FISHERIES HABITAT COMPENSATION PLANNING FOR MINE DRAINAGE IMPACTS AT THE ISLAND COPPER MINE

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ABSTRACT

The Island Copper Mine closed in 1995 after 25 years of productive life. The closure plan for the site was updated in 2004 using a risk-based approach to assess site risks and associated contingency measures. Closure planning studies predicted that ARD would worsen over time, and two small headwater lakes (the Twin Lakes) remained exposed to risks from potential increases in metal loads over the long term. A number of potential mitigation options were examined, and ultimately the Twin Lakes drainage and diversion option was selected because its implementation would ensure that any worsening ARD at the site would not impact the watershed as a whole. The project proceeded after CEAA screening and the approval of provincial and federal agencies. Five compensatory projects were completed to meet an objective of 2:1 fish habitat compensation, prior to the authorized destruction of the Twin Lakes. Compensation costs for ideal and typical compensatory works were $6/m^2$ to $40/m^2$, respectively. The successful completion of the Twin Lakes drainage and diversion project has eliminated the risk of future mine-related ARD impacts to the Stephens Creek watershed, while maintaining fish habitat quality.

INTRODUCTION

The Island Copper Mine was an open pit mining and milling operation that produced copper and molybdenum concentrates containing gold and silver as by-products (Figure 1). Located adjacent to the shores of Rupert Inlet on northern Vancouver Island, the mine began operations in 1971. By the time the mine closed in 1995, over 16,500 person years of employment had been created (Poling, 1998). Adjacent land use since pre-mine development has been dominated by forestry operations. The area is characterized by heavy rainfall averaging 1.8 m per annum, and temperature ranges annually from -8°C to 34°C with an annual mean of 9°C. The mine has been managed on a care and maintenance basis since its closure.

Planning for decommissioning at Island Copper was first addressed in 1988 when the company submitted a plan to expand the ore reserves and to proceed with development. Prior to 1988, there was no
regulatory requirement for Island Copper to submit a Closure Plan to any provincial ministry. The approval for the expansion was granted in 1988 and an amended reclamation permit was issued in 1989 that included a requirement that Island Copper develop and submit a closure plan for the property. A closure plan was developed in 1994, with addenda to the plan issued in 1996 and 2004.

The 2004 closure plan addendum addressed risks related to the industrial use areas, upland waste rock dumps, the pit lake, the beach waste rock dump, marine waters, and the downstream freshwater receiving environment of the Stephens Creek Watershed.

![Figure 1: Location of the Island Copper Mine](image)

This paper discusses the future potential risks related to acid rock drainage (ARD) at Island Copper were ultimately addressed through the removal of two small lakes from the watershed and the associated implementation of a No Net Loss (NNL) plan for fish habitat.

**BACKGROUND**

Reclamation

Reclamation at Island Copper started during operations in the 1990s, and of the 772 ha of originally disturbed land at the site, 689 ha has been reclaimed. Areas that were not reclaimed include access roads and the industrial site that was sold in 2004. To mimic successional patterns that occur naturally in the region, reclamation of lands has consisted of contouring and capping all of the dumps with nominal 0.5 m glacial till, seeding with a grass and legume mixture and planting with woody species. Red alder was selected as the primary vegetation species because it is a natural pioneer, owing to its association with nitrogen fixing bacteria. This species accounts for 86% of the approximate 600,000 trees that have been planted for reclamation since 1978 (Polster, 2007). Conifers have also been planted, including lodgepole pine, Douglas fir, hemlock, Sitka spruce, and red cedar. Grass and legume species seeded on
the upland dumps include creeping red fescue, perennial rye grass, orchard grass, timothy, red top, alfalfa, alsike clover and white clover.

Reclamation treatments at Island Copper now provide an array of stands of varying ages. Older stands now show the transition from an artificial assemblage of species to one that reflects the natural species diversity in the area (BHP Billiton, 2006). Forest stands on the North Dump are largely indistinguishable from similar 20 year old stands on local natural disturbances such as land slides (MEM, 2006). Aerial photographs of the site in the last year of production (1995) and in 2002 illustrate the dramatic effect that reclamation treatments have had on the site’s landscape (Figure 2).

