Mt. Washington Remediation Phase 1 Report

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Mt Washington Remediation

Phase I Report

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1 Introduction

SRK Consulting (Canada) Inc. (SRK) has prepared this report, which presents the results of Phase I of the development of an ARD remediation plan for the abandoned copper mine on Mount Washington.

In 2003 a unique partnership was formed between industry, government and the public with a goal to seek long term solutions to ensure a healthy ecosystem and a sustainable fishery on the Tsolum River. The partners consist of representatives from Timber West (landowner), Tsolum River Restoration Society (local community), Pacific Salmon Foundation, the Mining Association of BC, Department of Fisheries and Oceans Canada and the BC Ministry of Environment.

This report provides an overview of the project background, the option review process SRK carried out in Phase I, a discussion of the preferred remediation plan and recommendations for Phase II.

Phase II would involve the development of a detailed remediation plan of the mine site based on the results of Phase I. The scope of the work would involve:

- Designing the elements of the preferred option or combination of options including design drawings and the preparation of tender documents; and
- An engineering cost estimate of the capital, labour, monitoring and maintenance requirements for implementing the remediation plan.

Figures 1 and 2 provide a vicinity map and general location plan of the study area.

2 Background

2.1 Previous Projects

The study area consists of a small open pit copper mine, which operated on Mount Washington from 1964 to 1967. The mine is located on Vancouver Island approximately 18 kilometres northwest of Courtenay at an elevation of 1350 metres. The mine comprises the South Pit/Dump complex and the North Pit with adjacent East and West Dumps. Water quality data collected at both Branch 126 and in the Tsolum River at Murex Creek has indicated that the early reclamation work carried out in the late 80's and early 90's combined with the Spectacle Lake wetland constructed in 2003 has resulted in substantial improvement to the copper loadings in the Tsolum River (08HB089) as discussed further in Section 2.3. However, although the wetland has made significant improvements to the water quality in the Tsolum, the wetland is considered to be only part of the solution as wetlands have a finite lifespan as a treatment option.

Beginning in 1987, federal and provincial agencies funded studies to address the ARD problem. Subsequent fieldwork installed monitoring equipment (including fourteen shallow bore holes) and the placement of a partial cover on the East waste rock dump that was releasing copper into the environment. Other work completed in this program included placement of a limestone berm and some surface ditching as recommended by the remediation consultants. Work on various covers in the North Pit and monitoring scenarios continued until 1992, and included stripping the oxidizing rock, washing exposed bedrock and constructing several different kinds of covers.

In 1995 British Columbia Ministry of Environment, Lands and Parks (now the Ministry of Environment) set water quality objectives for the Tsolum River to establish the needed reduction in copper loadings. The objectives set two limits on dissolved copper concentrations in the Tsolum River below Murex Creek: i) the 30-day average concentration should not exceed 0.007 mg/L; and ii) the maximum concentration should not exceed 0.011mg/L.

In 2000, a water and copper load balance model was produced for Environment Canada entitled Hydrogeological and Hydrological Evaluations for Development of Remediation Options for Mt. Washington (SRK, 2000). The model was used to evaluate, the potential reduction in copper loading that could be expected from cover placement over source areas and/or improved diversion of upgradient shallow groundwater recharge.

In 2003 the Spectacle Lake Wetland Project, located downstream of the mine site, was implemented to achieve a water quality in Murex Creek that would be non-toxic downstream of the "triple confluence" of Pyrrhotite, McKay and Murex Creeks (see Figure 2).

2.2 Site Visits and Meetings

Project activities to date included an initial site visit by SRK and the project control team on September 14, 2006, a presentation by SRK to the Tsolum River Partnership followed by a second site visit on September 28, 2006 and a workshop held in Vancouver on November 1, 2006. The objective of the September 28, 2006 meeting was to introduce the SRK project team to the Partnership and to explain SRK's approach to the project. On January 23, 2007, SRK Consulting (Canada) Inc. presented results of Phase 1 of the Mt Washington Remediation project to representatives of the Tsolum River Partnership and a number of both government and non-government interested parties.

The initial site visit occurred on September 14, 2006 and involved Diane Ramage (Pacific Salmon Foundation), Wayne White (Tsolum Restoration Society), Margaret Wright (Department of Fisheries and Oceans), Peter Healey and Daryl Hockley from SRK.

The second visit occurred following the project kick off meeting held at the Mount Washington Ski resort on September 28, 2006. The participants include members of the project steering committee and three senior engineers from SRK. The Steering Committee comprised individuals from MOE, the MEMPR, DFO, TRRS, and the Mining Association of BC.

Both visits provided an opportunity for the partnership members to not only meet the project team but also to see first hand earlier remediation work that had been carried out on the site. The one day workshop was held on November 1, 2006 at the offices of SRK Consulting. Daryl Hockley from SRK facilitated the workshop. Presentations were made by SRK and MOE to provide the participants with some background information on the reduction in total copper concentrations in both Pyrrhotite Creek and the Tsolum River as a result of the earlier and more recent remedial work undertaken.

2.3 Water Quality

The copper concentrations in Tsolum River exhibit a distinct seasonal character. They are consistently high during the spring freshet, low during the summer baseflow period and quite variable during the fall and winter. Averaged over long periods of time (i.e., a week or more), the copper concentrations in the fall and winter tend to be lower than during the spring freshet

Figures 3 and 4 show the water quality data collected in the Tsolum River 500 m downstream of Murex Creek. The data show a substantial improvement over time in the copper concentrations in the Tsolum River. It is interesting to note that copper concentrations were significantly less during the 2003 freshet than previous years and that this improvement preceded the rerouting of Pyrrhotite Creek through the wetlands.

Figures 5 and 6 show the water quality data collected at Branch 126. These data also indicate a significant improvement in water quality from the site since the remediation work was completed in 1992. The decreasing trend in concentrations after 2003 suggests the recent observed improvements in water quality in Tsolum River are not entirely attributable to rerouting of Pyrrhotite Creek through the wetlands.

3 Review of Options

3.1 Top Down Process

In review of the options for this project, SRK has adopted a "top-down" approach for analyzing and selecting the preferred remediation method. "Top-down" is a term used in the software industry to describe a software development process whereby the end objectives direct every step of development. It can be contrasted with the "bottom up" approach whereby a number of initiatives (or scientific investigations) are started in the hope that they will somehow add up to the desired final product (or closure decision). In mine closure work, the ingredients necessary to initiate the top-down approach are a concise definition of the scope of the project and a compilation of all available information.

In the first step of the "top-down" approach, a one day workshop was held to identify possible remediation methods for the Mt Washington mine site. The format of the workshop was a group brainstorming session to identify all options. This was done to ensure that all possible remediation methods were under consideration. The work shop started with a common understanding of the project objectives. Remediation methods were then discussed and example options were developed. Each option was assessed by the group and preferred option or combination of options was agree to.

3.2 Options Identified in November Workshop

The November workshop concluded with a preferred method and a number of contingencies as shown on Figure 7. However, in order to evaluate these methods, it was agreed that additional information would need to be obtained and further analysis would need to be carried out in order to demonstrate the practicality and effectiveness of the methods selected. One of the key options that the workshop group felt was worth pursuing was the concept of a flow equalization reservoir located at Pyrrhotite Lake. The provision of an equalization reservoir at Pyrrhotite Lake has the potential of reducing the higher concentrations experienced in the Tsolum River. It was hoped that the reservoir would achieve this by storing a portion of the contaminated runoff from the mine during spring freshet for subsequent release during the remainder of the year. It was anticipated that the bulk of the releases from storage would be made during the fall and winter months, when dilution flows are relatively large in the receiving environment. The summer months typically experience the lowest flows of the year and therefore offer only limited capacity to receive releases from the reservoir (i.e., it wouldn't take much of a release from the reservoir during the summer to cause unacceptably high concentrations in the river).

In addition to the flow equalization concept, the workshop participants concluded that several contingency methods would also be assessed. These would include a possible upgrade of the existing surface diversion ditch upstream of the pit, the placement of some reasonable cover or combination of covers over the entire area of the pit and batch lime treatment with an in-line mixer located upstream of the Pyrrhotite Lake. Although the Spectacle Lake wetland was considered a short term solution, it was felt that it would function as a contingency polishing pond.

3.3 Detailed Analysis

3.3.1 Mass Balance Model

A mass balance model was developed to investigate the potential effectiveness of the various mitigation options identified during the November workshop. The model was set up to simulate copper concentrations at two key points within the upper Tsolum River catchment, namely: i) the outlet of the proposed equalization reservoir at Pyrrhotite Lake; and ii) Tsolum River just downstream of Murex Creek. The main inputs to the model were two historical records of flow and associated copper loading. The first record characterized the inflows from Pyrrhotite Creek to the equalization reservoir. The other represented the flow and copper loading generated by the remainder of the upper Tsolum River catchment, defined as the incremental area between Pyrrhotite Lake and a point on Tsolum River some 500 m downstream of Murex Creek.

The first step in developing the model was to select a suitable simulation period. This period had to satisfy the following three criteria: i) water quality sampling was frequent at both Branch 126 and the Tsolum River below Murex Creek; ii) the records of flow at these two sites were complete, or nearly so; and, iii) the data represented a reasonably stationary condition (i.e., no detectable trend in copper concentration due to mitigation measures at the mine). After scrutinizing the flow and water quality records at the two sites, the two-year period from March 2001 to February 2003 was adopted for the modelling period. Over this period, the copper concentration determinations were numerous at both sites. The flow record for the Tsolum River (WSC Station 08HB089) was complete and the flow record for Branch 126 only contained a short gap of missing data. The selected time frame met the third criterion because it represented a condition after the benefits of the initial mine remediation were realized (first detectable in the mid 1990's) but before rerouting of Pyrrhotite Creek through the Spectacle Lake wetland in the fall of 2003.

Operation of the model required continuous records of flow and copper concentration and, therefore, estimates had to be made for missing data. The process of making these estimates is known as "patching". Two methods were adopted for patching the water quality records. For short gaps, missing data were patched using linear interpolation. For long gaps (i.e., more than five consecutive days), correlations between copper concentration and coincidental flow rate were used. In the case of the Tsolum River, the correlation was made between copper concentrations in the Tsolum River and coincidental flows in Pyrrhotite Creek. The premise of this particular correlation was variations in flow from the mine should explain a significant amount of the variations in copper concentrations in the Tsolum River based on the fact that the mine is the single largest source of copper loading within the Tsolum River catchment. Long gaps in the water quality record of Pyrrhotite Creek were patched using correlations between concentration and flow at Branch 126. To capture seasonal differences in the correlation, a number of relationships were developed covering periods as short as a month to as long as a full season. The gap in the Pyrrhotite Creek flow record was infilled using a correlation between the coincidental flows at Branch 126 and at Piggott Creek (WSC Station 08HD030). Owing to similarities in elevational characteristics of their catchments, these two streamflow gauging stations experience flows that are highly correlated. As indicated earlier, no patching of the Tsolum River flow record was required. Figures 8 and 9 present the patched daily flow and copper concentration records for the Tsolum River and Pyrrhotite Creek, respectively, for the two-year period from March 2001 to February 2003. Symbols (filled squares) identify measured copper concentrations while solid lines show periods where concentrations were estimated. The green line on Figure 9 indicates the portion of the Pyrrhotite Creek flow record that had to be patched.

Upon completion of the data patching, the next step was to program the model in an Excel spreadsheet. The model incorporated the following features and assumptions:

- The model was operated on a monthly time step to avoid the complications of simulating transit time and attenuation as releases from the proposed equalization pond make their way down through the system of streams and wetlands to the Tsolum River.

- A monthly record of inflows to the equalization pond was estimated by scaling the observed flows at Branch 126 according to the ratio of catchment areas at the equalization pond and at Branch 126 (0.85 km^2 / 0.27 km^2). To account for orographic effects on catchment yield, the resulting flows were then reduced by 5%.

- The inflow of copper loading to the equalization pond was assumed to be exactly the same as measured at Branch 126 (i.e., no allowance was made for any additional loading generated by the incremental catchment between Branch 126 and Pyrrhotite Lake).

- The flows generated by the rest of the upper Tsolum River catchment were determined by subtracting the estimated inflows at the equalization pond from the observed flows at WSC Station 08HB089.

- The copper concentrations of the flows from the rest of the upper Tsolum River catchment were assumed to be constant at 0.0035 mg/L, based on background concentrations measured at Tsolum River above Murex Creek and at Murex Creek above Pyrrhotite Creek. The adopted background concentration is half the 30-day average objective for the Tsolum River.

- Owing to their greater availability, determinations of total copper concentration (i.e., dissolved plus particulate) were used to estimate dissolved concentrations at Branch 126 and at the monitoring site in Tsolum River below Murex Creek. An examination of water quality samples where both dissolved and total determinations were made suggests that the use of total metal determinations only overestimates the dissolved copper loading by a small proportion (< 15%).

- An algorithm was added to account for natural sinks that act in the Tsolum River catchment to reduce copper concentrations as water flows from the mine to the Tsolum River. The natural sinks (precipitation and absorption) were assumed to operate only during spring and summer, based on a comparison of the observed loadings at Branch 126 and at the monitoring site in Tsolum River. Furthermore, the effectiveness of the sinks was assumed to decrease as flow from the mine site increases. The character of the relationship between load reduction and flow rates was estimated through model calibration. The natural sink was estimated to remove up to 90% of the load released from the mine during the lowest flow period of the summer. During flows typical of the freshet, the natural sink was estimated to remove roughly half of the load that originally exits the mine development.

- An algorithm was added to simulate effectiveness of additional mitigation that could be implemented at the minesite (such as construction of additional covers or implementation of water treatment). Any new mitigation was assumed to cause a constant reduction in copper loading from the mine year-round (e.g., if the associated model parameter was set to 60%, then each of the simulated months would experience a 60% reduction in loading from the mine, be it during a wet fall month or a dry summer month).

- A routine was incorporated into the model to simulate the operation of the equalization reservoir. This routine was designed to allow for controlled release from the reservoir's outlet works and uncontrolled releases over a spillway. To simulate the copper concentrations of the reservoir outflows, the reservoir was assumed to act like a perfect mix tank.

Early in the development of the model, it was discovered that an equalization reservoir on its own could not achieve the 30-day average objective of 0.007 mg/L in the Tsolum River. The flow-weighted average copper concentration in the Tsolum River below Murex Creek is approximately 0.013 mg/L, or almost double the objective. The flow-weighted concentration represents the best long-term concentration that could be achieved with the equalization pond if it acted alone. Accordingly, all results from the model presented in this report include additional mitigation measures at the mine site proper.

A range of five scenarios were simulated with the mass balance model. The first scenario examined a situation in which the equalization reservoir was constructed and the required load reduction at the mine site was minimized. In other words, the total loading from the mine was reduced just enough so that the flow-weighted average copper concentration in the Tsolum River would equal the objective of 0.007 mg/L. The equalization reservoir would then be relied on to modify the hydrograph of Pyrrhotite Creek so that it more closely resembled the seasonal pattern of flow in Tsolum River. Figures 10 and 11 graphically illustrate the output from the model. Figure 10 estimates what the water quality would have been in the Tsolum River if the conditions for Scenario 1 had existed over the period March 2001 to February 2003. The top plot shows monthly copper loading in kg while the bottom plot presents the monthly average copper concentration in mg/L. For comparison, the historical copper loadings and concentrations for the same period are superimposed on these two plots (which represent present-day conditions, but without the added benefit of the wetland). As can be seen in the bottom plot, the simulated concentration is constant throughout the simulation period. To achieve this, the reservoir would have had to operate with almost perfect flow pacing. In other words, just enough water would be released from the reservoir to ensure that the concentration of 0.007 mg/L is just met in the Tsolum River. The data required to implement this scenario would be extensive indeed, with a minimal daily sampling of concentrations in the Tsolum River and in the reservoir. Also, the flows into the reservoir and in the Tsolum River would have to be measured on a continuous basis and be available in near real-time. The valve on the outlet works would probably have to be adjusted on a daily basis, particularly during periods of high flow. At a lower level of management, the reservoir would still be effective, but the concentrations would fluctuate about the objective level.

