ENVIRONMENTAL ASSESSMENT: MARATHON MINING PROJECT
EFFECTS OF AN OPEN PIT MINE ON THE WATERSHED

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TABLE OF CONTENTS

INTRODUCTION AND PROJECT DESCRIPTION 1
- ***Introduction*** 1
- ***Project Description*** 3

ACID MINE DRAINAGE FOR AQUATIC HABITAT AND FISH 5
- ***What is Acid Mine Drainage*** 5
- ***Effects of Geology and Hydrology on AMD*** 6
- ***Effect of AMD on Chemistry in Aquatic Environment*** 8
- ***Effect of AMD on Fish Populations*** 10

EFFECTS OF SEDIMENTATION ON FISH 11

RECOMMENDATIONS TO STILLWATER INC. 13
- ***Remediation Techniques for AMD*** 14
- ***Predicting Erosion and Sedimentation*** 15
- ***Mitigating Erosion and Sedimentation, BMPs*** 15

CONCLUSION 17

LITERATURE CITED 19

INTRODUCTION AND PROJECT DESCRIPTION

INTRODUCTION

While there have been improvements to mining practices in recent years, significant environmental risks remain. Mining is widely regarded as having adverse effects on the environment. Some of these effects include erosion, formation of sinkholes, biodiversity loss and contamination of groundwater by chemicals from the mining process, particularly open-pit mining (Monjezi et al. 2007). These impacts depend on a variety of factors such as the sensitivity of local terrain, the composition of minerals being mined, the type of technology employed, the skill, knowledge and environmental commitment of the proponent, and finally, our ability to monitor and enforce compliance with environmental regulations (SDWF 1999).

One of the problems is that mining has become more mechanized and therefore able to handle more rock and ore material than ever before. Therefore mine waste has multiplied enormously. As mine technologies are developed to make it more profitable to mine low grade ore, even more waste will be generated in the future. Ore is mineralized rock containing a valued metal such as gold or copper, or other mineral substance such as coal. The ore is then crushed into finely ground tailings for processing with various chemicals and separating processes to extract the final product. In Canada, on average, for every tonne of copper extracted 99 tonnes of waste material must also be removed (SDWF 1999).

A major environmental concern regarding mining activities is the contamination posed by the acid mine drainage (AMD) originating from the biochemical oxidation of pyritic minerals in both abandoned and active mines. This is a natural chemical reaction, which can proceed when minerals are exposed at the surface of the earth. These acidic conditions can cause metals in geologic materials to dissolve, which can lead to impairment of water quality when acidic and metal laden discharges enter waters used by terrestrial or aquatic organisms (Jennings 2008). In undisturbed natural systems, oxidation processes occur at slow rates over geologic time periods. Waste rock dumps have been designated as the main source of AMD; however, open-pit highwalls, underground workings, ore stockpiles, and concentrate storage and loadout areas can contribute significantly, generating volumes of AMD (McCloskey et al. 2005). Extensive research has been conducted in order to understand and reduce the AMD produced as a result of mining activities, focusing predominately on using physical, chemical, and passive treatment options to reduce AMD from surface waste piles and tailings.

Acid drainage has been identified as the largest environmental liability facing the Canadian mining industry and is estimated at $2 to $5 billion (MEND 2001). Environmental, human health, and fiscal consequences caused by AMD, if not mitigated, can have longlasting effects. AMD drainage continues to emit from mines in Europe established during the Roman Empire prior to 467 AD (Jennings 2008). The cost of mitigation of environmental damage from AMD is great. The U.S. Forest Service (USFS) estimates that between 20,000 to 50,000 mines are currently generating acid on lands managed by mining industries, having adverse effects on 8,000 to 16,000 kilometers of streams (USDA Forest Service 1993). The impact of acid mine drainage can be detrimental to ecosystem health and greatly impact fish populations. Heavy metals and low pH can alter water chemistry leading to low BOD levels. Productivity diminishes as pH decreases and heavy metals accumulate. Phytoplankton species can be reduced leading to cascading effects up the food chain (USDA Forest Service 1993). Fish populations face reproductive and feeding health problems from contaminated water bodies.