![Aerial photographs of Island Copper in final production year (1995) and post-closure (2002)](image)

**Figure 2: Aerial photographs of Island Copper in final production year (1995) and post-closure (2002)**

**ARD Status**

The majority of the 650 million tonnes (Mt) of waste rock stored at Island Copper was placed in the Beach Dump (560 Mt). Of the remaining 90 Mt of waste rock placed upland, approximately 86% is located in the North Dump. Constructed in 1971 and 1985, it contains approximately 77 million tons of rock (on average 63%) and glacial till (on average 37%) and covers about 175 ha. Side slopes range from 16 to 20 degrees, providing factors of safety acceptable for long-term stability of the dump. Although acidic drainage with elevated concentrations of copper and zinc was identified very early in the operation of the mine, recent studies in support of the 2004 closure plan addendum demonstrated that historical studies underestimated the acid generating potential of the upland waste rock dumps (SRK, 2003; BHP Billiton, 2004). The recent studies found that the fine fraction of the waste rock produced by blasting had a greater ARD potential than the rock as a whole. Earlier work analyzed whole rock samples primarily from drill hole cuttings and did not account for this factor. It was concluded that the majority of the waste rock is potentially acid generating, and that components of the rock containing higher sulphur concentrations are already acidic. Lower sulphur components of the rock are expected to become acidic in the future as the neutralization potential of the rock is gradually depleted. For the catchment of the North Dump, the worsening ARD quality over time may cause large increase in zinc loadings from the dump, as well as an increase in other metals.
Seepage waters from the different parts of the North Dump vary from seasonally non-acidic (Old North Dump) to perennially strongly acidic (eastern most regions). The strongest acidity is generally apparent where the glacial till content is lower (SRK, 2003). The majority of the drainage from the North Dump is collected in a ditch system and reports to the pit lake for semi-passive treatment. The pit lake fertilization treatment is described in Poling et al. (2003). Water draining from the Old North Dump is collected in the North Dump Drainage (NDD) ditch, however the portion of this ditch that is adjacent to the Twin Lakes is perched and constructed on waste rock. Water from this ditch is not completely contained and seeps towards East Twin Lake. Future worsening of ARD flowing in this ditch was of concern in terms of potential future risks to the water quality of the Twin Lakes and downstream water courses.

Twin Lakes

The Twin Lakes (Figure 3) are two small fish-bearing lakes located in the north-west corner of the Island Copper property near the south-eastern headwaters of the Stephens Creek watershed. A fish habitat and community characterization study conducted in 2004 identified five species of fish inhabiting the Twin Lakes: coho salmon (*Oncorhynchus kisutch*), prickly sculpin (*Cottus asper*), threespine stickleback (*Gasterosteus aculeatus*), cutthroat trout (*Oncorhynchus clarki*) and Dolly Varden char (*Salvelinus malma*), in descending order of relative abundance.

![Figure 3: Twin Lakes at Island Copper (note pre-mine lake contours that illustrate areas in-filled during early mine development)](image-url)
The lakes are twinned at a narrows that divides the lakes into East Twin Lake and West Twin Lake, which has an outflow draining to Francis Lake. The lakes occupy approximately 6% of the Francis Lakes drainage, and about 1% of the overall Stephens Creek watershed. The catchment area immediately north of the Twin Lakes extends over ground that has been logged and explored for minerals, but has not been disturbed by mining. The two streams that flow into West Twin Lake account for approximately 80% of the inflow water to the Twin Lakes system. The two inflows into East Twin Lake account for the remaining 20% of inflows to the lake system. Historically, a beaver dam controlled the outflow from the Twin Lakes system. Downstream of the beaver dam, the stream flows through a channel and into Francis Lake.

During the early development of the mine, the Twin Lakes were modified when the western edge of the North Dump was constructed next to East Twin Lake. The NDD ditch was constructed to divert runoff from the North Dump to the open pit. This perched ditch is constructed on waste rock, and leakage may contribute to future impacts to the Twin Lakes water quality. In addition, the southern halves of both lakes were filled with rock as part of mining operations (Figure 3).