Figure 11 comprises four plots that illustrate the four main water balance components of the reservoir: inflow, controlled release, spill and storage. An examination of these four plots reveals how the reservoir would behave in meeting the conditions of Scenario 1. During spring freshet, controlled releases from the reservoir would be constrained, thus forcing a portion of the incoming flows to be stored in the reservoir. These stored waters would then be carried over the full summer, when dilution flows are low, to be subsequently released during the fall and winter months. With this mode of operation, the flows in Pyrrhotite Creek below the reservoir would approximately match the flow pattern in the Tsolum River. Over the two-year simulation period, the reservoir would have required a live storage of about 500,000 m^3. In this simulation the storage was made large enough to prevent uncontrolled releases of water over the spillway.

Scenario 2 is the same as the first scenario, except diversion ditches would be constructed in the catchment of Pyrrhotite Lake, thus reducing the inflows to the equalization reservoir. The diversions would reduce the size of the catchment by about 0.19 km^2. Figure 12 presents the resulting water balance of the reservoir. The requirement for live storage would be reduced slightly to about 425,000 m^3.

Scenario 3 is another variation of the first scenario. A pipeline would be constructed to convey the mine water to Pyrrhotite Lake. To reduce the size of catchment controlled by the reservoir, a diversion channel would intercept the flows of Pyrrhotite Creek near the inlet of the Pyrrhotite Lake and divert these flows to a point downstream of the lake. The headworks of the pipeline would be constructed in Pyrrhotite Creek just below the East Dump. The coupled effect of the pipeline and diversion would be to reduce the catchment of the reservoir by about 0.6 km^2. With this scenario, the capacity of the reservoir could be reduced to about 200,000 m^3 (see Figure 13).

Scenario 4 examines a case in which no equalization reservoir is provided, but mitigation at the mine site reduces loading enough to prevent the 30-day average objective of 0.007 mg/L from being exceeded in the Tsolum River. To achieve this, the loading from the mine would have to be reduced by some 90%. Figure 14 shows the predicted water quality in the Tsolum River under this scenario.

The monthly average concentration reaches 0.007 mg/L on a few occasions, but otherwise lies below the objective level.

The final scenario also excludes the use of an equalization pond. Improvements in water quality are achieved by treating drainage at the outlet of Pyrrhotite Lake to a copper concentration of 0.05 mg/L. Figure 15 shows the resulting water quality in the Tsolum River. To be conservative, no allowance was made for the removal of copper by the natural sink. If this sink was simulated, then the concentrations would remain below the objective over the full two-year simulation period.

3.3.2 Flow Equalization Reservoir

The preferred method that came out of the workshop was the construction of a flow equalization reservoir in the vicinity of Pyrrhotite Lake. Aerial photos of Pyrrhotite Lake are shown on Figure 16.

In order to evaluate this option, SRK developed preliminary engineering designs for the reservoir embankment (see Figure 17). Available storage in Pyrrhotite Lake was based on information provided by Environment Canada (Appendix A). It was estimated that with an assumed load reduction at the mine site of 60 percent, the reservoir storage would have to be about 500,000 m^3 to achieve the required water quality objective for dissolved copper in the Tsolum. Using available topographic maps provided by Timberwest, the embankment would have a crest elevation of 1058m with an average dam height of 9m (see Figure 18). A typical dam section is shown on Figure 19. A storage capacity curve for a number of different configurations is presented in Figure 20.

To optimize the embankment design, SRK evaluated several different configurations including the construction of surface water diversions around Pyrrhotite Lake, together with the piping of contaminated seepage from the pit to the flow equalization reservoir at Pyrrhotite Lake. Both of these alternatives reduced the storage requirements and consequently the height of the embankment. Table B-1 presents a summary of the design parameters and the capital (direct and indirect) and operating cost for each of the alternatives. Typical details of the liner installation are provided in Figure 19.

3.3.3 Covers

General

SRK has evaluated a number of alternative cover options for potential ARD remediation measures in the North Pit. The estimated area of the North Pit is 38,000 m^2. A plan showing the extent of the North Pit cover is provided in Figure 21. The following sections present an overview of each of the cover options.

Low Permeability Soil Cover

A low permeability soil cover would consist of 1 m thick compacted till similar to the cover placed over the East Dump in 1988.

The original borrow area for the East Dump cover is located approximately 5 km from the mine site. The till in this borrow area is not considered ideal for a cover over the pit because of the low percentage of fines and the available material at the borrow area has not been determined at this stage of the study.

However, for the purposes of this option evaluation study, the cost estimate for till supply assumes that till could be obtained from a site, a similar distance away.

The unit costs used to prepare the comparative cost estimate were based on the BC Blue Book 2005-2006. The projected unit cost to load, haul, dump and place is estimated to be $27.78 per cubic metre. A summary of the direct and indirect cost estimates to place a soil/till cover is provided in Table B-2. The approximate total capital cost for the soil/till cover is $2 million. A summary of the benefits and disadvantages of the cover option are provided on Table B-3.

Bituminous Liner

The next cover option considered for the North bit was a geosynthetic bituminous liner. The liner would similar to the asphalt impregnated geotextile installed in 1992. The natural ground would require subgrade preparation and regrading in places to a minimum 3H:1V slopes. Subgrade preparation would include removal of the large boulders and any low spots would be filled in. The subgrade would also need to be re-contoured to form a continuous smooth surface. The finished subgrade surface would require compacted prior to liner deployment. The NP2 type bituminous liner has a unit cost of $18.50 per m^2 with an estimated 10% for waste and overlap. The installation procedures and specifications would be provided by the contractor during detail design. It was assumed for the purposes of this study that a 0.3 m soil cover would be placed over the liner. As shown on Table B-2, the total capital cost for this option was estimated to be about $1.44 million. A summary of the benefits and disadvantages of this cover option are provided on Table B-3.

Concrete Cap

The concrete cap option is expected to require extensive engineering work for both design and quality control during construction. The subgrade preparation will require re-sloping to a minimum 3H:1V, clearing all boulders and debris, and re-contoured.

The subgrade will need to be compacted to minimize settlement. The cap would be a minimum 50 mm thick. The concrete is expected to be premixed and transport to site. The unit cost for the concrete is estimated at $210 per cubic metre. As shown on Table B-2, the total capital cost for this option was estimated to be about $2 million excluding the forms, subgrade and finishing work. A summary of the benefits and disadvantages of this cover option are provided on Table B-3.

Geosynthetic Clay Liner

An alternative to the bituminous liner cover is a geosynthetics clay liner (GCL) cover. The installation of a GCL is similar to the bituminous liner but would require more quality control and engineering. The GCL would need a bedding layer of 50 mm minus material. A bentonite powder would be spread along panel seams as sealant. It is suggested that the GCL would require a cover to provide confining pressure and UV protection. As shown on Table B-2, the total capital cost for this option was estimated to be about $1.85 million. A summary of the benefits and disadvantages of this cover option are provided on Table B-3.

3.3.4 Surface Diversions

Surface diversions have been considered for all the options evaluated in this study. The uphill diversion as shown on Figure 23 was assumed to be in place for all of the mass loading model runs. Surface water channels would be constructed on the surface of the proposed pit cover to direct clean water away from the pit surface. As previously discussed in Section 3.3.2, surface water diversions were also factored into the different scenarios for the flow equalization reservoir. A plan showing the approximate location of these diversions is shown in Figure 24. Typical details of the diversions are shown on Figure 25.

Table B-4 provides a summary of the capital and operating costs for the surface diversion options.

3.3.5 Pipelines

Two pipeline options were evaluated in this study. The first pipeline was included as an option under Method Option 3 (See Table B-9). The concept would involve collecting the runoff from partially covered pit area and directing the flow in a HDPE 200 mm diameter pipeline to the Pyrrhotite Lake Flow Equalization Reservoir (FER). As shown on Table B-1, this option reduced the dam height of the FER from 9 m to 4.5 m and the required storage capacity from 500,000 m^3 to 200,000 m^3. A plan of the alignment of the pipeline is shown on Figure 26.

The second HDPE pipeline would be part of the Method Option 4, which would convey seepage from the underdrain beneath the full pit cover to Pyrrhotite Creek for lime treatment. It is assumed the pipeline diameter would be no greater than 100 mm.

Capital cost for the installation of the pipelines are shown on Table B-5

3.3.6 Water Treatment

Although it is believed that the cover will in time effectively reduce the copper loading from the mine area by 90% and hence meet the water quality objective in the Tsolum River, water treatment would likely be required in an interim period until the cover achieves its optimum effectiveness.

The purpose of this section to provide an overview of a proposed chemical water treatment system and to provide a preliminary estimate of the lime and power requirements, an estimate of the sludge generation and design issues that would need to addressed in Phase II.

There are a number of mechanical devices available that can be used to either dose dry lime or lime slurry to the flow in Pyrrhotite Creek. One such device is the "Aqua-Fix" system. It relies on a water wheel which drives a lime dosing mechanism to deliver lime to the flow at rate proportional to the flow in the stream. The system is available at different sizes, with hopper capacities of up to 75 tonnes.

It is assumed that such a system could be installed in Pyrrhotite Creek at either Branch 126 or at Pyrrhotite Lake. For the purposes of this study the following assumptions were made:

- Average flow of 18.9 L/s (Branch 126);
- Average copper 3 mg/L;
- Acidity:Copper ratio of 8-12;
- Average acidity 40 mg $CaCO_3$ eq./L; and
- Peak flow of 150 L/s for one month.

The annual hydrated lime demand ($Ca(OH)_2$) is expected to be between 25 tonnes depending on the utilization that can be achieved. The treated water would be allowed to flow to Pyrrhotite Lake where most of the precipitates that would be formed would be expected to settle out and accumulate. Additional polishing could be expected if the Pyrrhotite Creek diversion through Spectacle Lake is maintained.

A typical hydrated lime applications system would normally require a silo for dry storage and a slurry tank to mix and store the lime slurry. This system would require agitation equipment and a recirculation loop. Alternatively, the slurry could be delivered to the site and hence, eliminate the need for a silo. Another option is to apply the lime directly, which would eliminate the need for a slurry tank or agitator. In summary, and without any further analyses at this stage, it is believed that the power requirement would be minimal (less than 10hp) and a small generator would surfice.

It is estimated that based on a lime consumption of 25 tonnes a year, and assuming 3 percent solids by weight, the system would generate about 2000 m^3 of sludge every year.

Based on this preliminary overview of a treatment system, the following conclusions were reached:

- Treatment system is relatively simple;
- Hydrated lime in bulk delivery;
- Silo and dry application;
- Local power, if necessary;
- Capital cost around $75,000-$200,000;
- Lime cost of $15,000 per year;

- Settling time requires that Pyrrhotite Lake is part of system;
- Sludge storage is key;
- Sludge volumes could be higher than estimated;
- Possible issues;
  - The treatment process could overtax attenuation capacity;
  - sludge removal may be required; and
- Water treatment should only be implemented in combination with source control at the mine.

4 Preferred Remediation Plan

Using the results of the mass loading model to examine the effectiveness of each of the remediation options, SRK was able to develop a number of conceptual options, which were then turned into conceptual level engineered designs. Capital and annual operating costs were then developed for each remediation component as shown in Appendix B, Tables B-1 to B-5. Four combination methods options were then developed and costed. The results are presented in Appendix B as Tables B-6 to B-10. The preferred option is Method Option 4.

On January 23, 2007, SRK Consulting (Canada) Inc. presented results of the Phase 1 study to representatives of the Tsolum River Partnership and a number of both government and non-government interested parties. The different options were debated during the meeting. During the discussion a number of issues were raised by the participants. These issues include the need for post closure revegetation of the site, providing marmot habitat and the need to collect more water quality data from the site following this years freshet to better optimize the cover design.

The preferred remediation option would include a cover over the entire pit area to reduce the loading by at least 90 percent of the current load from the site. The function of the cover would be to separate clean runoff water from the contaminated water, reduce infiltration, allow revegetation and provide marmot habitat. Options for the cover would include till only, a bituminous liner plus till or a asphalt impregnated geotextile plus till.

Surface diversions would also be considered as part of the overall method. The diversions being considered include groundwater drains, the uphill diversion, clean water separation and a diversion around the Branch 126 wetland, collecting underdrain seepage from beneath the liner, and feeding to a sump at the low point of the cover. A 100 mm HDPE pipeline would convey this contaminated seepage to a water treatment plant at either Branch 126 or Pyrrhotite Lake.

Short- term treatment of the mine site water would be by a lime addition system located at Branch 126 or Pyrrhotite Lake. SRK would consider construction of berms in Branch 126 wetland area. There would be one berm at the eastern end of the wetland to raise the water level and one at the midpoint to segment the reservoir. The treatment would continue to rely on Pyrrhotite Lake and Spectacle Lake wetland as polishing ponds. It is believed that it could take between 5 to 10 years for the new pit cover to reach optimum efficiency. In the meantime, short term water treatment would be implemented.

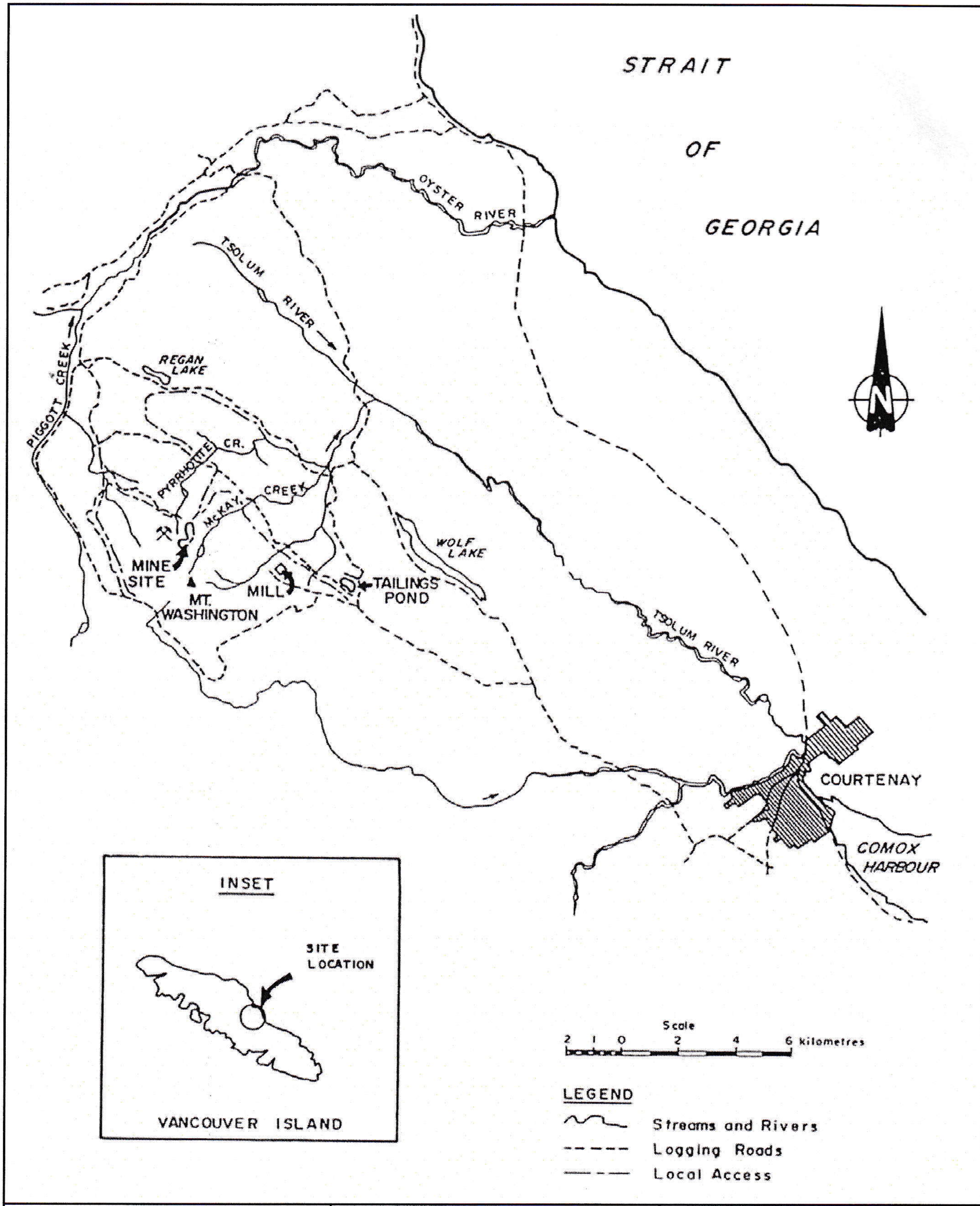
A monitoring and maintenance program would be developed to monitor the improvement of the water quality both in Pyrrhotite Creek and the Tsolum River.