Erosion and sedimentation present another environmental issue for mine sites. When material is disturbed in significant quantities, as it is in the mining process, large quantities of sediment are transported by water erosion. The sediment eventually drops out of solution and sedimentation occurs at some point downstream from the erosive source. The degree of erosion and sedimentation depends on the degree to which the surface as been disturbed, the prevalence of vegetative cover, the type of soil, the slope length, and the degree of the slope. Erosion can adversely affect soil organisms, vegetation, and revegetative efforts because it results in the movement of soil, including top soil and nutrients, from one location to another. Although sediment and its associated effects on water clarity and turbidity is an inherent component of aquatic systems, it is apparent that there is an increased risk to the survival and well-being of aquatic organisms when levels of sediment exceed background values for a particular period of time (Birtwell 1999).

PROJECT DESCRIPTION

The Marathon Platinum Group Metals-Copper (PGM) Project is located approximately 10 km north of the Town of Marathon, Ontario. The proposed project would include three open pits, an ore processing plant, tailing and mine rock storage facilities, site access roads, a 7 kilometre power transmission line, explosives factory and magazines, water management facilities, ancillary mine infrastructure, and associated activities (CEAA 2011). Ore will be processed (crushed, ground, concentrated) at on-site processing facilities. A final concentrate product containing copper and platinum group metals (gold, platinum, and palladium) will be transported off-site via road and rail to a smelter and refinery for subsequent metal extraction and separation. The rate of production would be approximately 22,000 tonnes per day with a proposed operating mine life of approximately 11.5 years (Marathon PGM Corp. 2010). The proposed project site is in an area characterized by dense vegetation, moderate to steep hilly terrain with a series of streams, ponds and small lakes. The Project area is bounded to the east by the Pic River and Lake Superior to the west (Marathon PGM Corp. 2010).

The project is subject to review under the *Canadian Environmental Assessment Act* given the requirements for Fisheries and Oceans Canada, Transport Canada and Natural Resources Canada to issue permits, approvals, authorizations, and licenses pursuant to the *Fisheries Acts*, the *Navigable Waters Protection Act* and the *Explosives Act* (CEAA 2011). The Project is also subject to review under the Ontario *Environmental Assessment Act*. The commencement of a Comprehensive Study was amended on July 19, 2010 where the Proponent submitted an addendum to the Project description on July 21, 2010. Fisheries and Oceans Canada and Transport Canada provided advice to the Canadian Environmental Assessment Agency (CEAA) that the project may result in significant adverse environmental effects. Taking this advice into consideration, the CEAA recommended that the Minister of Environment refer the project to a review panel (CEAA 2011). As a result on October 7, 2010, the Minister of

Environment, Jim Prentice, announced that the Project will undergo a federal EA by way of an independent review panel.

Consultation with First Nations, local communities, and other stakeholders has been underway since 2004, and will occur through all mine life phases. As part of the consultation process, there has been considerable discussion with regards to the potential use of Bamoos Lake as a process solids storage option and fisheries resources on and around the project site in general. In recognition of this discussion, in 2010, Marathon PGM Corp decided to withdraw the option of using Bamoos Lake as a process storage option.

ACID MINE DRAINAGE FOR AQUATIC HABITAT AND FISH

WHAT IS ACID MINE DRAINAGE?

Acid mine drainage (AMD), or acid rock drainage (ARD), is a consequence of metal mining processes resulting severe acidification of soil and surface water (Freedman 2010). AMD has been identified as one of the biggest environmental concerns in the mining industry (Eglebor & Oni 2007). Acid rock drainage is produced from waste, overburden or exposed by-products of reduced sulphur compounds, typically iron pyrite or iron disulphide, reacting with atmospheric oxygen or water (Eglebor & Oni 2007). The elimination of air and/or water from the system would stop the oxidation process from taking place (Skousen *et al.* 1998). Specialized acidophilic bacteria, *Thiobacillus ferrooxidans*, can catalyze sulphide reactions causing the rate of the reaction to increase by several orders of magnitude (Reclamation Research Group 2008). The following equation demonstrates the reaction (Freedman 2010):

$$4\ FeS_2 + 15\ O_2 + 14\ H_2O \rightarrow 4\ Fe(OH)_3 + 16\ H^+ + 8\ SO_4^{2-}$$

The production of hydrogen ions is the cause of acidification, sometimes as low as a pH of 2 (Freedman 2010). The metal composition and concentration along with the pH level depend on the species and quantity of sulphide materials (Skousen *et al.* 1998). Metals, such as sulphate, aluminum, iron and manganese, can be dissolved by acidic conditions leeching dissolved materials into the watershed (Reclamation Research Group 2008). The resulting elements, such as sulphate, aluminum, iron, and manganese, as well as those elements associated with mine tailings, discharge into the environment causing physical, chemical and biological damage to terrestrial and aquatic ecosystems (Freedman 2010). Waste rock dumps have been designated as the main source of AMD, however open-pit highwalls, underground workings, ore stockpiles, and concentrate storage and loadout areas can contribute significantly, generating volumes of AMD (McCloskey et al. 2005). Extensive research has been conducted in order to understand and reduce the AMD produced as a result of mining activities, focusing predominately on using physical, chemical, and passive treatment options to reduce AMD from surface waste piles and tailings.