The water quality in the hypolimnion of West Twin Lake has been deteriorating and a short-term measure was implemented for two years that pumped hypolimnetic water to the pit lake during high winter flows. This was done as a contingency measure to protect Francis Lake water quality in the event of failure of the beaver dam, at the outlet of West Twin Lake, during high flows. Although this mitigation reduced the risk of downstream release of hypolimnnetic water from the lake in the event of a beaver dam failure, the mitigation was not practical for the long-term and did not sufficiently reduce long-term risks.

**RISK MANAGEMENT PROCESS**

Island Copper closure plans were prepared in 1994 and updated in 1996 and 2004. The 2004 closure plan provides updates to:

- Develop a long-term water management program to ensure that water quality objectives continue to be met.
- Continue to develop productive end land use including wildlife habitat and economic development. Wildlife goals are supported by the development of sustainable vegetation covers, by erosion resistant water courses, and by sustaining fish habitat along the foreshore.
- Minimize long-term care and maintenance requirements while maintaining a high standard of performance in areas of Health, Safety, Environment and Community.

The development of the closure plan began in the late 1980s with regular updates based on assessment work and option analysis. The 2004 update of the closure plan was prepared using a risk-based approach that sought to minimize the negative long-term health, safety, environment and community impacts. The closure plan update was the culmination of two years of work that included (Pierce and Wen, 2006):

- Initial closure option screening
- Risk rating of initial options
- Internal peer review of preferred options
- Residual risk rating of preferred options
- Closure plan risk-based valuation analyses
• Closure option selection
• Internal review of selected options
• Development of site risk register of selected options
• Risk rating of selected options
• Regulatory approvals
• Implementation of closure options

Post-closure residual risks, which are those risks that remain after closure and reclamation activities have been executed, were reviewed based on the timing and probability of the risk eventuating. The consequence of each risk, should it eventuate, was considered and the associated activities and costs were estimated.

It became apparent after nearly 10 years of post-closure monitoring that the care and maintenance, monitoring and site management would be required in perpetuity. This change was required because of the risks associated with mine drainage and requirements to treat the drainage (Pierce and Wen, 2006). The paradigm for site management was adjusted to reflect this reality – Planning for In Perpetuity Mine Closure.

An assessment of the specific risks related to the water quality in the Twin Lakes, and in the larger Stephens Creek watershed, identified that a permanent solution was required to ensure good long-term water quality in these water bodies. The risk of deteriorating water quality was estimated to increase over time as the carbonate neutralizing potential depleted in the waste rock. A number of mitigation options were assessed, including among others, the *status quo* (long term pumping of hypolimnetic waters to the pit lake), construction of cut-off walls to prevent seepage waters from entering the lake, and the removal of the Twin Lakes from the Stephens Creek watershed. The *status quo* was deemed unacceptable because the long-term quality of seepage waters entering East Twin Lake was predicted to deteriorate. The option to install a cut-off wall between East Twin Lake and the Old North Dump was also deemed unacceptable because the design could not ensure complete capture of seepage waters. The predictions of long-term worsening water quality meant that neither of these options sufficiently minimized risks related to the health of the Twin Lakes and the larger Stephens Creek watershed.

A third option was to divert the Twin Lakes away from the natural system and into the pit lake for treatment. A planning study showed that the Twin Lakes supported a fish community typical of BC coastal watersheds. Therefore, integral to the Twin Lakes diversion plan was the authorization and implementation of a fish habitat compensation plan. Preliminary upset costing placed the Twin Lakes diversion project and associated fish habitat compensation at approximately six times the cost of proposed alternative mitigation, including the construction of cut-off walls at the Twin Lakes. Once implemented, however, the Twin Lakes diversion option would ensure that the Stephens Creek watershed would be protected from any long-term worsening of ARD conditions at Island Copper.
The Twin Lakes diversion project was developed as part of the 2004 closure plan update. The diversion of the Twin Lakes was chosen as the best option to meet the objective of good long-term water quality in the Stephens Creek watershed. The concept for the diversion project was:

- Divert the majority of flows around West Twin Lake to its outflow
- Construct the diversion as fish habitat
- Construct a ditch to drain the Twin Lakes into the pit lake for semi-passive treatment
- Design and construct additional fish habitat to compensate for the loss of the Twin Lakes fish habitat