Additional work that would be needed prior to implementing the construction program would include monitoring of this years 2007 freshet, treatability tests, identification of till and gravel borrow areas, assessing the requirements for vegetation and marmot habitat, the completion of detailed engineering and a review of the final construction cost estimates.

This report, on Phase I of the Mt Washington ARD Remediation Project, has been prepared by SRK Consulting (Canada) Inc.

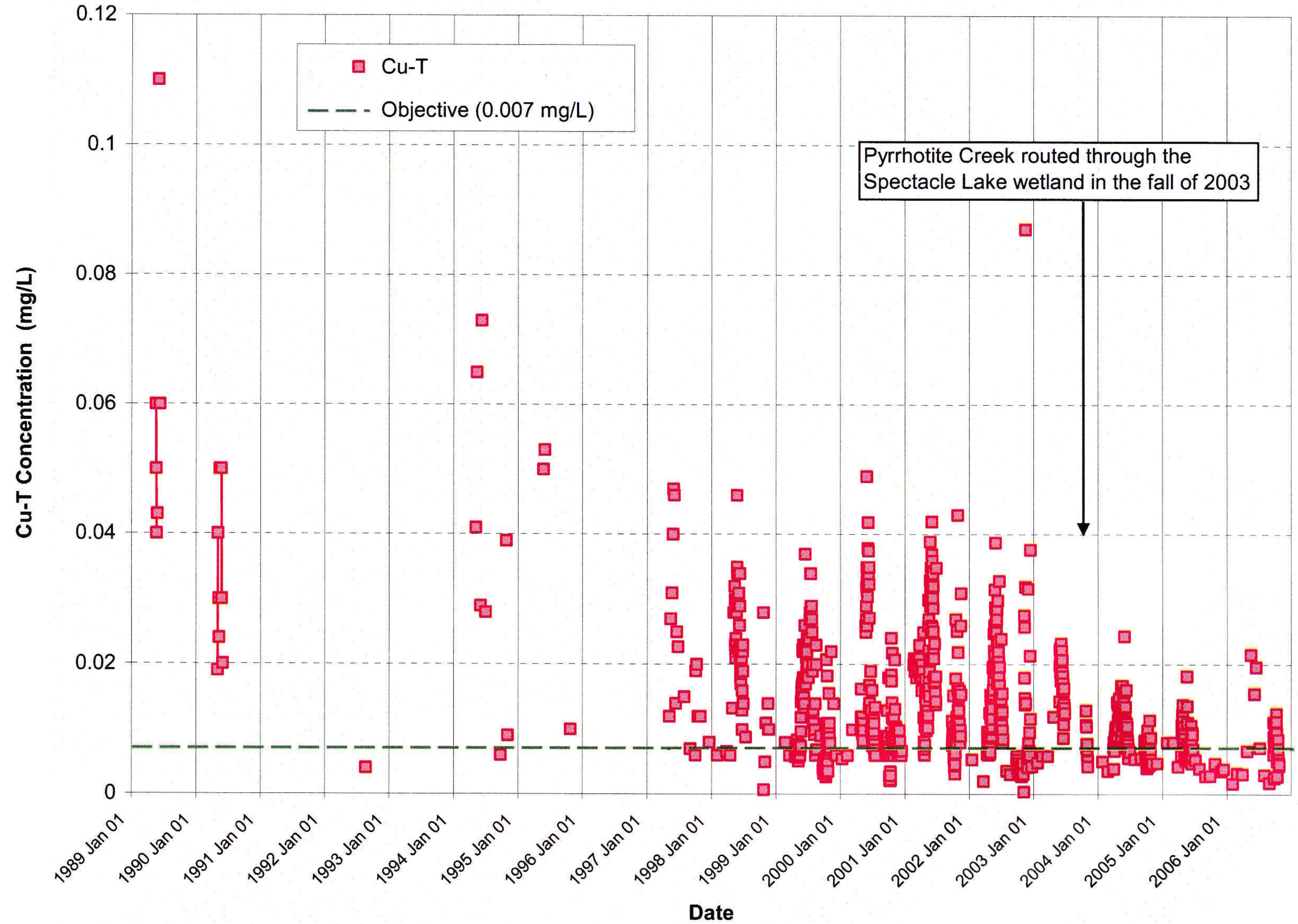
Peter Healey, P.Eng.

Pat Bryan, P.Eng



SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Vicinity Map		
Job No: 1CT001.000 Filename: Figure-1-10to15.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 1

SRK Consulting Engineers and Scientists	MT. WASHINGTON	MT. WASHINGTON
SRK JOB NO.: 1CH005.000.300		Location Map and Catchment Areas
FILE NAME: TotalPlanRev2.dwg	Tsolum River Partnership	DATE: Feb. 07 · APPROVED: · FIGURE: 2



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VANCOUVER

Tsolum River Partnership

Historical Water Quality (Total Cu vs. Time) Tsolum River below Murex Creek

Job No: 1CT001.000

Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt

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Phase I Report

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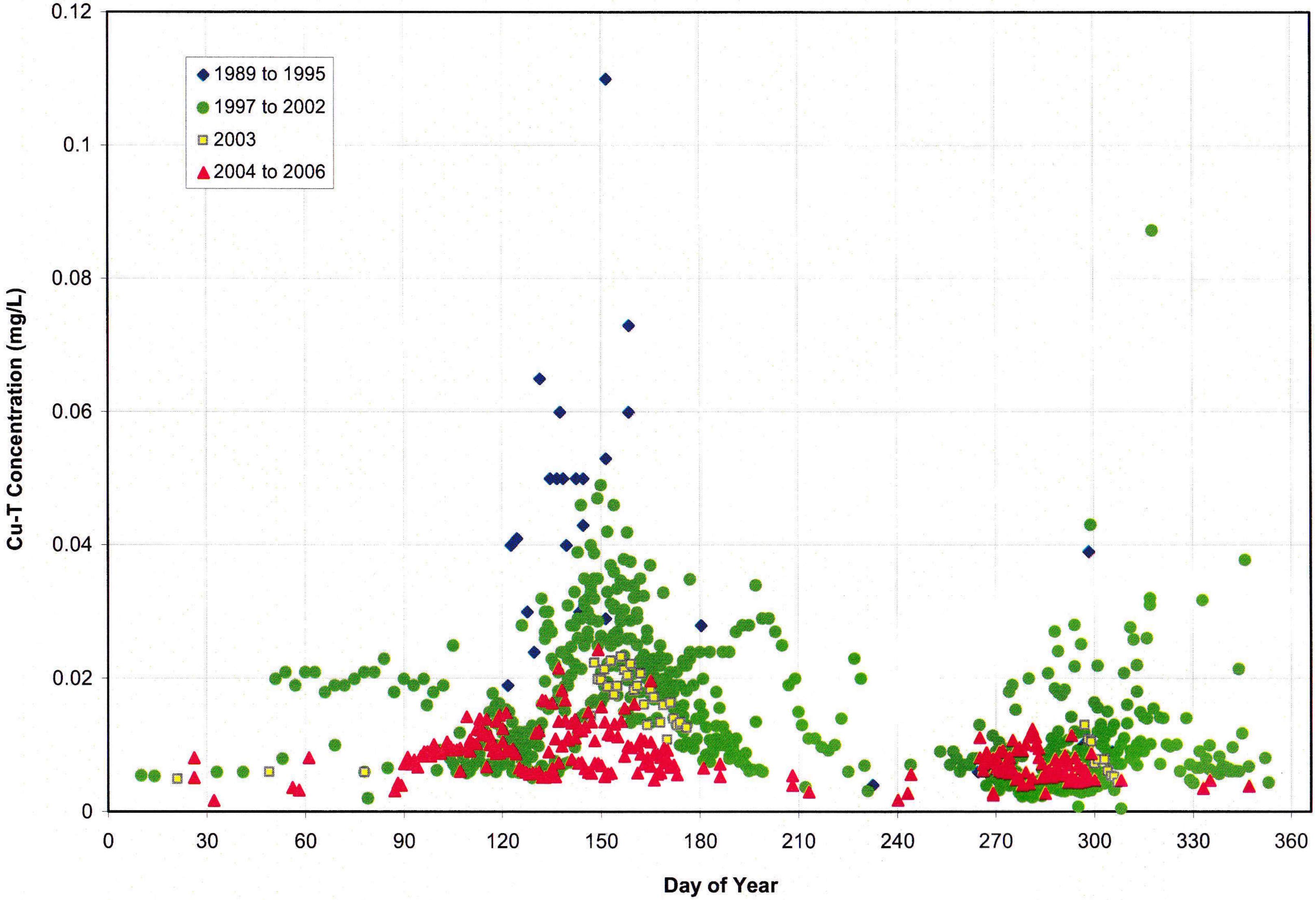
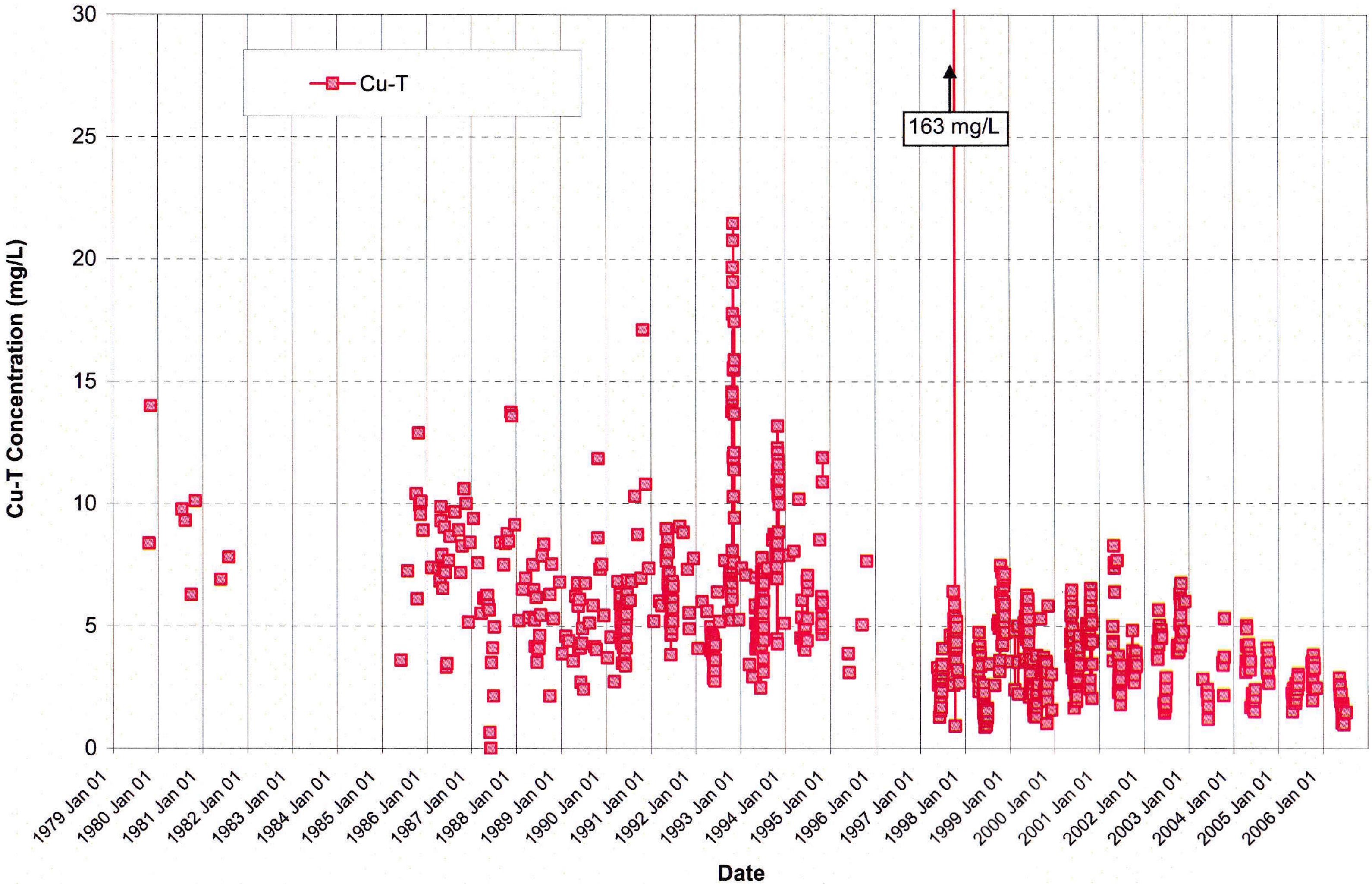
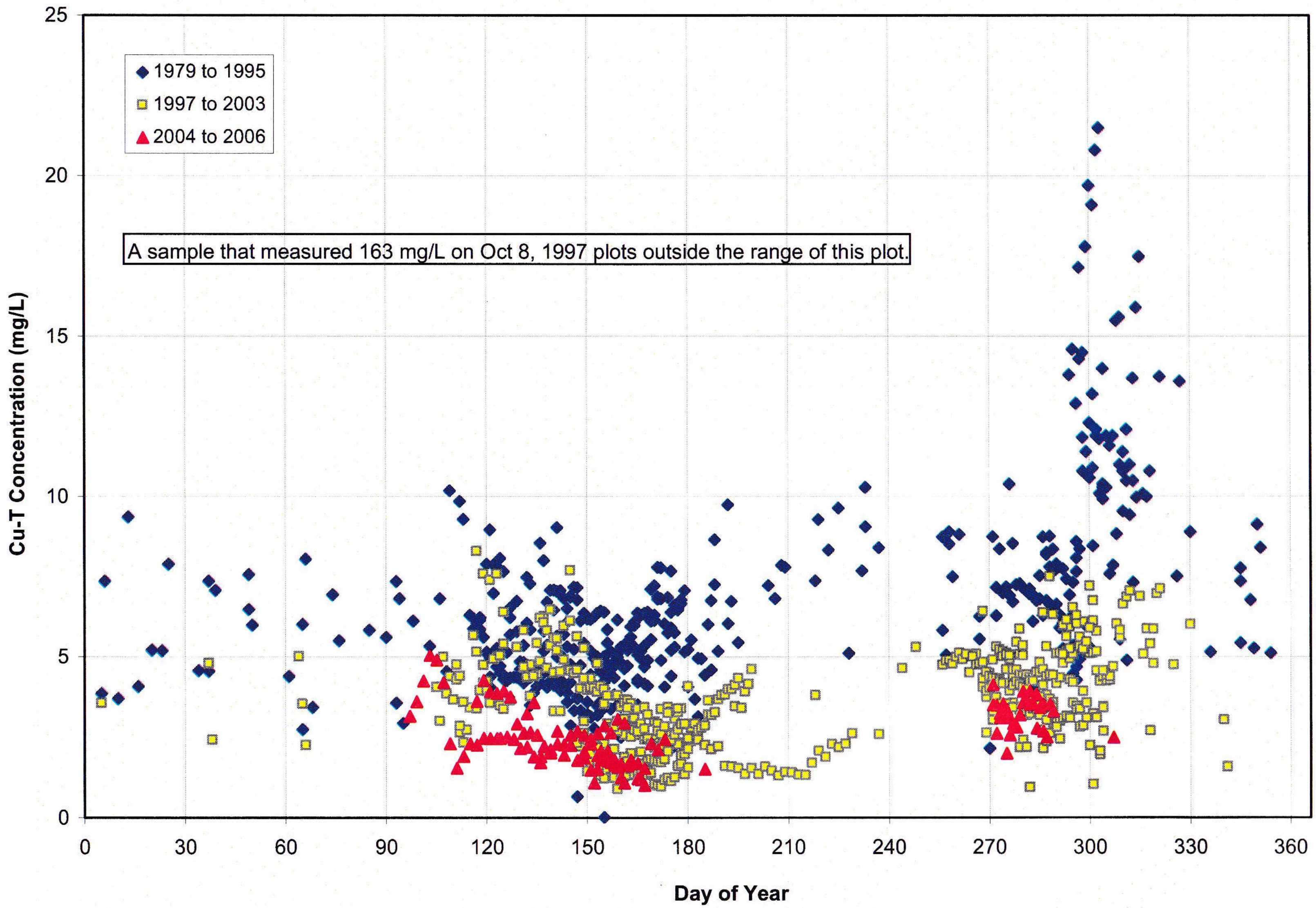