EFFECTS OF GEOLOGY AND HYDROLOGY ON AMD

The natural contents of overburden materials are significant in understanding the neutralization potential of the substrate (Skousen *et al.* 1998). The amount of alkaline material in overburden may equal or overpower the acid potential of the material (Skousen *et al.* 1998). The alkaline material may be able to lessen oxidation or neutralize acid formation (Skousen *et al.* 1998). These rocks can also influence bacteria and limit solubility of ferric iron, reducing acid generation (Skousen *et al.* 1998). Alkaline rocks are defined by alkali ($Na_2O + K_2O$) and silica contents and can include limestone (Fitton & Upton 1987).

Bedrock containing bicarbonate (HCO_3^-) acts as a buffering system, reacting with hydrogen ions to form water and carbon dioxide (Eglebor & Oni 2007). The presence of limestone or dolomite in bedrock of a watershed or aquatic sediment influences the concentration of HCO_3^- in streams or lakes (Freedman 2010). While AMD can still cause damage to limestone or dolomite dominant bedrock, waters may experience less harm than those with soluble or porous bedrock such as granite, gneiss or quartzite (Eglebor & Oni 2007). Watersheds with such bedrock can be easily acidified and will naturally maintain a low pH with no additional remediation (Freedman 2010).

The location of the mine site is within the geological boundaries known as the Superior Province (Mines and Minerals Information Centre, 1994). This area is composed of greenstones (metamorphosed volcanic rock), metamorphosed sedimentary rock and granite (Mines and Minerals Information Centre 1994). Unlike alkaline rocks, these substrates do not help neutralize acid materials entering water bodies (Eglebor & Oni 2007).

Rainfall and snowmelt can flush toxic elements from waste sites downstream into rivers and lakes (Eglebor & Oni 2007). Stream chemistry, particularly pH and dissolved organic carbon concentration, as well as hydrologic and environmental conditions greatly influence processes (Niyogi *et al.* 1999). As water moves away from an AMD source, the neutralizing capacity of the underlying bedrock and non-acidified waters interact causing a reduction in pH (Freedman 2010). As the pH reaches 3, iron precipitates out leaving a yellow-orange substance known as “yellow boy” (Niyogi *et al*. 1999). Yellow boy produces additional acidity and is highly reactive with the sediment in the stream (Brady *et al.* 1986).

The deposition rate is usually greatest at the point of entry to the stream as well as at the convergence of streams with mine drainage and “pure” streams (Niyogi *et al.* 1999). The formation of yellow boy occurs almost immediately after contaminated water comes in contact with pure water, which is the reason for seeing high concentrations at confluent sites (Brady *et al.* 1986).

Changes in hydrology, such as changes in precipitation rates or flooding events, can change the capacity of management structures or lead to severe erosion (Stratos Inc. & Brodie Consulting Ltd. 2011). Impoundment structures might be damaged as a result and release contaminants into water systems (Stratos Inc. & Brodie Consulting Ltd. 2011). At the same time, increased precipitation events can cause sulphate concentrations to decrease as more water enters the stream (Saria *et al.* 2005).

EFFECT OF AMD ON CHEMISTRY IN AQUATIC ENVIRONMENT

The deposition of metal oxides in streams collecting acid mine drainage can vary temporally and spatially (Niyogi *et al*. 1999). The pH of water is the principal variable affecting freshwater biota as well as physical and chemical factors in aquatic ecosystems (Niyogi *et al.* 1999). Acid discharge, in general, has a pH in the range of 2 to 3.5 and will increase in downstream locations due to dilution and groundwater buffering (Brady *et al.* 1986). Furthermore, dissolved iron and sulphates can also be found at reduced levels further downstream from discharge due to dilution and precipitation events (Brady *et al.* 1986). Low pH as well as the inhibition of activity of aquatic organisms resulting from acid mine drainage maintains a minimal biological oxygen demand (BOD) in aquatic habitats (Brady *et al*, 1986). At low pH values and BOD, denitrification is limited (Saria *et al.* 2005).

