Tr'ondëk Hwëch'in Placer-Specific Wetland Reclamation Guidelines

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Disclaimer

This guide is intended to assist placer operators to plan wetland reclamation that will restore wetland function to the mine site. Use of the approaches outlined herein will not, in any way, constitute a defence in a court of law if an operator were to be investigated and subsequently prosecuted for a violation of the *Placer Mining Act* and *Placer Mining Land Use Regulation* or any other legislation.

About this Guide

The emphasis of this guide is on reclamation principles as applied to placer mining but may be extended beyond that to reclamation and restoration aspects for all Yukon riparian (river channel) wetlands. This guide contains general information about wetlands that placer miners need to know about before mining in and near wetlands. This guide is broken into two parts with attached appendices:

- **Part I:** wetland science and placer mining.
- **Part II:** information to assist miners in developing a mining plan that minimizes wetland loss and addresses progressive wetland reclamation.[1]
- **Two Appendices:** wetland class descriptions, and frequently asked questions about reclamation methods and performance indicators.

[1] Because of the fragility and importance of wetland function, progressive reclamation is required.

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Goal of Wetland Reclamation

The goal of placer-specific wetland reclamation is to preserve wetland functions by mimicking the natural site. By mimicking the natural, pre-disturbance site, a self-sustaining wetland will more likely be achieved. A self-sustaining reclaimed wetland will not require regular maintenance and therefore will have a better chance of success over a long term.

Not all wetlands perform all functions, nor do they perform all functions equally well. It is important to acknowledge that it may not always be possible to reclaim wetlands with an identical class of wetland. A change in class of wetland (e.g., from a bog to a shallow open water wetland) may be an acceptable wetland reclamation strategy but may also trigger additional compensatory requirements for increased reclamation area from regulators.

Proponents who are proposing to disturb wetland(s) must justify why the disturbed wetland(s) may need to be reclaimed with a different wetland classification. Regulators must ensure that disturbances to the wetland(s) do not diminish environmental or social factors. In addition, regulators must gauge the amount of proposed wetland disturbance with the watershed before granting mining authorizations.

PART I: Wetland Science and Placer Mining

Wetland values are typically disproportionately high compared with other ecosystems. This is commonly true because they occupy so little area relative to the surrounding uplands, and provide concentrated benefits for so many organisms, including humans. The biodiversity and benefits of wetlands must be understood before changes to wetland ecosystems are contemplated. In addition, impacts to these wetland values have downstream repercussions and risk negatively affecting interrelated environmental and social systems.

As scientists discover and explain the importance of wetlands to the environment and ultimately to human and community health, authorizing the disruption or destruction of wetland function becomes an increasing liability for regulators. Previous leniency in mining practices is no longer acceptable in light of our advancing wetland knowledge. In order to adapt to this changing regime, placer miners need background understanding about wetlands so that their function can be effectively restored after mining.

Types of Wetlands

This guide uses the five common classes of wetlands identified in the Canadian Wetland Classification System; **marshes, bogs, fens, swamps and open shallow water wetlands**. For descriptions and important functions of each, see **Appendix I**.

Wetland Functions

Each class of wetland contributes useful features to the entire landscape such as:

- water sources;
- filtration of muddy floodwaters;
- slowing floodwaters and reducing downstream erosion and flooding;
- food and cover for fish and wildlife;
- winter travel corridors for caribou, wolves, foxes, moose, and others;
- insect production in warm shallow waters;
- fish spawning and rearing habitat for fingerlings;
- nest sites and feeding areas for water birds, and
- plant decomposition areas adding fish/ insect food and nutrients to downstream rivers.

Some species such as moose, caribou, foxes, and many birds can use both wetland and upland habitats; however, many specialist species such as frogs, waterfowl, fish and aquatic insects, are completely dependent on wetlands for feeding, travelling, breeding and survival.

Species reliant on wetlands in the Yukon range from the wood frog, which needs clear shallow water with vegetation for breeding; to the rusty blackbird, which nests in low shrubs within wetlands; to muskrats, which feed on aquatic plants in shallow wetlands.