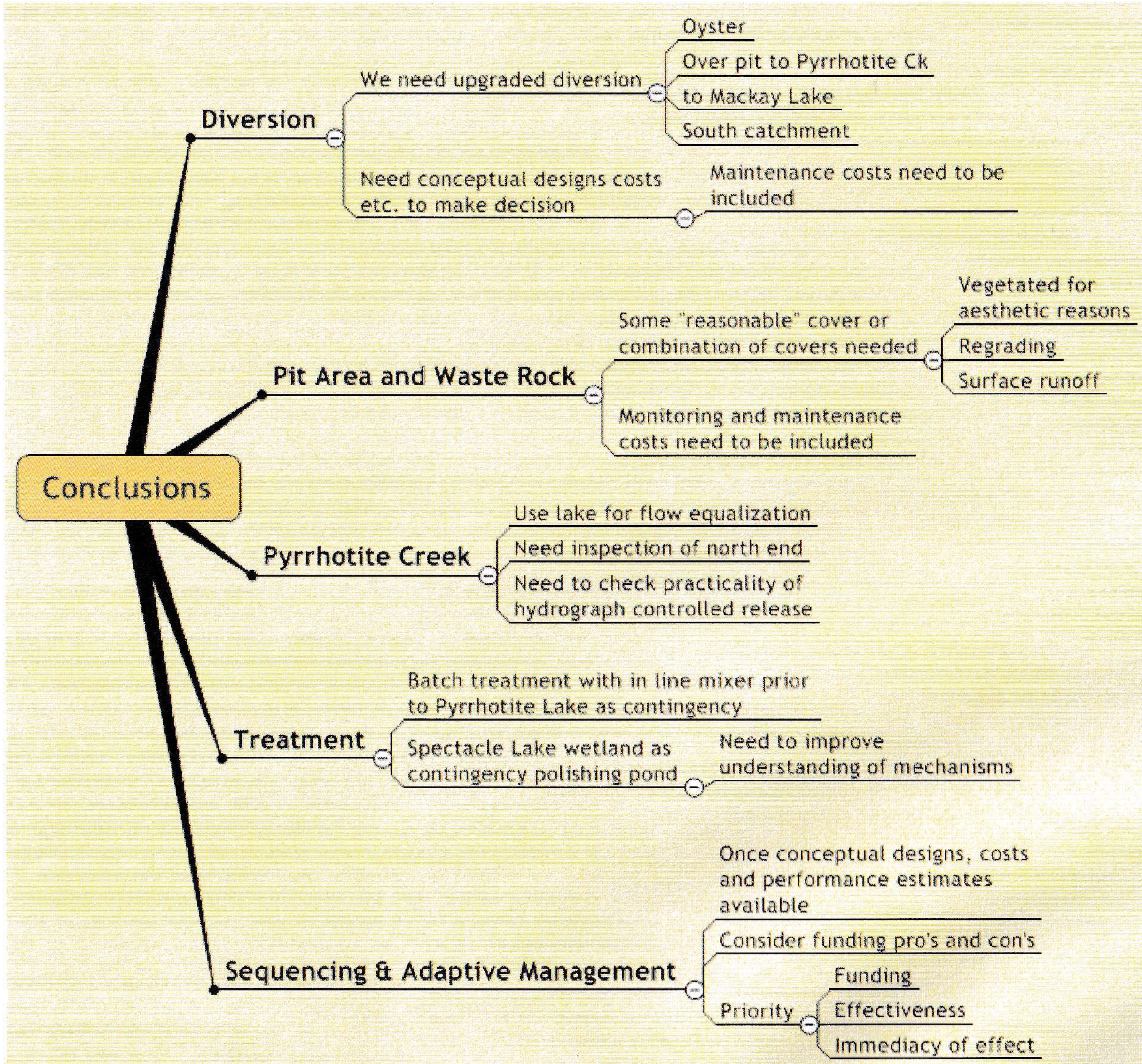
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Historical Water Quality (Total Cu vs. Day of Year) Tsolum River below Murex Creek
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 · Approved: · Figure: 4



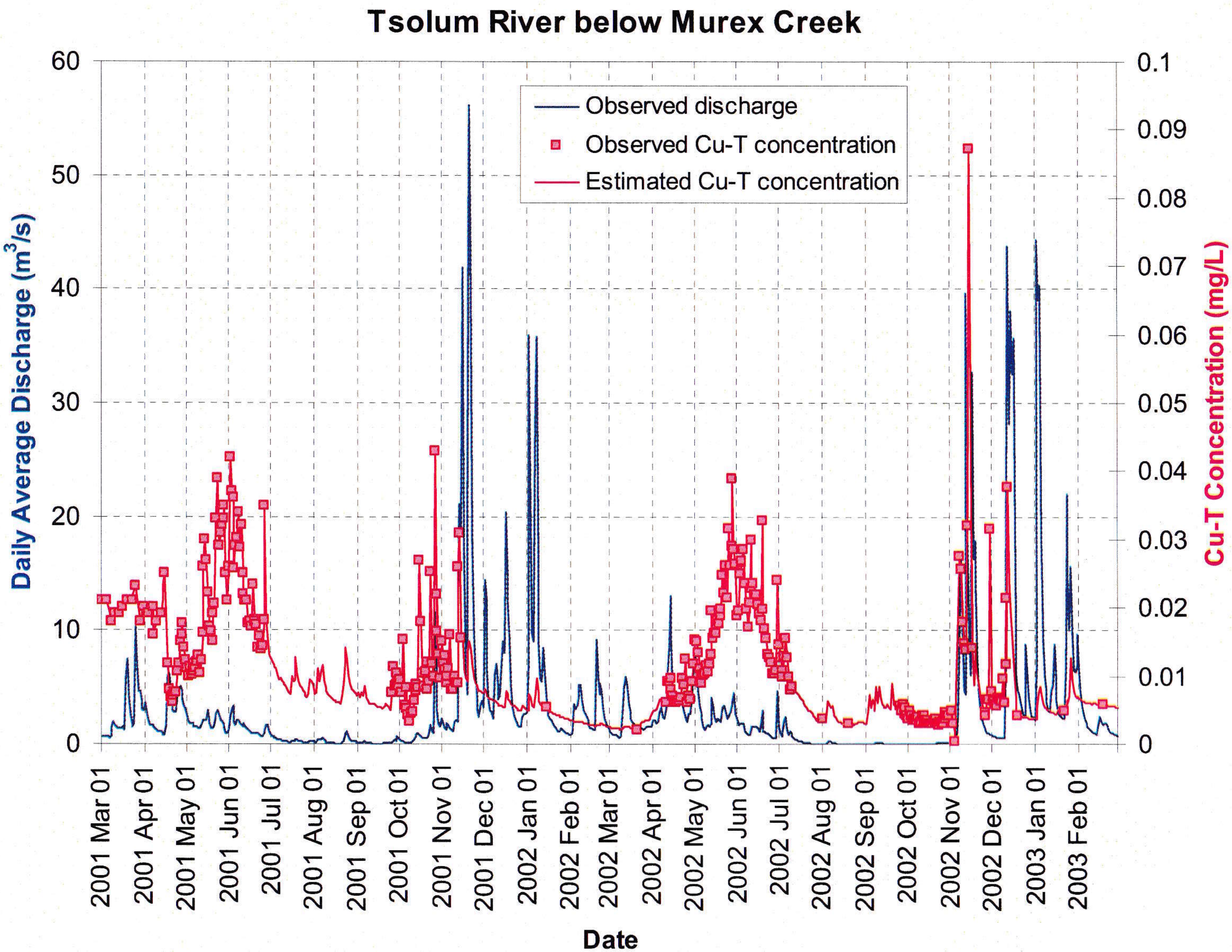
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Historical Water Quality (Total Cu vs. Time) Branch 126		
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 5



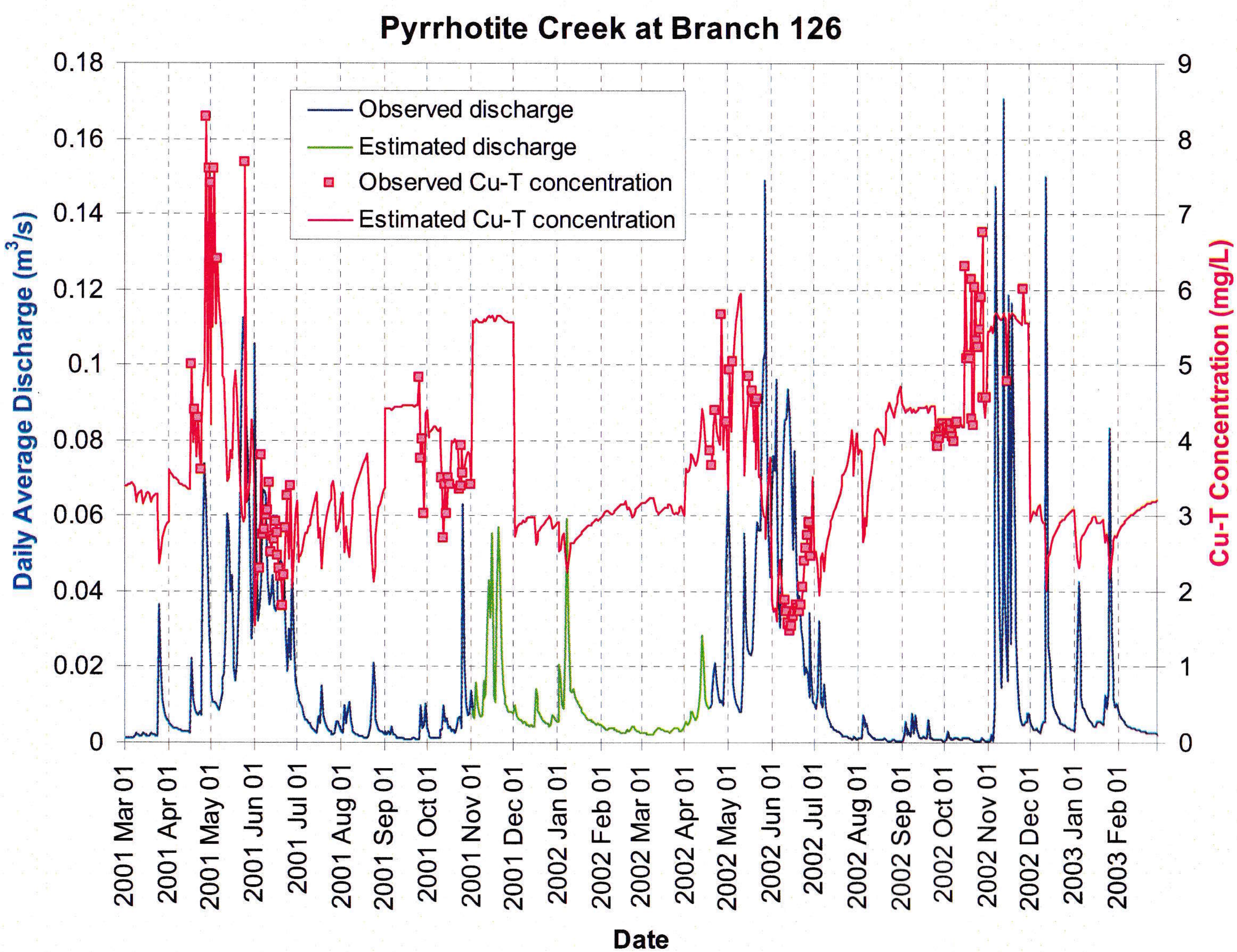
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Historical Water Quality (Total Cu vs. Day of Year) Branch 126
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: 6



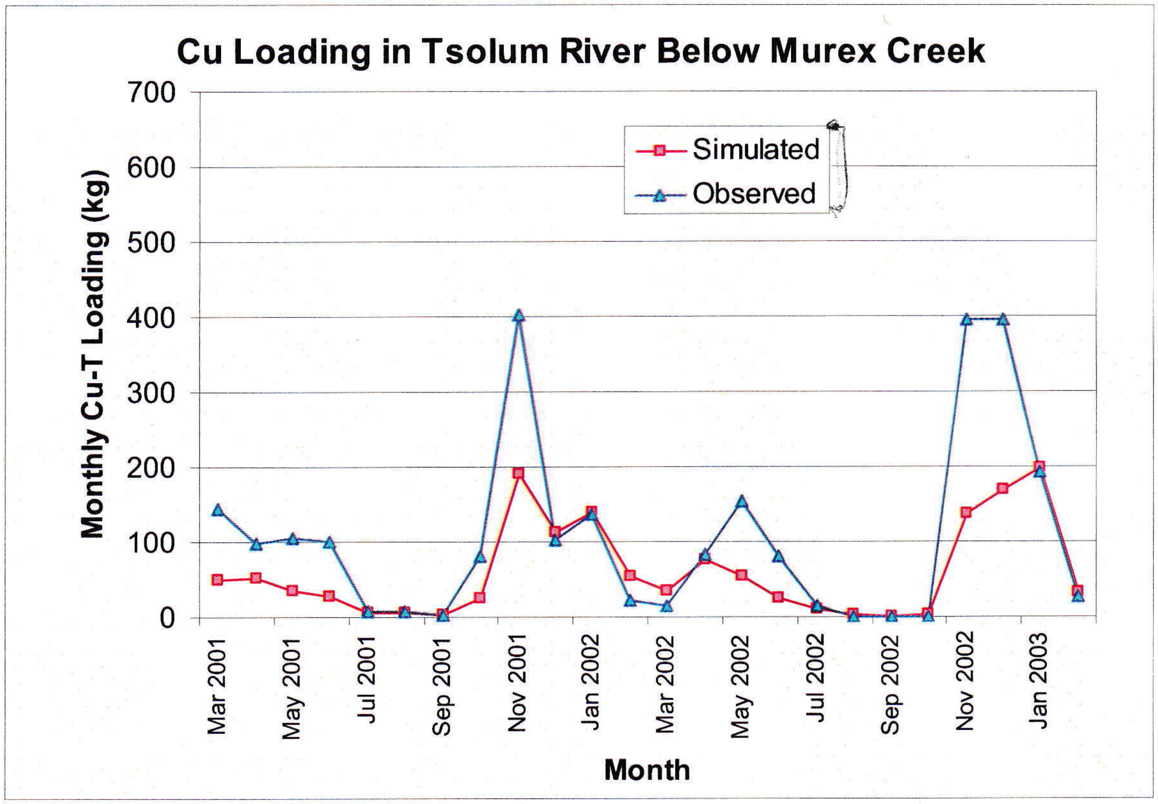
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Workshop Conclusions
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: 7

