on the metal rich acid rock drainage will need to be assessed. The metal rich sediments discharged into Howe Sound are concentrated in an alluvial fan within 3 km. of the shore but also cover most of the inner basin of Howe Sound. Locally sediment from the Squamish River and local creeks has covered deposited tailings and reduced metal contamination of surface sediments.[6] Proposals to construct a marina and dock adjacent to Britannia Beach will need to examine the effect sediment disturbance will have on the submerged tailings geochemistry and resulting biological impacts. It is essential that the development proposals for the Britannia Beach area incorporate low impact development methods. The low-impact development approach "combines a hydrologically functional site design with pollution measures to compensate for land development impacts on hydrology and water quality".[7] Design parameters for stormwater and rainwater treatment features depend on the existing site hydrology, runoff volumes, peak discharge, frequency and duration of discharge and groundwater recharge as well as proximity to building foundations, space restrictions and importantly in this area, soil and sediment conditions. In the Britannia Beach development area the existence of extensive quantities of mineral-rich rock and sediment will be a very important factor in determining what environmentally sensitive low-impact development approach to take.

Leaching of metal rich sediments.
Beach front parking lot, Britannia Beach,
September 2003.

[6] Hagen, Mike, *Britannia Marine Sediment Contamination*, Environment Canada, March 2, 2001.
[7] *Low-Impact Development Design Strategies*, Department of Environmental Resources, Prince George's County, Maryland, June 1999, 1:1.

A.2 POLLUTION AND REMEDIATION

Hanako Amaya

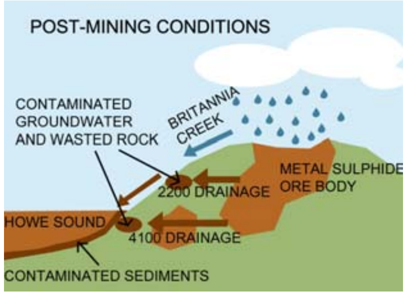
A.2.1 History of the Pollution

The Britannia mine is known for being one of the largest metal pollution sources in North America. Before mining, very little environmental impact caused contamination to Howe Sound and local water systems because of the limited exposure with ore body to air and water. The mining operation, called sublevel caving methods and started in 1902, formed a number of open pits that caused the snow melt and precipitation to contact with metal ore body in underground mine workings. The contaminated water, called Acid Mine Drainage (AMD) or Acid Rock Drainage (ARD) in general terms, was discharged in either the 2200 level portal or 4100 level portal. The 2200 level flows into Jane Creek and then Britannia Creek before reaching Howe Sound. The 4100 level goes deeper underground and discharges directly to Howe Sound. The ongoing discharge of highly toxic AMD is affecting aquatic habitat.

Pre-Mining Condition

A.2.2 Remediation Project Background

In 1974, the owner of the Britannia Mine stopped operation with meeting regulatory requirements, which caused greater impact to the environment than today's reclamation standards. The discharged AMD has resulted in nearly 40,000,000 tonnes of contaminated sediments in Howe Sound. The first remediation project was completed on December 31, 2001. The installation of a concrete plug carried out by University of British Columbia and Copper Beach Estates Ltd stopped the 2200 level portal discharge and diverted AMD into the 4100 level portal. The plug cleared the surface flow of drainage. However the contaminated drainage from 4100 level portal still discharges an average of about 500 cubic meters per hour of AMD into Howe Sound.



Post-Mining Condition

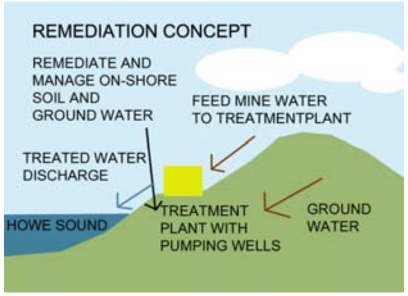
A.2.3 Remediation in the Past

The first remediation was attempted in 1974 by planning a lime-based neutralizing treatment plant that was never built. In 1991, the report done by Steffen Roberson and Kristen explored different ARD treatment methods. However, these methods were inefficient. Environment Canada funded the research of lime-based high-density sludge treatment, which includes storage of sludge at the former Mount Sheer town site and the use of underground workings as a reservoir to store seasonal ARD flows. A number of studies have been undertaken; one of them is Biosulphide Process by NTBC Research Corporation. This method employs sulphate reducing bacteria (SRB) to convert the sulphate in the ARD to hydrogen sulphide and also to precipitate copper, zinc and cadmium. Other studies that have been considered were KB-1 (Klean Earth Environment Company), the use of natural zeolites or algae Chlorella , ground cover, cementitious fill and so on.