As previously mentioned, yellow boy is precipitated iron once pH is greater than 3 (Freedman 2010). Yellow boy particles are relatively large in size and as they settle on the bottom of rivers it can smother bottom-dwelling organisms (Freedman 2010).

Water bodies that have been acidified or contaminated by metals through natural or experimental means or as a result of mining can affect occupying phytoplankton, even at low levels (Kalin *et al.* 2006). In streams, rivers or lakes, phytoplankton diversity can be greatly reduced with a pH less than 4 (Kalin *et al.* 2006). In an experiment performed in Boomerang Lake in northwestern Ontario, researchers found a major decline in the number of taxa of algae from acid mine drainage (Kalin *et al.* 2006). It should be noted that Boomerang Lake is a shallow headwater lake with outflow into Confederation Lake, and could be used to model flow through water bodies. It was suggested that populations of phytoplankton would not persist if contamination load increased and remained consistent (Kalin *et al.* 2006). Given the eleven-and-a-half year lifespan of the mine, algal populations could be greatly reduced. However, the nature of flow through sites may assist population health. At the same time, growth of phytoplankton can indicate aspects of features of water chemistry (Freedman 2010). For example, water bodies with *Eunotia exigua*, *Frustulina rhomboids saxonica* and *Pinnularia hilseana* are indicative of acidic water with high metal content (Freedman 2010). In fact, the deposition of metal precipitates is the limiting factor influencing biomass downstream of ADM sites (Niyogi *et al.* 1999).

Phytoplankton is at the bottom of the food chain and changes in diversity can affect the food web of an ecosystem (Kalin *et al.* 2006). Increases in algal populations can increase fish populations while decreases in phytoplankton can lead to decreases in fish biodiversity (Freedman 2010). Productivity of affected streams and lakes can be greatly reduced if algal levels are reduced (Freedman 2010).

EFFECT OF AMD ON FISH POPULATIONS

Fish and aquatic organisms can be greatly affected by acid mine drainage. Fish exposed to metals and hydrogen ions through their gills experience impaired respiration from acute or chronic toxicity (Reclamation Research Group 2008). Species are indirectly exposed to metals from ingestion of contaminated sediments and food (Reclamation Research Group 2008). Furthermore, abundance and diversity of aquatic insects is greatly reduced in streams which can cause fish to be malnourished or underfed (Browne 2007). Fish are most affected by stream waters with a pH below 5.5 (Reclamation Research Group 2008). Yellow boy can coat the surface of streambeds destroying habitat used for spawning and feeding (Reclamation Research Group 2008). Researchers have found impaired reproduction of fish living in contaminated streams as well as high instances of juvenile and larval mortality (Browne 2007). As a result, the abundance of fish can be greatly reduced in AMD contaminated waters (Browne 2007). By eliminating a significant portion of acid and/or metal load from the watershed, control strategies might improve stream health allowing fish populations to become re-established (Skousen *et al.* 1998).

Fish assemblages can also be used to identify environmental stress of acid mine drainage in streams and lakes (Freund & Petty 2007). Like benthic invertebrates, fish populations represent local conditions and stresses (Freund & Petty, 2007). Fish are excellent indicators of chronic stress and the effects of habitat fragmentation due to their mobile nature (Freund & Petty, 2007). Stillwater has monitored the location of fish within the streams around the mine site with varying results (Marathon PGM Corporation 2010). In the streams with fish populations, Stillwater could utilize fish monitoring techniques to gain insight into the acid being released into the watershed.

EFFECTS OF SEDIMENTATION ON FISH

Soil erosion is a naturally occurring process that plays many important roles in the development of drainage basins, stream channel processes and aquatic habitats. Erosion rates are easily accelerated when land is disturbed by natural events and human activities. Increased rates of soil erosion can impact physical and biological equilibriums that have been established over long periods of time within watersheds. Once significant impacts caused by excessive soil erosion have occurred, it can take many years before natural conditions are reestablished (EDI 2003). These impacts can have significant consequences to the aquatic environment and the fisheries resource, especially when cumulative impacts over broad spatial and temporal scales are considered. Sediments occur naturally and are integral components of aquatic systems. Nearly all waters have some solid matter in suspension of physical, chemical or biological origin that might improve stream health allowing fish populations to become re-established (Skousen *et al.* 1998).