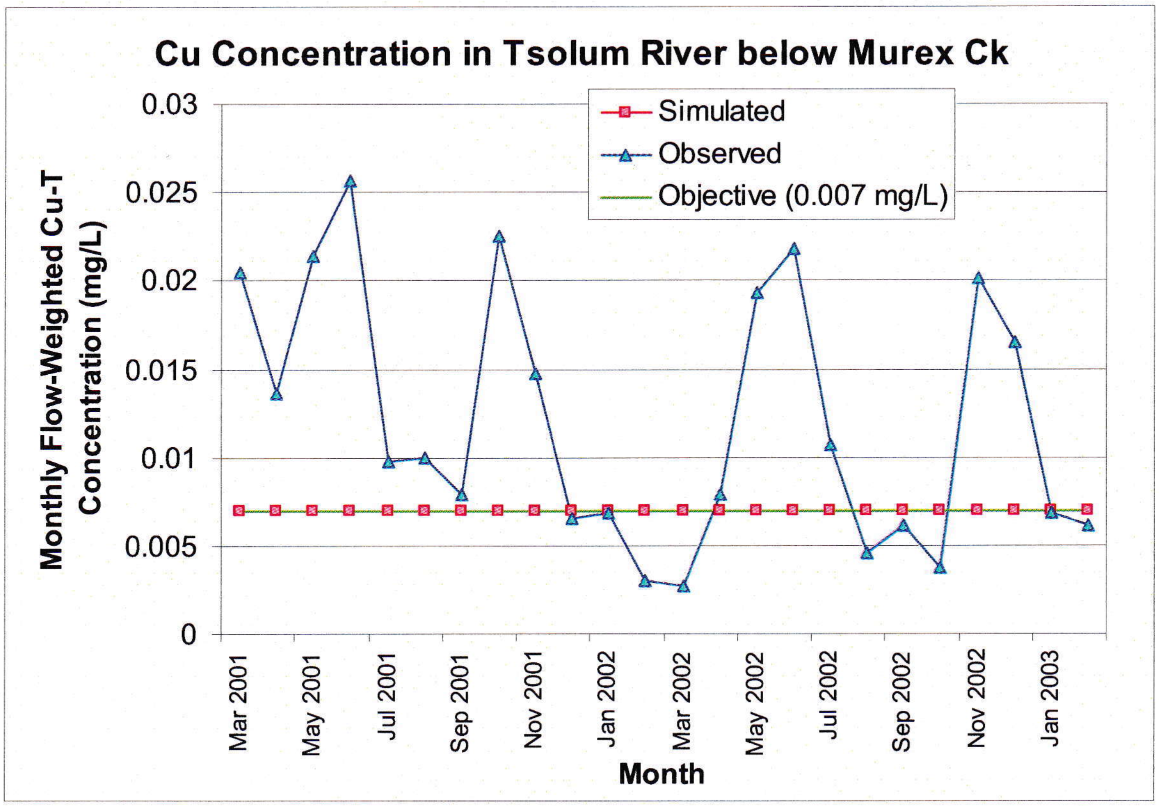


SRK Consulting Engineers and Scientists VANCOUVER	**Tsolum River Partnership**	**Tsolum River Patched Data**
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 · Approved: · Figure: 8

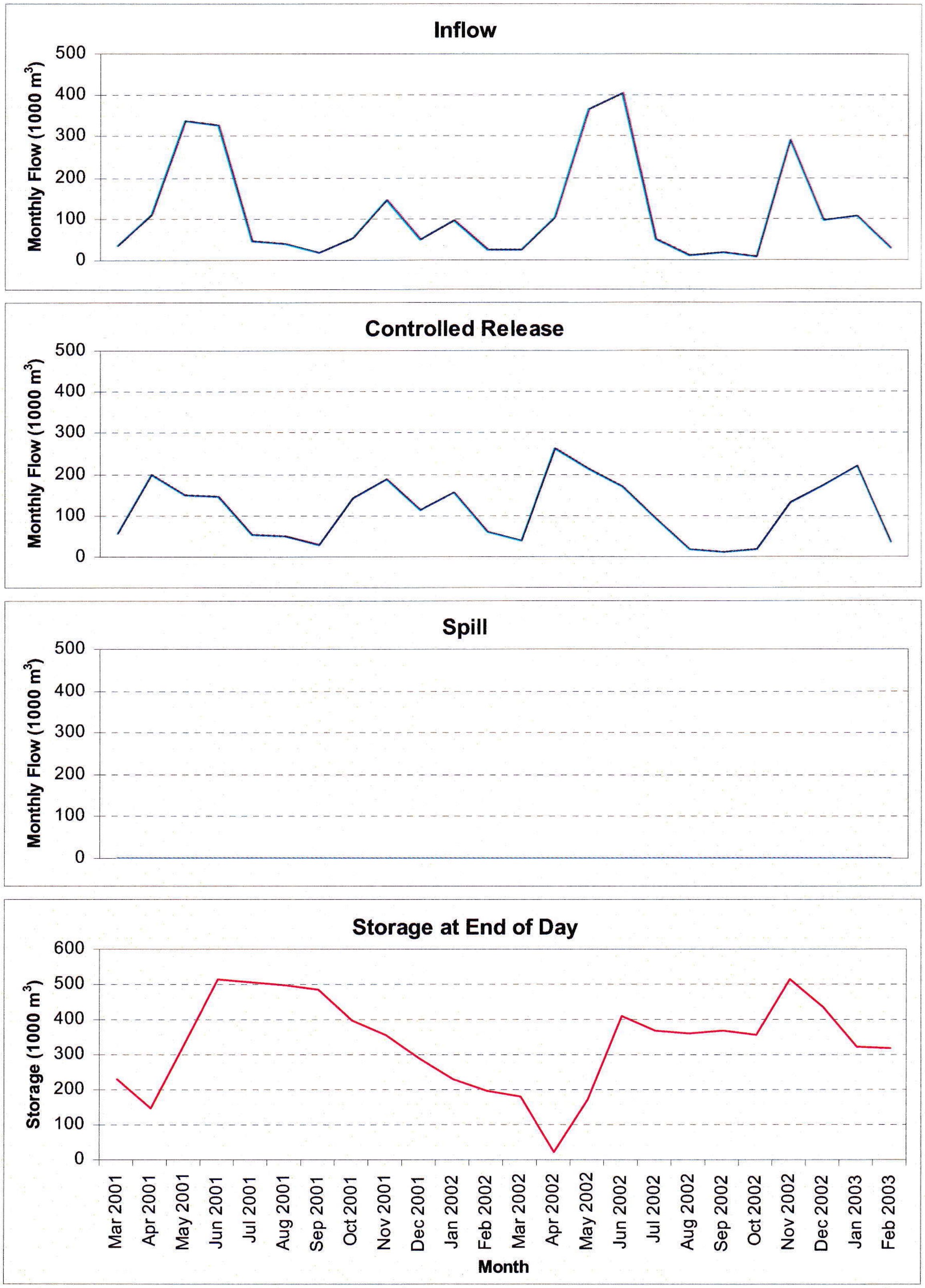


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Pyrrhotite Creek at Branch 126 Patched Data		
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 9





SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Scenario 1 60% Load Reduction at Mine and Equalization Reservoir		
Job No: 1CT001.000 Filename: Figure 1_Location.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 10



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Tsolum River Partnership

Scenario 1
Equalization Reservoir
Water Balance

Job No: 1CT001.000
Filename: Figure 1_Location.ppt

Mt. Washington Remediation
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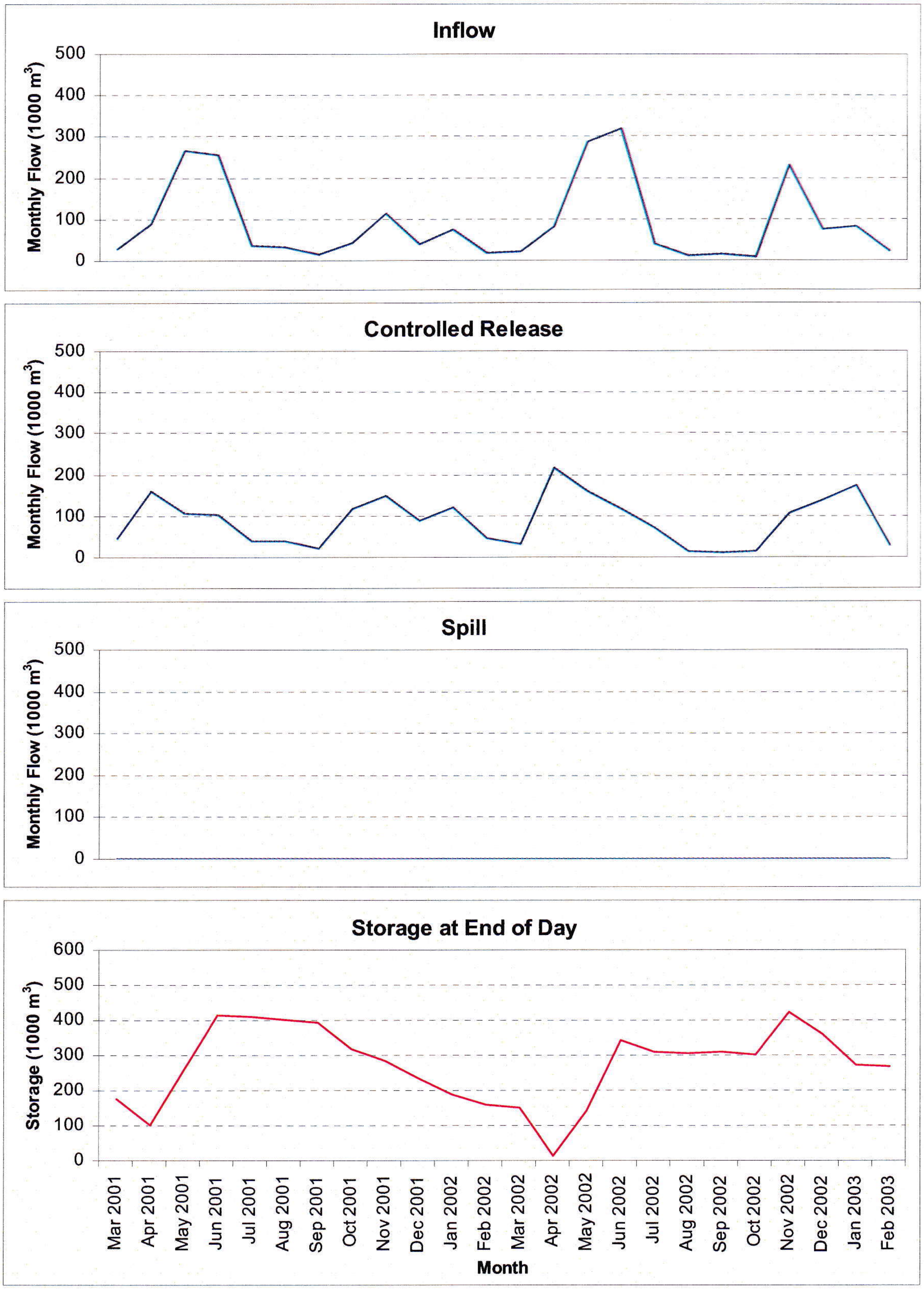

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Tsolum River Partnership

Scenario 2
Same as Scenario 1 Except Diversions Constructed in Catchment of Pyrrhotite Lake

Job No: 1CT001.000
Filename: Figure 1_Location.ppt

Mt. Washington Remediation
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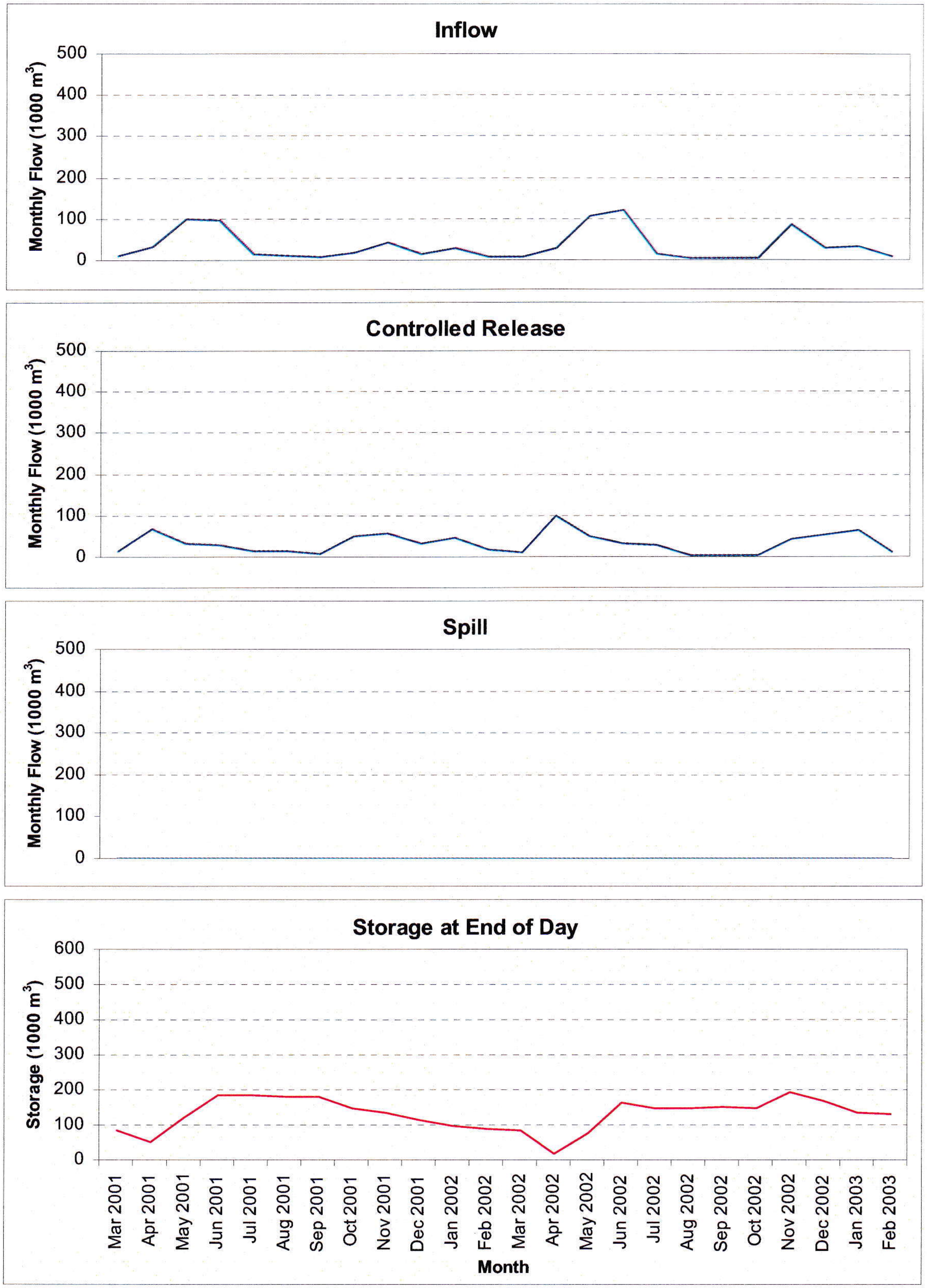
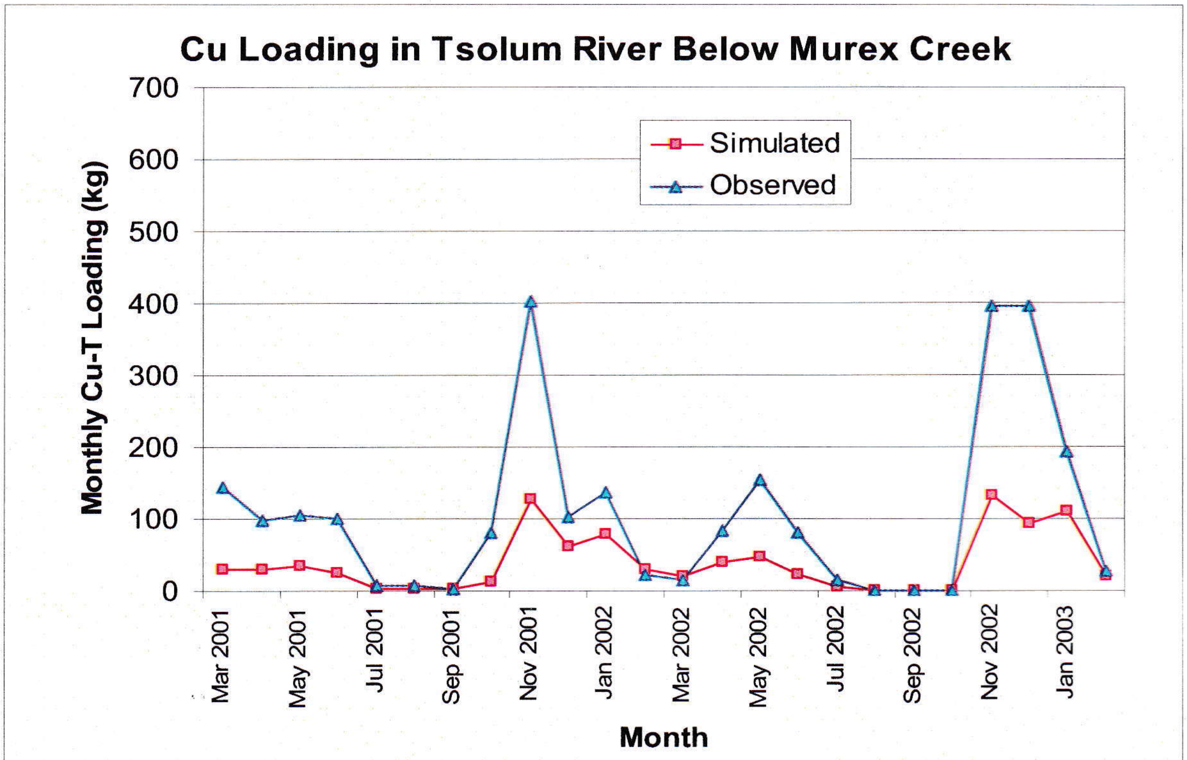
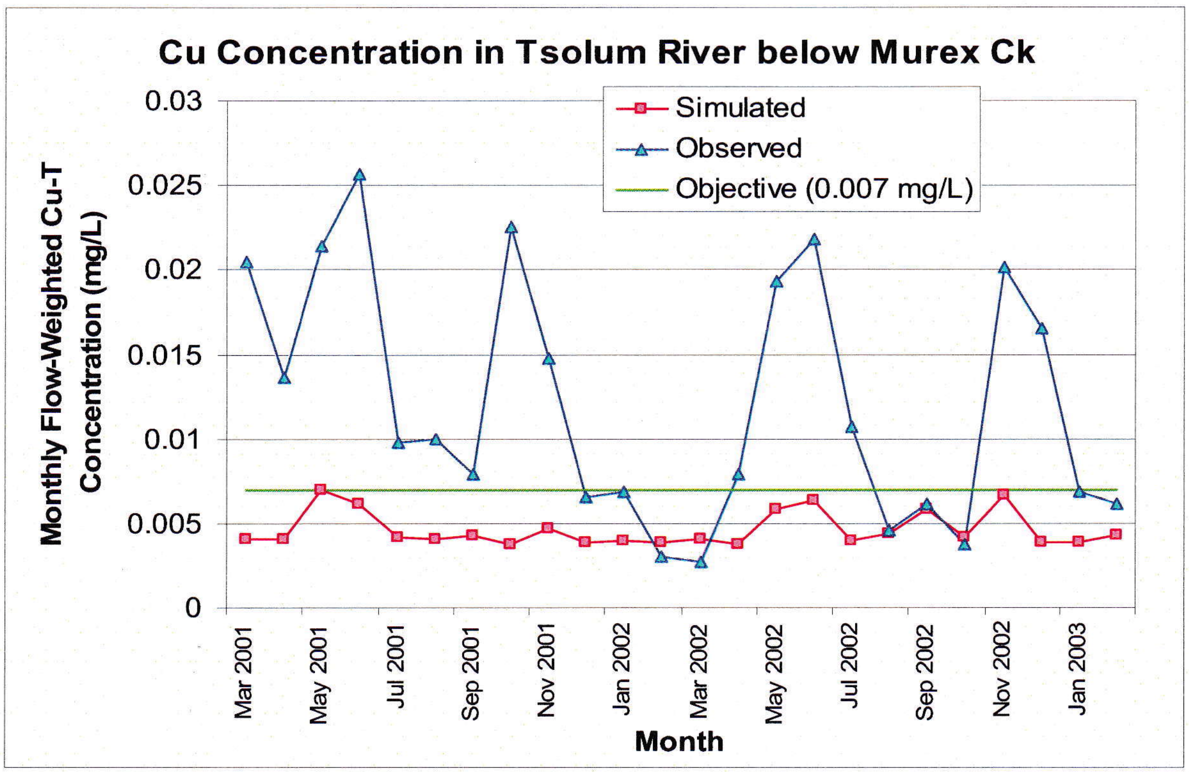
Date:	Approved:	Figure:
Feb. 2007		12