Arial View of Open Pit Complex
•from Price et al 1995•

A.2.4 Current and Possible Water/Soil Treatment

The current water treatment process employed in the water treatment plant is High-Density Sludge (HDS) treatment, which removes dissolved metals from ARD by applying lime neutralization. HDS produce chemically more stable sludge and cleaner water with lower cost in comparison with conventional lime neutralization. The alternate solutions to remediate the contaminated site are suggested in Britannia Fan Area Remediation Planning Document. One of the examples is capping. Water/soil covers and asphalt can be used to stop or reduce oxygen from contacting the sulphidic waste. Source removal is the other method to excavate and transfer to the site where environmental effect is low. Contaminant source removal could also apply to the potential shoreline remediation by removing ARD-impacted sediment.



Current Remediation Concept by Province of BC

A.3 VEGETATION AND TERRESTRIAL HABITAT

Sarah Howie

A.3.1 Vegetation

The Britannia Beach area falls within the Coastal Western Hemlock (CWH) biogeoclimatic zone, dry maritime (dm) subzone. Annual precipitation at Britannia Beach averages about 2370mm; high rainfall and mild temperatures create excellent growing conditions and a long growing season. Dominant vegetation associated with the CWHdm includes Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), vine maple (*Acer circinatum*), salal (*Gaultheria shallon*), sword fern (*Polystichum munitum*), and bracken fern (*Pteridium aquilinium*).

Seven vegetation associations were detected during a site visit:

Howe Sound Shoreline: Most of the shoreline in this site has been damaged by human activities, particularly by railway and highway construction. Those vegetated areas which have persisted or regrown post-development are dominated by black cottonwood (*Populus trichocarpa*) and red alder (*Alnus rubra*), with scattered Douglas-fir and western hemlock.

Stream Riparian: The open, rocky edges of lower Britannia Creek are dominated by black cottonwood, red alder, and birch (*Betula* sp.), with scattered hemlock seedlings, shore pine (*Pinus contorta var. contorta*), hardhack (*Spiraea douglasii*), and oceanspray (*Holodiscus discolor*). Shaded reaches of creeks in this site would be dominated by black cottonwood, western red cedar, and western hemlock, with an understory of salmonberry (*Rubus spectabilis*), vine maple, and willow (*Salix* sp.).

Flat Lowland Deciduous: This relatively flat southern section of the site is dominated by deciduous trees that include black cottonwood, red alder, and birch.

Mixed Deciduous / Coniferous Slopes: The forested slopes that immediately surround the Britannia Beach community are dominated by bigleaf maple (*Acer macrophyllum*), birch, western red cedar, western hemlock, and Douglas-fir, with an understory of vine maple, salmonberry, salal, and sword and deer ferns.

Coniferous Slopes: These steep slopes that form the upper backdrop for the Britannia Beach site are dominated by western hemlock, Douglas-fir, and western red cedar.

Strengthening Habitat Connections:

- Each stream should be given a 50-metre buffer from any future development
- Any development pattern should ensure that environmentally sensitive areas are connected by strips of existing vegetation to facilitate wildlife movement throughout the site
- Any areas designated by the OCP as Park or Open Space should be connected by a vegetated network of linkages
- Developed areas should appear as patches within a vegetated matrix
- Wildlife access to the waterfront should be improved; some options include:
  - Limit public access at the convergence of any streams with Howe Sound
  - Construct wildlife overpasses to cross highway and railway barriers
  - Preserve as much of the existing waterfront vegetation as possible

Removing Barriers:

- Any new highway development should provide bridges over streams that maintain the 50-metre buffer to ensure adequate space for wildlife movement

Disturbed Slopes: There are several open rocky slopes surrounding the Mining Museum that appear to be unstable due to the young age of the pinoneering trees, which include birch, alder, hemlock, and Douglas-fir.