Wetland Soil Ecology

Wetland soils have unique properties. They are different from upland soils because they are saturated for long periods of time. Wetland soils have distinct chemical environments, specialized microbes capable of existing in low-oxygen flooded environments, and frequently, structured organic matter in root channels. In short, wetland soils are specialized and not easily replaceable. Sodden soils have special chemical properties such as low oxygen, higher solubility of some chemicals, and slow rates of decomposition.

It is important to note that riverside gravel bars are also important features for plants, insects and fish. Well-washed mineral substrates range from gravelly to sandy to silty and regardless of grain size, ground up rocks are their primary ingredient. The proportion of organic accumulation is much lower than in peatlands (discussed below) but still adds a rich, dark, organic component to mineral-based wetland soils, meaning that gravel bars can become productive growing areas.

Wetland soils take a long time to develop. For example, it takes long periods of time to generate organic material contained in structured layers at the surface and in dissolved carbon in the gaps between soil particles. These micro-level conditions progress at the soil-particle level, yet they can occur across broad expanses of wetland territory. These conditions are virtually impossible to create quickly and effectively, thereby, their creation requires natural processes and long-term development.

It takes years, decades or even centuries for the deep layers of plant litter to accumulate, nutrients to infuse and for roots and stems to create dense deposits of plant-based organic matter that is fertile habitat for plants and animals. Water cover decreases the exposure of wetland soils to air, so this organic matter decays more slowly than on land and it accumulates instead of being converted to nitrogen, oxygen and carbon dioxide gasses. Plant accumulations are the origins of bog and fen soils (Appendix I).

Wetlands also have unique plant species that play an important role in the wetland ecosystem. Only specialized wetland plants are able to thrive in the unique, wet soil conditions. Where wetland plants grow, the soil surface is sewn together with living root mats, meaning soils do not wash away easily. Because the roots release oxygen into the surrounding soils, they alter the growing conditions and soil chemistry to provide habitat for insects and other vegetation.

Peatland

Peat is simply the partly decomposed stems, roots, and leaves shed by plants. Two of the specialized wetland classes described in Appendix I, **fens and bogs**, are wetlands that produce peat at their base. Eventually fens and bogs grow on a base of peat; however, the layers of peat act differently depending on depth of burial.

The surface contains green living plants and roots, as well as rough intact dead stems with the consistency of a kitchen sponge. There are large pore spaces in this superficial layer, enough oxygen for insects to live, and water can flow moderately well through this zone. When droughts occur, these wetlands continue to slowly release large volumes of water that support river flows and fish habitat; this is an extremely important function. The released water is dark-colored like strong tea because it carries valuable dissolved carbon that benefits aquatic plants, insects eating those plants, fish eating those insects, then ultimately, water birds, grizzly bears, ospreys. Humans who eat the fish and/or trap the animals from this food chain also benefit from this wetland function.

Lower down in the peat layers, usually 10-20 cm below the surface, conditions are very different. The peat layers are more decomposed, sometimes looking like **black muck**. There are very few pore spaces below 30 cm depths, so water flow is extremely slow there.

Finally, there is essentially no oxygen in deep peat. This zone is cold and dark, and has no water flow. The peat is as acidic as a pickle jar. Deep peat provides one of the world's largest carbon storage areas.

Wetland Hydrology (Water Movement)

The hydrology of wetlands is intricate and is extremely difficult even to approximate. Water reaches wetlands in a number of complex ways. We can see the rain and snow fall and flow to wetlands, but other water from underground sources flows invisibly into, through or under wetlands. Additionally, wetland types often merge into one another depending on water sources and soil types.

> *Many Yukon riparian systems support elaborate and complex fen wetland systems along their banks and valley floors. These are important systems where plants, sediments and currents have worked together for thousands of years.*

Riparian wetlands often have multiple scales of water movement laterally and longitudinally, with the surface waters of a river linked to the slower sub-surface flows. Indeed, there may be a second "river" flowing through the shallow permeable sands and gravels of the river bottom. The undisturbed beds of almost all Yukon gold-bearing streams have a slow-moving current of water that moves through the sandy soils *underneath* the river's surface flow.

The subsurface flow mixes in and out of the surface water along the length of the river, where sand acts as a very effective filter by trapping silt, nutrients, leaf and organic debris. In addition to this "purification," water moving between the river and the subsurface supports many sediment-dwelling organisms such as mayflies, stoneflies, caddisflies and midges that contribute to the food source for fish and bird communities.