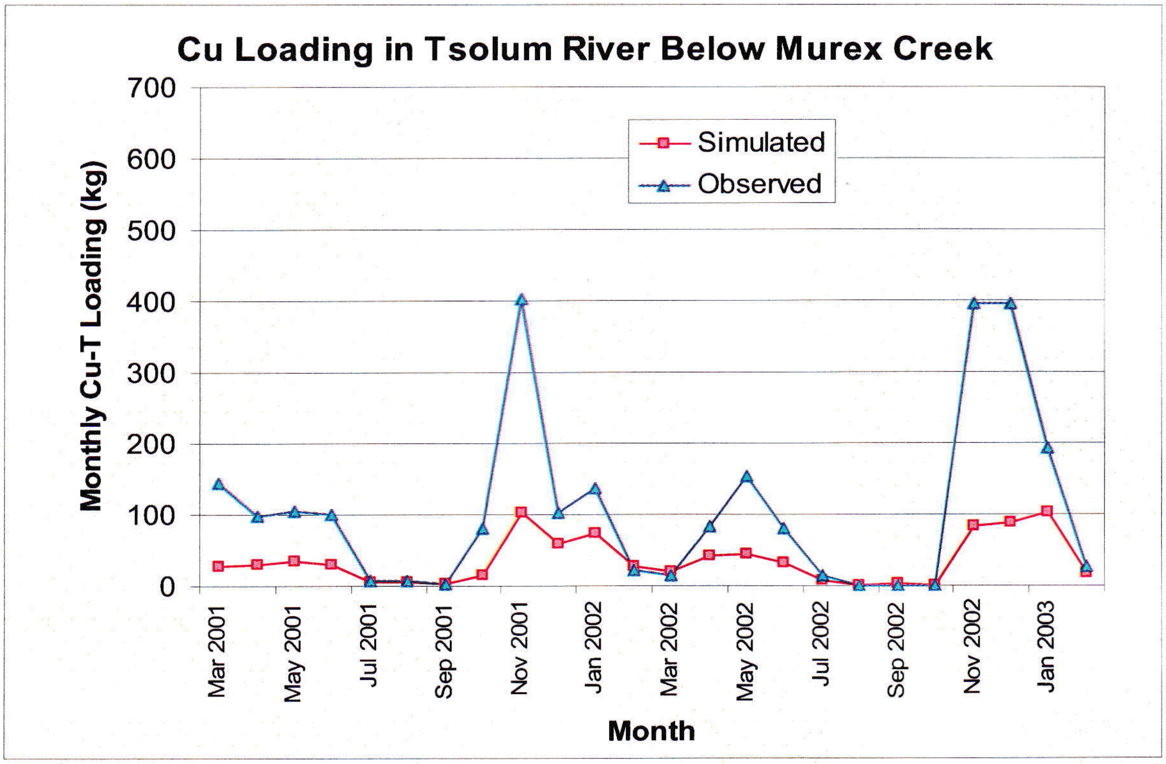


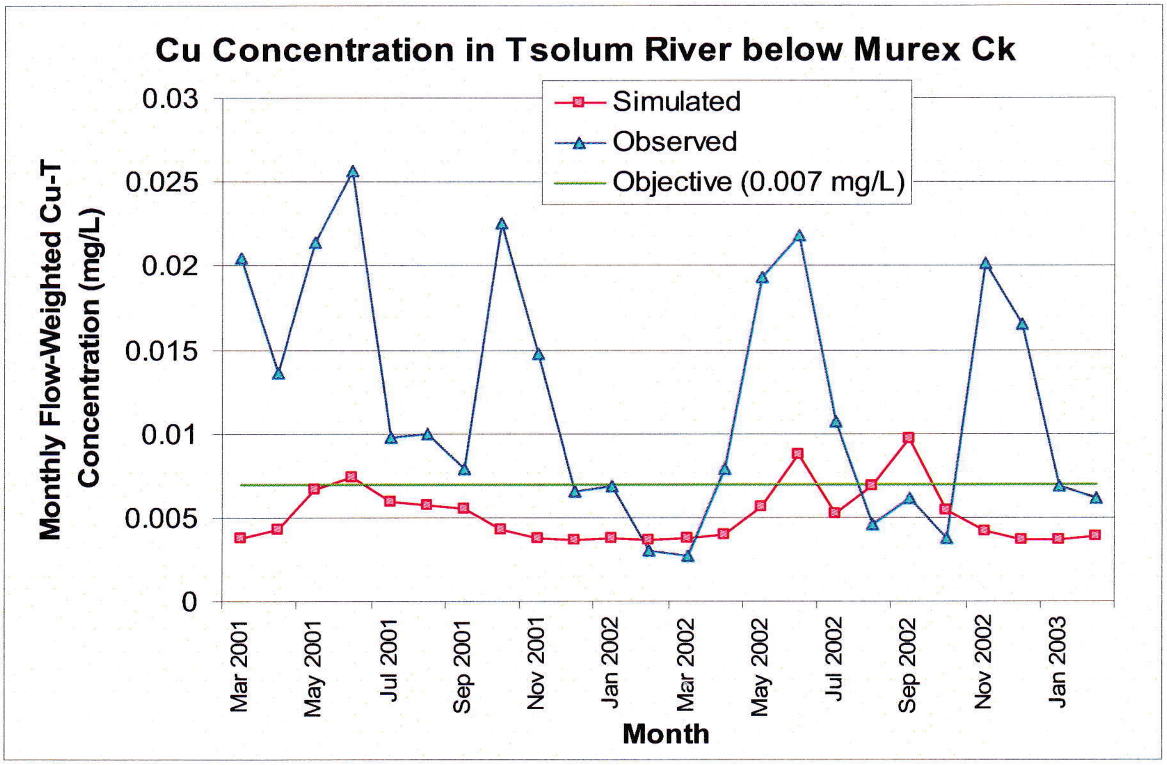
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Scenario 3 Same as Scenario 1 Except Pipeline Used to Convey Mine Water to Pyrrhotite Lake
Job No: 1CT001.000 Filename: Figure 1_Location.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 · Approved: · Figure: 13





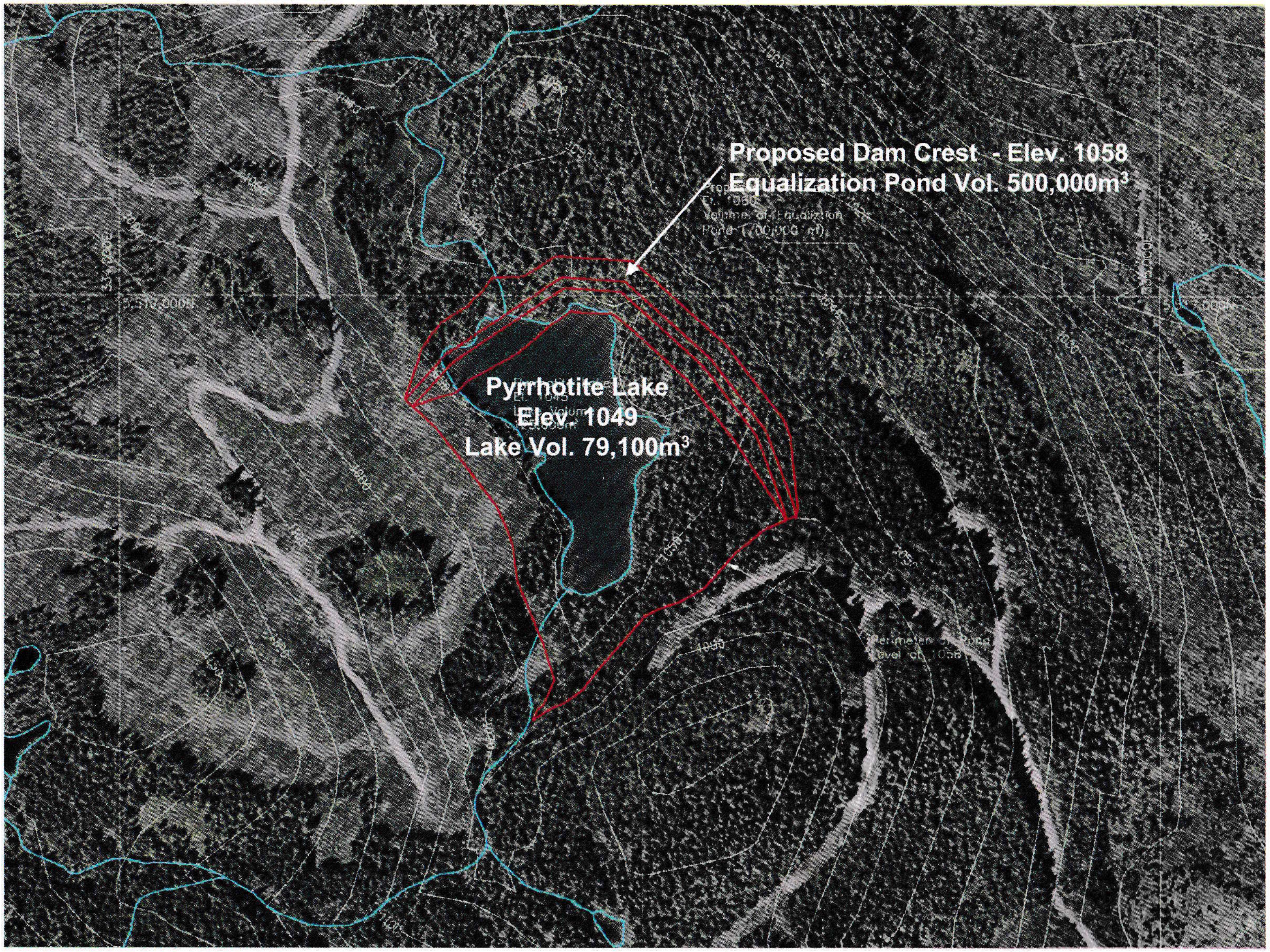
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Scenario 4 No Equalization Reservoir with 90% Load Reduction at Mine Site		
Job No: 1CT001.000 Filename: Figure 1_Location.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 14



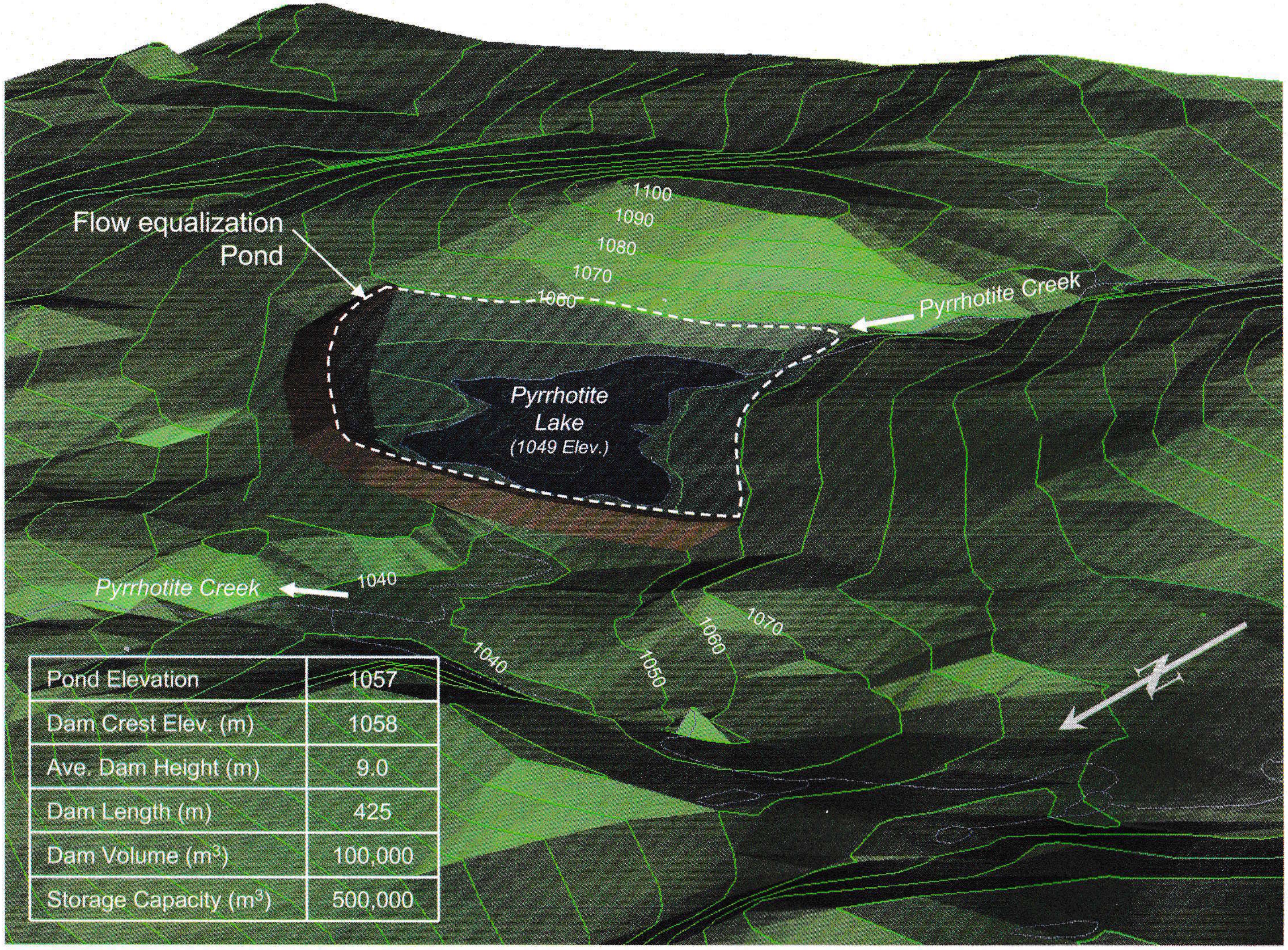


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	**Scenario 5** No Equalization Reservoir and Outflows from Pyrrhotite Lake Treated to a Concentration of 0.05 mg/L
Job No: 1CT001.000 Filename: Figure 1_Location.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: 15