Although straightforward in concept, it was identified early on in the project planning phase that permitting and the identification of fish habitat compensation projects would be the most challenging aspect of the project. Permitting challenges were expected because numerous community stakeholders and a multitude of regulatory agencies would be involved, and because the removal of the Twin Lakes from the natural system would be covered under the Department of Fisheries and Oceans (DFO) federal Policy for Management of Fish Habitat that applies to all habitat that directly or indirectly influences the productive capacity of fish-bearing waters (DFO, 1986). The Twin Lakes system supports the rearing of coho salmon and cutthroat trout (as well as the ‘blue-listed’ Dolly Varden char), and therefore it indirectly supports the commercial fishery of coho in waters around the northern end of Vancouver Island and the recreational fishery of cutthroat trout in Stephens Creek. The removal of the Twin Lakes from the natural system would necessitate Harmful Alteration, Disruption or Destruction (HADD) of fish habitat under the Fisheries Act, thereby triggering the Canadian Environmental Assessment Act (CEAA, screening level). Any HADD related to the project would require a Fisheries Act Authorization (FAA).

The DFO Policy objective is “net gain of productive capacity of fish habitat.” The guiding principle of habitat conservation is “no net loss of the productive capacity of habitat.” In simple terms, it means that any fish habitat lost to a project must be replaced with an equal amount of fish habitat. There is a hierarchy of preferences:

- Avoid HADD by redesigning or moving the project
- Compensate by replacing lost habitat with natural habitat on site (i.e., like-for-like compensation)
- Compensate by increasing the productive capacity of existing habitat on site (i.e., compensating for one type of fish habitat with habitat of a different type, preferably on site)
- Compensate by replacing lost habitat with natural habitat in another watershed
- Compensate by using artificial production (e.g., fertilizing lakes or building hatcheries)

The first option could not be met because significant residual risks were expected even with the construction of a cut-off wall to isolate the Twin Lakes from waste rock seepage. The next three options in the hierarchy were chosen.

A Habitat Evaluation Procedure (HEP) was used to develop the NNL plan for the Twin Lakes at Island Copper. HEP was originally developed by the US Fish and Wildlife Service in response to initiatives by the US government for sustainable management of water resources. HEP is a generalized procedure for
assessing habitat suitability in streams and lakes. By multiplying habitat area by Habitat Suitability Indices (HSI), the HEP produces Habitat Units (HU) that are indices of both habitat quantity and quality. There are four steps in HEP:

- Initial scoping
- Development of Habitat Suitability Indices (HSI)
- Habitat assessment of the project area and of the compensatory works
- Preparation of a budget of lost and gained HUs

The flowchart linking these steps is shown in Figure 4. This process was followed in the development of the NNL fish habitat plan for the Twin Lakes. The HSI models allowed habitat to be weighted by its value to fish, thereby identifying those types of habitat that truly contribute to overall productive capacity and those types that contribute little. This allowed the preparation of defensible habitat budgets. A number of recent examples of NNL plans are based on habitat suitability modelling.

The initial scoping was conducted as part of the 2004 closure plan update. This included field studies to identify potential compensatory works in Stephens Creek, and neighboring watersheds. A total of 11 candidate compensatory projects were identified that could contribute to a compensation ratio of 2:1 or greater that has been recommended to attain the guiding policy principle of No Net Loss (Minns, 2006).

Figure 4: Links between steps in the calculation of habitat units
HSI models for the species affected, either by habitat loss or habitat gain, were then used to calculate HU budgets. The following four HSI models were used: coho salmon (McMahon, 1983), chum salmon (*Oncorhynchus keta*) (Hale *et al.*, 1985), cutthroat trout (Hickman and Raleigh, 1982) and rainbow trout (*Oncorhynchus mykiss*) (Raleigh *et al.*, 1984). All four models were based on a comprehensive review of the published scientific literature and were described as being applicable to small coastal streams such as Stephens Creek, and the neighbouring Quatse River. No HSI models exist for the other three species present in the Twin Lakes (Dolly Varden char, prickly sculpin and threespine stickleback) due to a lack of sources of information on their habitat preferences or their lack of importance for recreational or commercial fisheries.