Aquatic organisms have adapted their life cycles to accommodate natural variations that increase sediment load in waterways ensuring the survival of the species (Birtwell 1999). In addition to natural seasonal fluctuations of sediment levels in the aquatic environment, there are catastrophic events, such as certain anthropogenic activities that have the potential to add unusually large amounts of sediment into a water body, thus affecting its physical, chemical, biological structure, and integrity. Activities such as gold mining may cause significant environmental changes proximal to the activity and at distances further downstream. Low energy river-reaches become depositional zones due to sedimentation. The result can be channels clogged with sediments, partially damming, and restricting fish movement (Stapper 2006).

It has been determined that certain concentrations of sediment kill fish directly. The effects of elevated levels in sediment in the wild could be more harmful to fish in the short-term, with respect to sediment type, fluctuations in dissolved gases, feeding patterns, and food supplies. The Proponent has identified spawning habitats for rainbow trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*) in streams which will be directly impacted by the project.Rainbow trout exhibit three different life history strategies: (1) they may occur in streams above waterfalls in a non migratory form where only a short section of stream provides the living space for all stages and activities, (2) populations may reside in large rivers and spawn within the river and adjacent tributaries, and (3) the fish reside within a lake and spawn in outlet or inlet tributary system. These different life histories utilize different parts of the stream/lake depending on the age and activity of the fish (Hartman and Miles 2001). The fry of this species feed primarily on drifting invertebrates. Studies have reported a decrease in invertebrate abundance and a change in community composition resulting from sedimentation (Shaw 2001). Invertebrates become dislodged into the water column by rolling or saltating particles. Many taxa rely on a filter-feeding apparatus to remove fine particulate organic matter from the water column, and these can become clogged by sediment thereby reducing their feeding efficiency (Shaw 2001). For many fish the successful capture of prey is a fundamental requirement in order to obtain food. For opportunistic sight feeding juvenile salmonids, this process may be affected by variations in suspended particles (Birtwell 1999). Changes to the quantity and composition of available food resources can directly influence the growth of resident fish. Sediment can also indirectly affect fish growth through modifications of behavior and habitat.

RECOMMENDATIONS TO STILLWATER INC.

The prevention and management of AMD at mine sites includes management of water, tailings, and waste rock (Stratos Inc. & Brodie Consulting Ltd. 2011). Acid production can be reduced as ore is being mined and should be key in the management plan. Storage facilities for tailings need to be examined to reduce oxidation potential. The plan for acid discharge into the watershed should include prevention, reduction and remediation.

Mining activities have the potential to expose large areas of soil and rock to the processes of erosion.Mine pits, roads, tailings dams, waste rock, ore piles, and other facilities are potential sources of sediment that can be transported and deposited in streams and other water bodies. If properly planned and managed, adverse impacts to water quality and aquatic resources can be minimized or prevented. To prevent potential impacts, water and sediment management needs to be considered from the beginning of any mining plan.

REMEDIATION TECHNIQUES FOR AMD

There are a number of techniques that can be utilized by Stillwater to reduce acidity of water as it enters streams around the mine site. Addition of limestone into the watershed is a common practice of many mines to reduce acidity (Hedin *et al.* 1994). Researchers have found that adding limestone does increase the pH of water, depending on the rate of water flow (Hedin *et al.* 1994). It has further been suggested that limestone substrates can help retain some solid materials from acid mine drainage (Hedin *et al.* 1994).

Researchers suggest building permeable reactive barriers to improve bacterial sulphate reduction and metal sulphide precipitation (Waybrant *et al.* 2002). These barriers are installed in the path of mine discharge, and remove iron and other metals (Waybrant *et al.* 2002). Bacteria in the barrier convert sulphates into sulphides by the oxidation of organic carbon (Gibert *et* al. 2011). In turn, the sulphide can precipitate dissolved metals resulting from acid mine drainage (Gibert *et al.* 2011). The barriers release carbon, nitrogen and phosphorous, which are necessary for growth of species (Waybrant *et al.* 2002). The barrier can clog over time and hydraulic conductivity can be reduced (Gibert *et al.* 2011). Therefore, it is important in this technique to ensure permeability is maintained for the lifetime of the mine (Gibert *et al*. 2011).

PREDICTING EROSION AND SEDIMENTATION

Sediment and erosion control measures should be in place during and after operations that have potential to cause sedimentation into a watercourse. Baseline knowledge of soil erosion, transport, and deposition of eroded sediment into streams and other water bodies is essential to mine planning and operation. The measurement and prediction of the amounts of erosion and sedimentation is related to the measurement and prediction of site hydrologic variables such as precipitation, runoff, and stream flow. To characterize baseline conditions at mine sites and to predict potential adverse impacts from sedimentation requires adequate spatial and areal characterization of gross erosion and sediment yield. Analytical software programs are available to predict sediment yield and sediment transport in large watersheds (Compton 2003). These can be incorporated into GIS applications to provide spatial evaluation of erosion potential and sediment yield.