SRK Consulting Engineers and Scientists VANCOUVER	**Tsolum River Partnership**	**Aerial Photos of Pyrrhotite Lake**
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: **16**

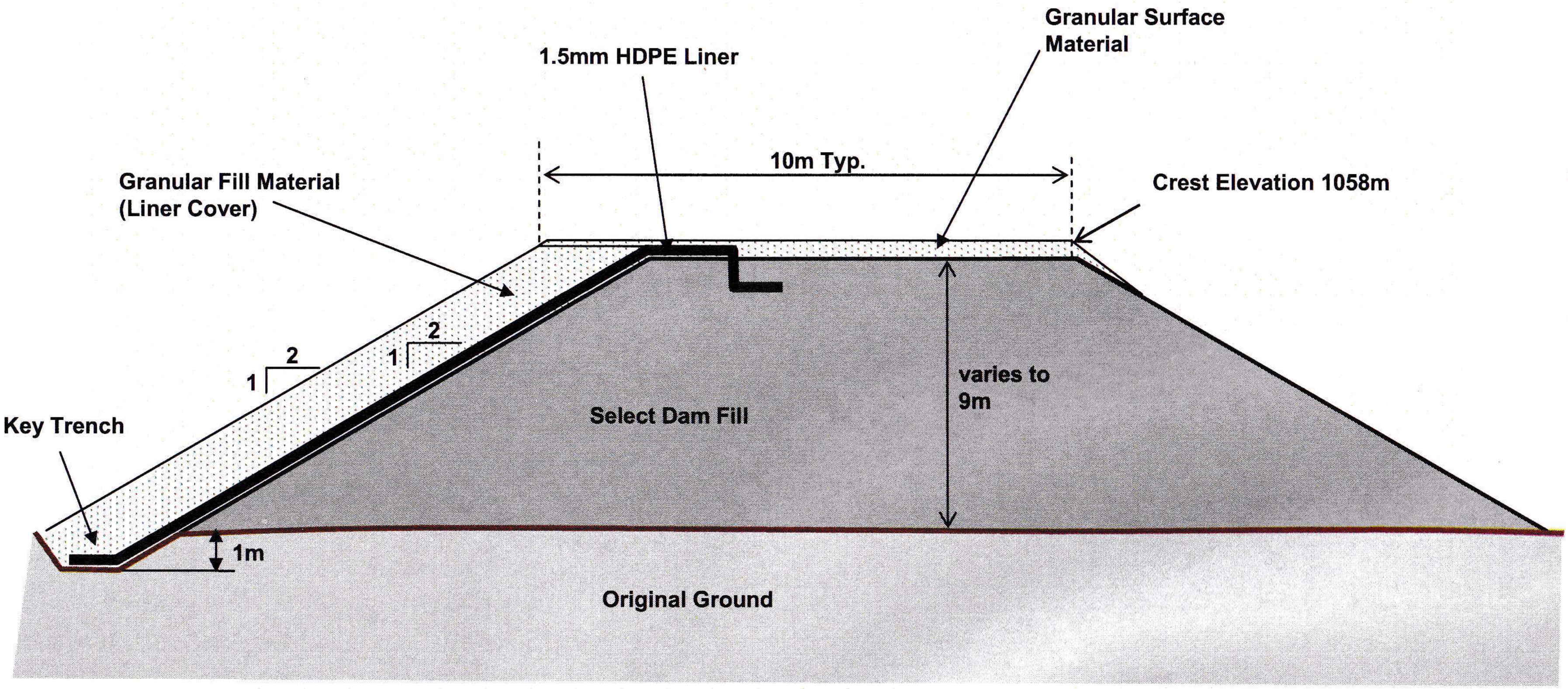


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Site Plan of Potential Flow Equalization Reservoir (Elev. 1058) (Method Option 1a)
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 | Approved: | Figure: 17

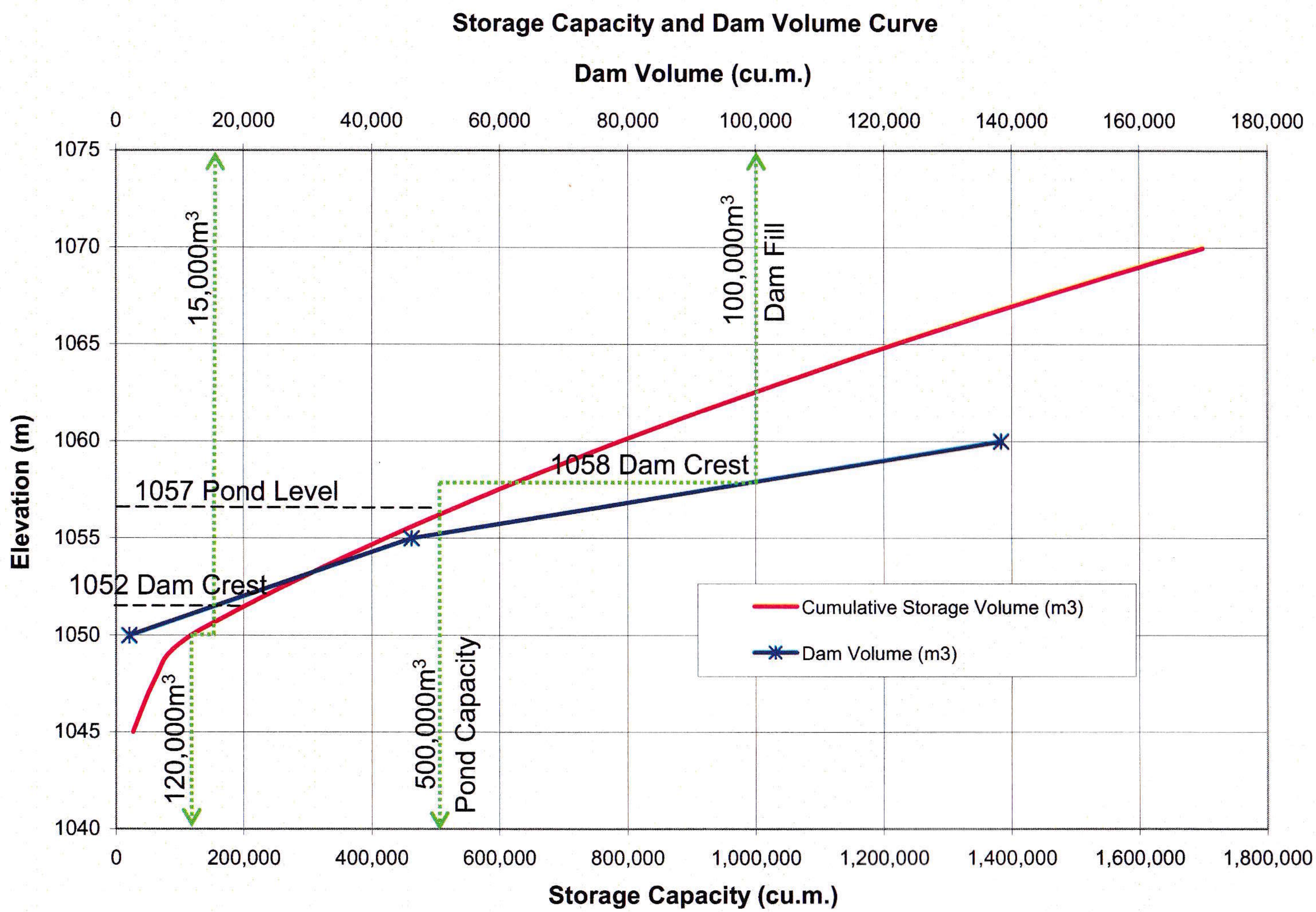


Pond Elevation	1057
Dam Crest Elev. (m)	1058
Ave. Dam Height (m)	9.0
Dam Length (m)	425
Dam Volume (m^3)	100,000
Storage Capacity (m^3)	500,000

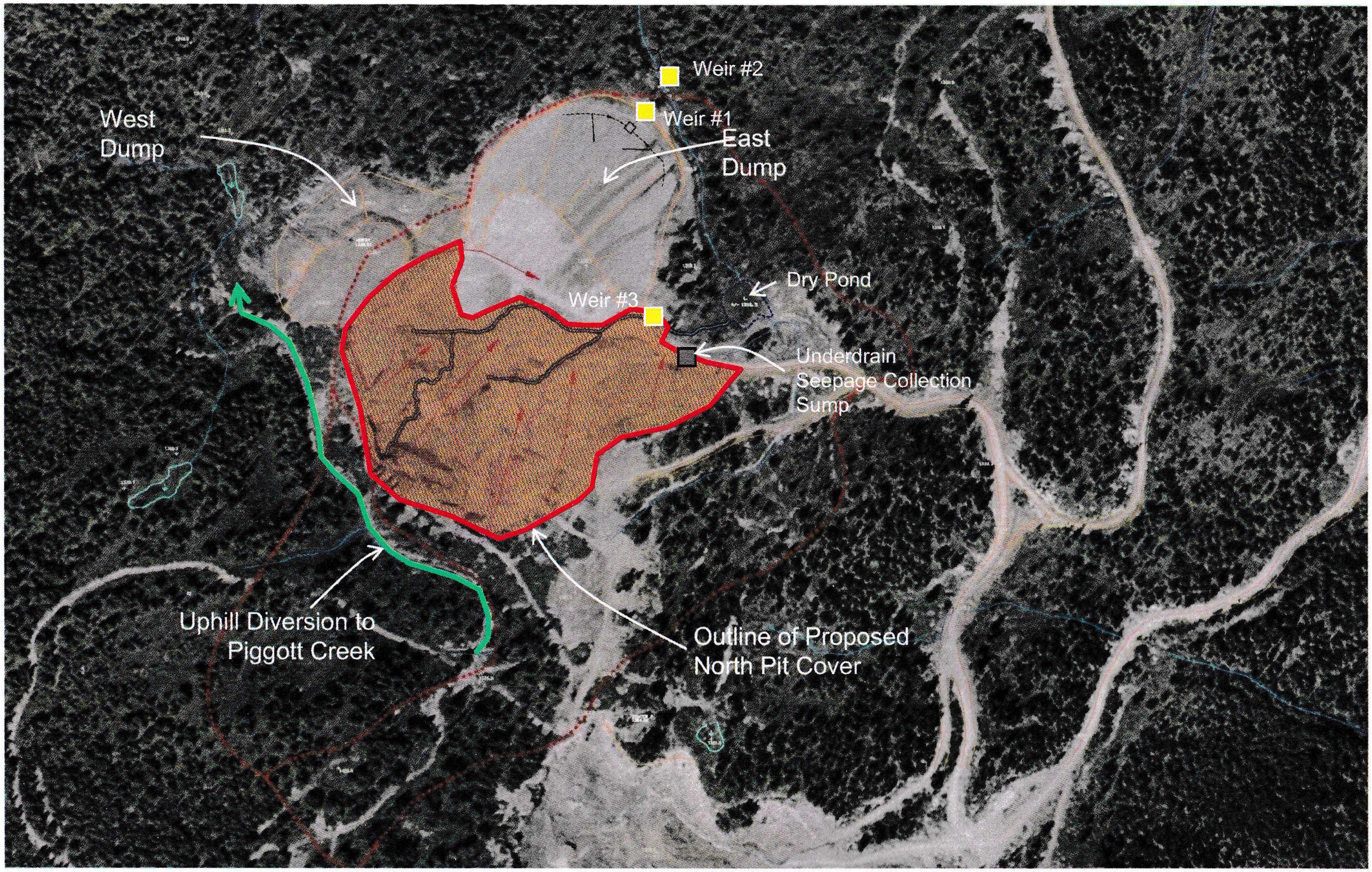
SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	3D Schematic of Flow Equalization Reservoir (Elev. 1058)
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 · Approved: · Figure: 18



SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Flow Equalization Reservoir Typical Dam Section (Method Option 1a)		
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 19

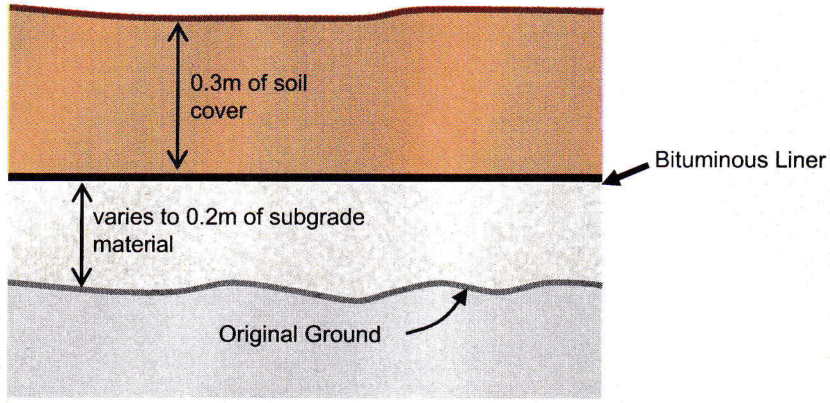


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Flow Equalization Reservoir Storage Capacity Curve
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 · Approved: · Figure: 20

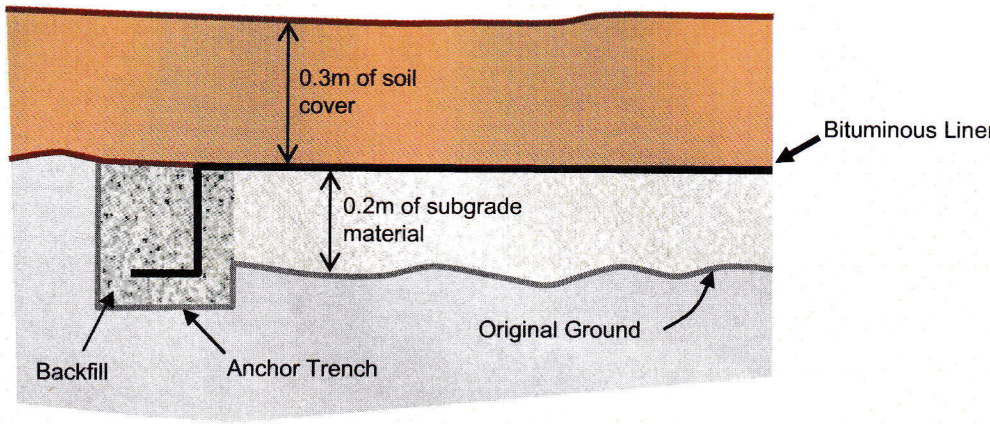


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Site Plan for North Pit Cover
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 | Approved: | Figure: 21