Each of the HSI models that were used included a number of variables for which a suitability index (SI) has been developed for the different life history stages of the species in question (*e.g.*, for coho salmon: adult migration, spawning/incubation/emergence, rearing and over-wintering). The SI is a unitless number that ranges from 0 (unsuitable) to 1 (optimal). To calculate the number of HUs lost or gained, this SI value is multiplied by the area of habitat to which it applies. Each HSI model assumes that a stream’s carrying capacity for a given life stage is limited by the lowest SI score for any of the variables associated with that life stage. For example, if the percent fines in the spawning substrate for a stream reach were greater than 50%, then the HSI for that reach would have a value of 0.0 and the habitat would be classified as unsuitable for spawning, regardless of the SI values for other variables associated with spawning habitat. This limiting factor approach was used throughout the HU budget calculations, primarily because it is the most conservative approach. The limiting factor approach assumes that all variables are equally important, which may not be the real case. However, any errors in calculating habitat lost and gained were assumed to cancel each other out because the calculations used the same approach.

After discussions with community stakeholders, and a review of risks related to implementing each of these compensation projects, a number of projects were selected over others. In a stakeholder meeting, DFO stated that improvements to fish habitat in the Quatse River had been identified as a top priority for the North Island. A previous project had attempted to improve the habitat in this river by constructing a dam at the outlet of the Quatse Lake to retain water in the winter for discharge during low flow summer months. This dam was not operating as designed and an opportunity was identified to upgrade the dam and for this to contribute to compensation for the Twin Lakes.
Figure 5: Fish habitat compensation projects

a) Quatse Lake Dam upgrade, b) enhancement of fish passage at J3 culvert, c) creation of Twin Lakes diversion habitat (photos by Sean Reilly and Jason Pellett, EBA Engineering Ltd.).

A total of five compensatory projects were undertaken after receiving approvals from Provincial and Federal agencies, including the issuance of an FAA: 1) the Twin Lakes diversion adjacent to the Twin Lakes, 2) two projects elsewhere in the Stephens Creek watershed, 3) one project on the Quatse River, and 4) the Quatse Lake dam upgrade to increase summer low flows in the Quatse River. Figure 5 shows pictures taken after completion of four of the compensatory projects. Together these compensatory works were designed to achieve a compensation ratio of 2:1. The compensation works were completed prior to the authorized destruction of the Twin Lakes.

The elapsed time from start to finish was three years. The timeline for the planning, field studies, permitting, engineering, construction and follow up reporting is presented in Figure 6. The time required for the various phases of the project can be divided as: 30% planning, 30% permitting, 21% engineering, 16% procurement and construction, 3% follow up reporting. Scheduled monitoring required under the FAA is planned over the next 10 years to evaluate the performance of the compensatory works.

The cost to construct the compensatory works, including engineering, construction, environmental and permitting (including external legal counsel), averaged $11/m². However, the Quatse Lake dam upgrade represents a large compensation area with construction works limited to a small area (the dam), and skew the overall costs downwards. Considered on its own, the cost of the Quatse Lake dam upgrade was $6/m², in terms of the entire area improved in the river. The remaining projects were completed at a cost
of $40/m², which is a relevant number for similar compensatory works being planned elsewhere in British Columbia. The assumptions related to these estimate are inherently linked to, among others, the type of habitat lost and compensated for, access to the site, labour costs available to the project.

CONCLUSIONS

A risk-based approach is being used to effectively manage Island Copper’s closure and reclamation. In perpetuity management of the site is being addressed through long range planning and the management of key risks. Worsening ARD has been predicted at the site, and plans have been put forward for the long-term management of water quality. As part of this plan, future worsening of ARD seepage into the Twin Lakes was identified as an important risk in the long-term. The option of draining the Twin Lakes to the pit lake for treatment was selected based on greater risks related to proposed alternative solutions. The drainage of the Twin Lakes was initiated after the NNL plan was implemented in the field, targeting 2:1 compensation. Compensation costs for ideal and typical compensatory works were $6/m² to $40/m², respectively. The Twin Lakes drainage and diversion have eliminated the risk of future mine-related ARD impacts to the Stephens Creek watershed, while maintaining fish habitat quality. Performance monitoring is planned to evaluate the long-term effectiveness and sustainability of the compensatory works.

REFERENCES


DFO. 1986. Policy for the Management of Fish Habitat. Fish Habitat Management Branch, Department of Fisheries and Oceans, Ottawa, Ontario.