Disturbed Flats: Several disturbed sites are present in the vicinity of the developed areas, and are dominated by invasive exotic species including Japanese knotweed (*Polygonum cuspidatum*), Himalayan blackberry (*Rubus discolor*), scotch broom (*Cytisus scoparius*), and grasses.

A.3.2 Species at Risk

A species is at risk if it has been identified by the provincial government as red or blue-listed. Red-listed species are those which are threatened or endangered and blue-listed species are at risk of becoming threatened due to human activities or natural events.

Mammals at risk in the Vancouver-Squamish region include Townsend's Big-eared Bat, Keen's Long-eared Myotis, Wolverine, Fisher, and Grizzly Bear. Birds at risk include Great Blue Heron, Short-eared Owl, American Bittern, Marbled Murrelet, Green Heron, Band-tailed Pigeon, Peregrine Falcon, Lewis' Woodpecker, Surf Scoter, Western-Screech Owl, and Spotted Owl. Amphibians at risk include Coastal Tailed Frog, and Red-legged Frog.

Red-listed plants in the Vancouver-Squamish region include Geyer's onion, cliff paintbrush, spotted cowbane, marginal wood fern, Washington springbeauty, and Olney's bulrush.

A.3.3 Wildlife Habitat Issues

Riparian areas provide good east-west connections through the site. The Britannia Beach Official Community Plan (OCP) protects the streams on site with 30-metre buffers.

The OCP protects much of the existing mature forest, although some of the proposed development sites, particularly those located in the upper reaches of the Britannia Creek watershed, may impact habitat quality.

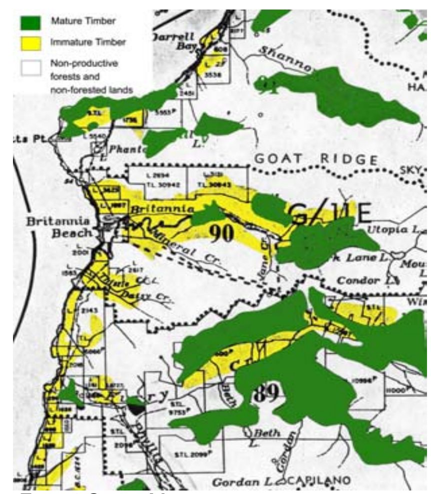
The current railway and highway that run through the site create major barriers to wildlife movement and limit access to the waterfront of Howe Sound.

At Risk Species:

- An environmental site assessment should be conducted to determine presence of red-listed plants and at risk wildlife
- An analysis of habitat requirements for the identified at risk species suggest two vital habitats for preservation in this site:
  - Riparian areas and associated cottonwood stands
  - Mature forests (particularly coniferous)

Slope Stability:

- To maintain slope stability, any construction should be restricted to areas with less than 15% gradient



Forest Cover Map

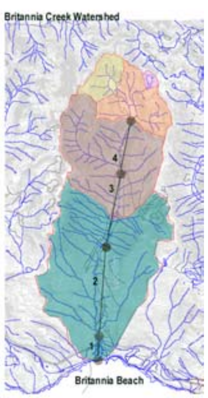
A.4 STREAM SYSTEMS AND STREAM HABITAT

Katie Murray

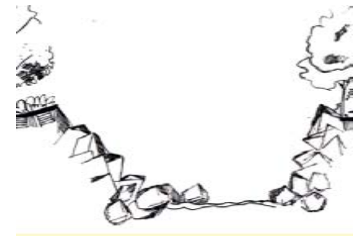
A.4.1 Britannia Creek Character

Water systems are life supporting, and healthy waterways are essential for the maintenance of terrestrial and aquatic life. The health of watersheds depends on many physical and biophysical factors ranging from land use practices, hydrological cycles, climate, geology, and landforms. Many activities have and continue to take place in the Britannia creek watershed, including mining, forestry, tourism and potable water. All of these factors effect the hydrological cycle, which in turn affects stream habitat and quality. For the purposes of this study, the historical and current biophysical conditions of Britannia creek will be analyzed with the hopes of providing insight into the sustainable management of this valuable freshwater resource.