BEST MANAGEMENT PRACTICES FOR MITIGATING MINING EROSION AND SEDIMENTATION

Best Management Practices (BMP) are schedules of activities, prohibition of practices, maintenance procedures, and other management practices that effectively and economically control problems without disturbing the quality of the environment (Compton 2003). This approach involves minimizing the potential sources of sediment. To accomplish this, BMPs are designed to minimize the extent and duration of land disturbance to protect soil surfaces once they are exposed. BMPs are designed to control the amount and velocity of runoff and reduce its ability to carry sediment by diverting incoming flows, and utilizing sediment-capture devices to retain sediment on the project site. Below are some examples of erosion control methods which may be employed, depending on site conditions.

When operations are undertaken streamside, a good erosion control mechanism is a vegetated buffer between the area of works and the stream. Better protection is provided by increasing the streamside protection buffer (B.C. Ministry of Agriculture, food and fisheries 2004). Where exposed earth or sediment may be adjacent to a watercourse, controlling erosion can be as simple as seeding as soon as possible to prevent sediment entry into the watercourse during precipitation. Spreading straw or hay mulch over exposed soils may also be an effective temporary measure to control erosion. During heavy rainfall and thawing events, water movement on site may be significant. Strategically placed ditches and runoff collection structures can help direct water movement on site by reducing the total amount of water and reducing its interaction with erosion prone sites. Coarse rock and equipment to build ditches and dams are easily obtained on site, requiring little maintenance, making them effective improvements.

Installing a silt fence as a sediment control method is a common method employed. Geotextile materials, stretched along stakes, are used to protect downslope areas and prevent further movement of the sediment as it is being transported. Impermeable polyethylene sheets can offer immediate and temporary erosion control (Compton 2003). Their use is suited for emergency responses or for short term protection in an area where the sheets will not be distributed, because they are susceptible to tearing or movement by wind and heavy rainfall events.

It is important to realize that specific site conditions will determine which methods are appropriate and when they should be implemented. Proper planning is the essential ingredient in the prevention and avoidance of unnecessary environmental degradation. Once properly planned, environmental degradation can be avoided by implementing a variety of runoff, erosion and sediment control methods throughout the duration of the mining operations. Preventative methods will reduce the overall impact of the mine, improve public support and reduce costs associated with reclamation activities.

CONCLUSION

The importance of minimizing and preventing impacts to aquatic environments during the extraction or development of mining facilities cannot be overstated due to the social, economic and intrinsic values of aquatic resources. Acid mine drainage is of primary concern to environmental health. It is a natural process that can be greatly accelerated by mining practices. Geology and hydrology around the mine site can contribute to the negative effects of AMD. Low pH and heavy metals decrease the quality of water and habitat and when released into streams can end up residing in connecting lakes. The impact of acid mine drainage can be detrimental to ecosystem health and greatly impact fish populations. Heavy metals and low pH can alter water chemistry leading to low BOD levels. Productivity diminishes as pH decreases and heavy metals accumulate. Phytoplankton species can be reduced leading to cascading effects up the food chain. Fish populations face reproductive and feeding health problems from contaminated water bodies.

Although soils that are exposed during placer mining activities can be susceptible to wind erosion, it is of much less concern than soil erosion caused by water. Water is a necessary component of gold mining operations and as operations typically occurs within, or adjacent to, natural water bodies, the concern for negative impacts created by erosion and the potential for associated sedimentation is high with respect to aquatic communities and their habitats. Due to the force of gravity, soils eroded and transported down slopes by water, often end up in water bodies when not obstructed in some way. Erosion and sedimentation occurring as a result of natural resource development and extraction activities have important implications in terms of their environmental and financial impacts. Increased sediment causes changes in channel shape and form, stream substrates, the structure of fish habitats, and the structure and abundance of fish populations (Birtwell 1999).

Acid mine drainage and erosion are of great importance to aquatic ecosystem health and should be managed to reduce the impact. The combination of both impacts on an ecosystem can increase the damage to ecosystem health. Although the costs of implementing effective control measures can be expensive, the costs of not meeting the requirements can be even more expensive in the long term.

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