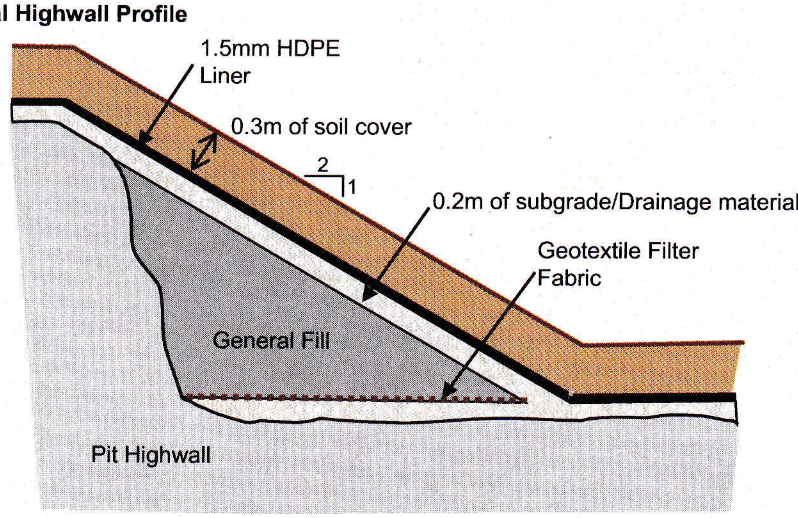
Typical Liner Cover Detail



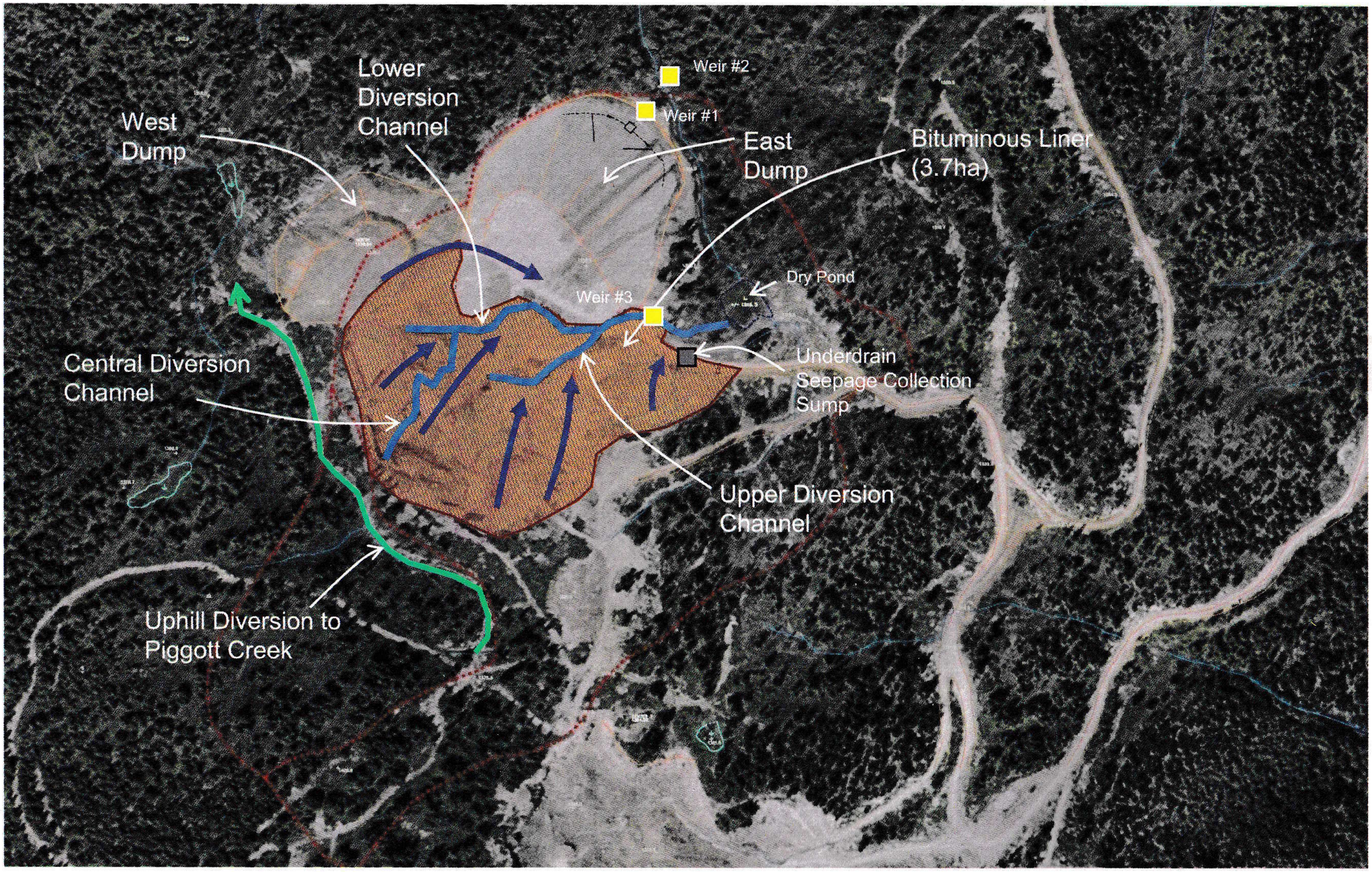
Typical Liner Anchorage



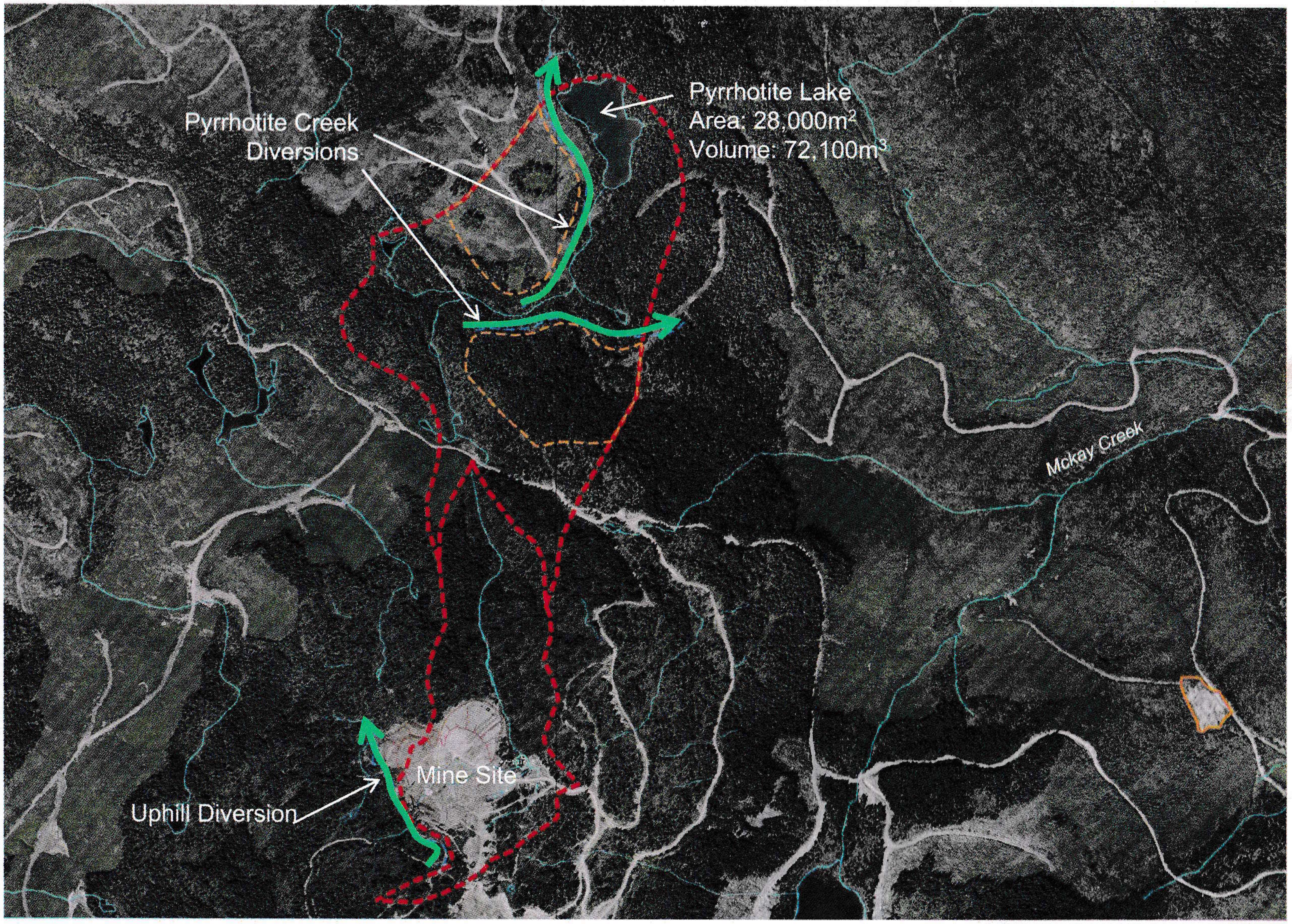
Typical Highwall Profile



SRK Consulting *Engineers and Scientists* VANCOUVER	**Tsolum River Partnership**	**Typical Details for Bituminous Liner**
Job No: 1CT001.000 Filename: Figure 21_25-Typ Details.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 | Approved: | Figure: 22

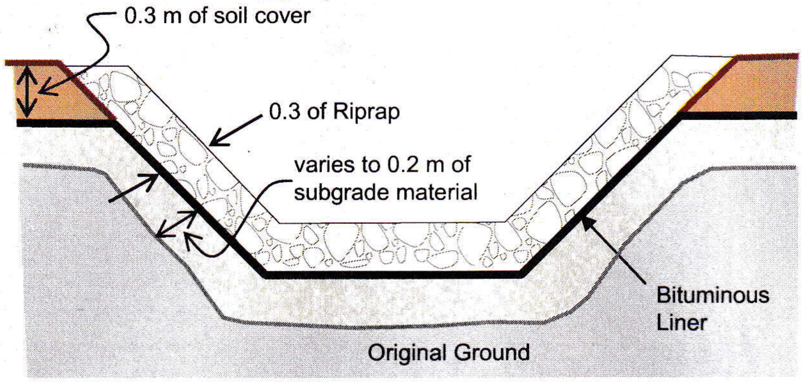


SRK Consulting Engineers and Scientists VANCOUVER	**Tsolum River Partnership**	**Surface Diversions at Mine Site**
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: 23

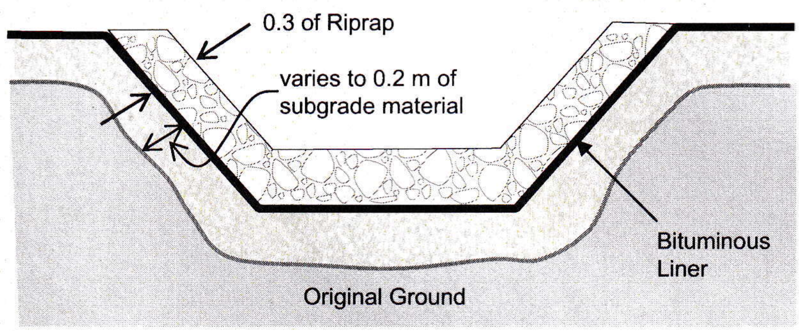


SRK Consulting Engineers and Scientists VANCOUVER	Tsolum River Partnership	Pyrrhotite Lake Surface Water Diversions
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: 24

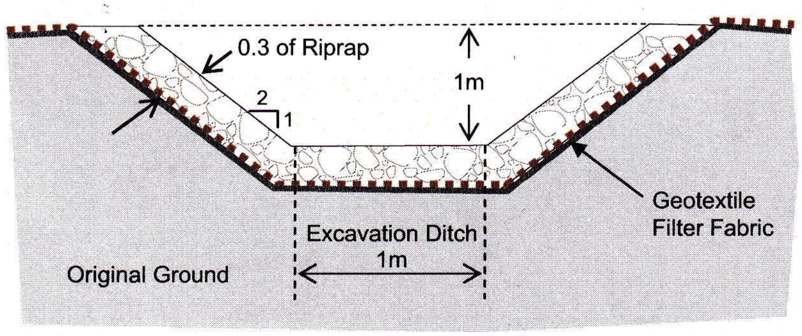
Typical Pit Drainage Channel Section



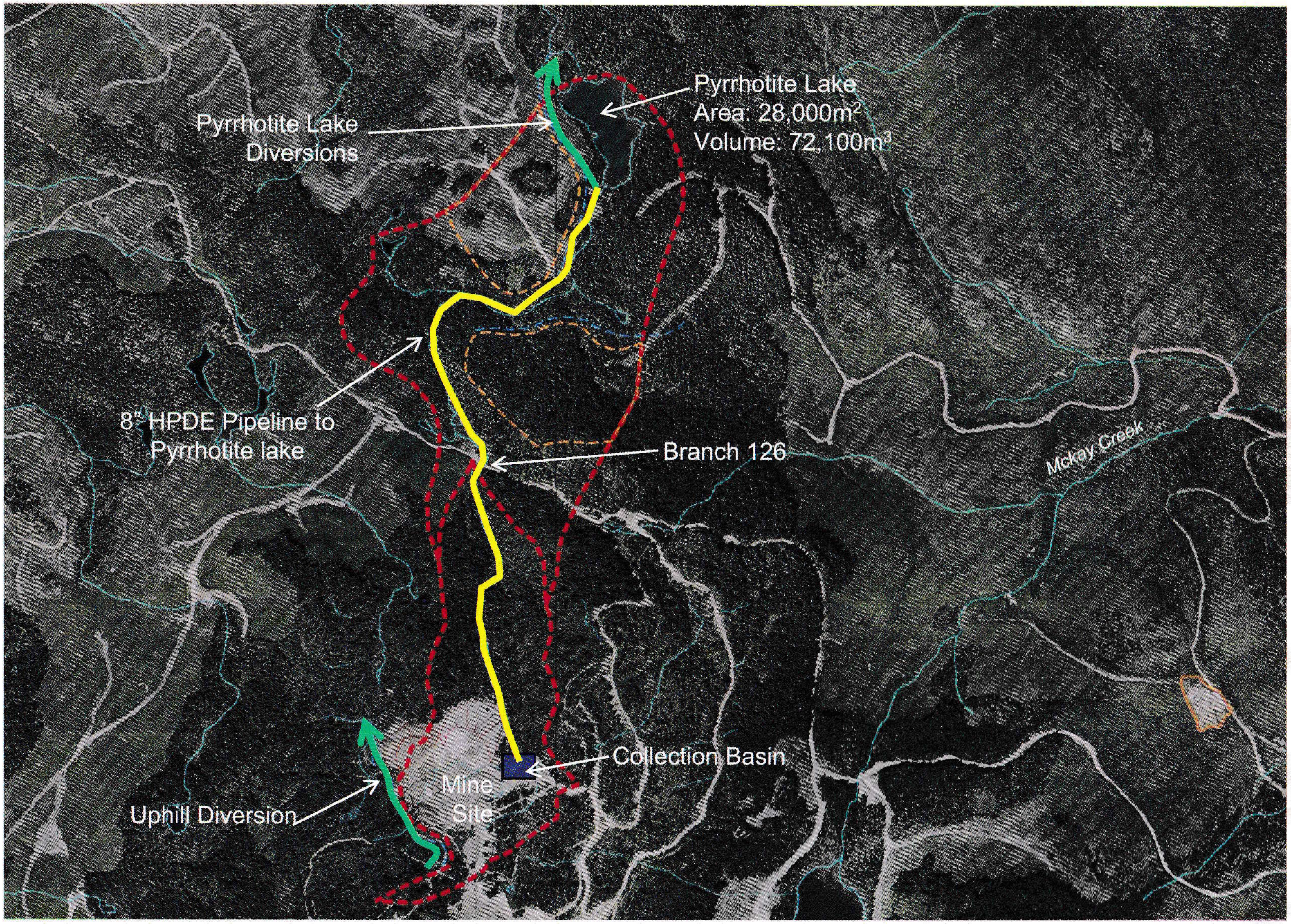
Typical Uphill Diversion



Typical Surface Diversion Channel – Pyrrhotite Lake



SRK Consulting Engineers and Scientists VANCOUVER	**Tsolum River Partnership**	**Typical Details for Surface Diversions**		
Job No: 1CT001.000 Filename: Figure 21_25-Typ Details.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007	Approved:	Figure: 25



SRK Consulting Engineers and Scientists VANCOUVER	**Tsolum River Partnership**	**Pipeline Alignment** **Site Plan**
Job No: 1CT001.000 Filename: Figure 3-9_16-20-Branch126-TsolumRiver_20070220.ppt	Mt. Washington Remediation Phase I Report	Date: Feb. 2007 / Approved: / Figure: **26**