<u>Stream Hydrology</u>



Britannia Watershed encompasses the breadth of Britannia creek, which is a typical coastal mountain stream of British Columbia. Britannia Creek can be divided into four reaches, or areas of distinct biophysical classification. Reach one, the lowest section, runs from Howe sound up to the base of the mountain slope. The slope here ranges from 2 – 3.5 %, and is primarily composed of steep rock stream banks devoid of vegetation. The creek lies on the edge of flat, buildable area that is the gravel delta of Britannia creek. This area has historically flooded its banks, and requires careful attention. Reach two of Britannia extends uphill for an additional 2 km and includes one small dam put into place for mining purposes. This area consists primarily of steep bedrock channels, sometimes confined by large boulders. A high flow velocity is possible here during a large flood event. The third classification, or Reach three, continues upstream past tunnel dam and flattens out to approx 9% slope near Marmot creek. There are high amounts of sediments available above Tunnel dam, which can be transported downstream in a dam breach event. It is evident that the spillway on Tunnel dam does not have the capacity to withstand a 200-year flood. The gradient of the creek increases once again in Reach four, and the slopes are moderately covered with boulders and talus peaks. From 1920 to 1974, low flows were recorded due to the diversion of water for hydroelectric power. Debris built up during this period, and began eroding as stream flow was introduced after 1974. These slopes and streambeds remain unstable to this day.



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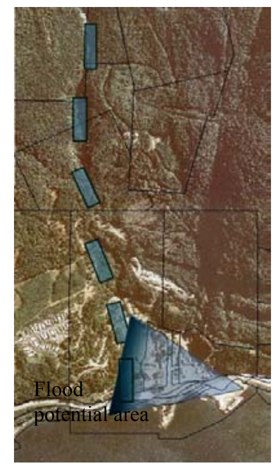
The Current Stream Situation is hard and channelized.



Dams upstream are degrading due to acid drainage and could cause a massive failure moving large amounts of sediments and water into Britannia creek. Without careful and creative management, the lower areas adjacent to Britannia creek have a high chance of additional flooding.

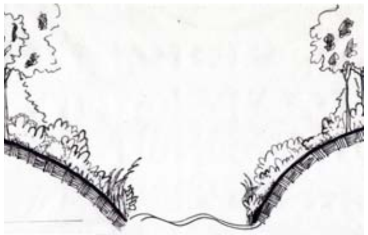
A short duration high intensity storm could cause a 200-year flood, which would move at 45m3/s, and flow overtop the railway and highway.

Stream Habitat

- Vegetation – The lower reach of Britannia creek is presently lacking sufficient streamside vegetation. The creek banks are too steep to allow for soil and vegetation to grow, and the banks are filled with pipe outlets creating point source pollution and erosion. Additionally, the natural curvilinear flow of the creek is disrupted and forced through a straight channel. This disturbs sediment flows and increase flood flow velocities. Valuable streamside wildlife habitat has been lost and connections to other habitat types severed.
- Aquatic habitat – Due to increased flow velocities and steep stream bank situations, aquatic organisms are unable to live in Britannia creek. Because there is no adequate streamside vegetation, temperature is not regulated and nutrients are not available for consumption.
- Human Recreation- Britannia creek is currently not providing a setting for human recreational use, and offers little to no opportunity for educational and recreational situations.

The upper reaches of Britannia creek have, historically, not supported a variety of aquatic life. The metal leachate naturally produced by the local geology inhibited the formation of aquatic organisms.

The lower reaches of Britannia Creek could be potential habitat for salmon and trout, but these areas are devoid of aquatic life due to contamination and stream channel disruption.



Stream bank remediation is necessary to provide a healthy stream habitat.

Riparian areas are typically important habitat for wildlife, and can be used as corridors for connecting to larger habitat types.

A.4.2 Creek Conservation Guidelines for Development

- Develop and implement a flood control plan that has the least impact on the hydrological cycle and the daily lives of the community.
- Develop sound storm water guidelines that limit impervious surfaces and allow for maximum infiltration to the ground.
- Limit stream crossings and disturbances.

Britannia c.1916 What not to do!

- Limit building in the areas adjacent to the creek to allow for seasonal creek fluctuations and possible flooding.