Wetland Plants

Like wetland soils and hydrology, the plants of wetlands are specialized too. Relatively few plant species can survive in flooded soils. Upland plants simply die when water infiltrates the pore spaces in soil; their roots drown because the exchange of gasses becomes restricted, their leaves wilt and the plant perishes.

Wetland plants have special ways of extracting oxygen from water or by carrying atmospheric gasses up and down their stems, much like an internal air hose, allowing them to survive in saturated soil. Other wetland plant adaptations include seeds that require water (or wind) for transport. Underwater wetland plants are particularly good at absorbing the long light wavelengths that filter through clean water. Finally, the extensive roots that anchor these plants in soft soils also prevent erosion and uprooting during high water.

Many species of the Carex genus, better known as sedges, grow only in wetlands. These grass-like plants provide, for example, habitat for waterfowl and juvenile fish, and food for moose, muskrats and geese. Carex aquatilis*, known as the water sedge or leafy tussock sedge, is a common sedge in Yukon wetlands and decomposes to form peat.*

Wetland plants do not just *respond* to their environment, they also *affect* it by stabilizing and trapping sediments to build land. This function is particularly important in riparian wetlands because rushing water keeps sediments suspended for long distances. Dense aquatic plant stands create a network of slow or still water patches in the current by increasing the "surface roughness" of the channel. These vegetated sites allow suspended sediments to settle out and lodge, thereby clearing the water column. Like the sand-filtered groundwater flow, slowing the current is a second way wetlands filter flowing water and improve its quality for downstream users.

A third way wetlands trap sediments, nutrients and pollutants is by creating surfaces for attachments. Slippery films of natural microscopic algae, bacteria, and viruses attach themselves to river rocks, plant stems and river bottoms. These slippery aggregates are called "biofilms" and they are usually less than 1 mm thick. Although fishermen know how slippery they are, biofilms ooze a sticky protein-based material that has a fly paper effect in capturing and incorporating fine particles in the water. Biofilms also develop on decomposing leaves, twigs and branches and capture particles flowing against them. In turn, these biofilms become a primary food source for a range of aquatic insects that scrape and consume them.

Challenges to Wetland Reclamation

The interactions of wetland soils and water are likely the most fundamental, complicated and intertwined challenges in wetland reclamation and may explain why wetlands are so much harder to reclaim than upland sites. Indeed, some classes of wetlands are very difficult or impossible to reclaim. The slow process of organic decomposition over time creates a unique environment, meaning that reclaiming wetlands to anything near their original conditions is a time-consuming and expensive process that sometimes stalls at unproductive levels for long periods.

Re-constructing complex flow-through groundwater supplies to wetlands has rarely proved successful and is another reason why effective reclamation of wetlands is so difficult. Examples of fen wetland reclamation trials have been relatively unsuccessful to date.

For instance, Colorado scientists attempted to reclaim short stretches of mountain fens similar to those that exist in Yukon. Over a 15-year period, they had limited success despite significant investment in this reclamation attempt. In another example, two large Alberta oil companies, Suncor and Syncrude, attempted to create groundwater-dominated fens on mined tailings. The costs were great, estimated by some at over $1 million per ha. By year 8, the recovery process resulted in marshes, some fen characteristics and intermixed upland vegetation, trees, grasses and a few mosses. While the mossy spots are encouraging, the water flows, water and soil chemistry, lack of organic matter, and encroachment of invasive weedy species show the difficulties in recreating true fen wetlands.

How much Wetland Disturbance is Acceptable?

Given the important functions played by wetlands at a landscape level, and the challenges in reclaiming them due to the complex interactions of biotic and abiotic factors, how much wetland disturbance in a river system is acceptable?

It is up to the regulator to determine the percentage of tolerable infringement on a wetland within a wetland complex. This determination is particularly tricky when it comes to peatland, which cannot be restored by any known method.

When mining is proposed, the regulator must also gauge the percentage of wetland that needs to remain undisturbed to ensure the continuity of wetland function remains on site. Proponents may be required to include intermittent reaches of intact wetland in their mining plans to maintain water quality and connectivity, wetland function and the presence of key indicator species along the river corridor.

Biological Indicators and Specialist Species

Any disturbance to a wetland affects the whole river system. Additionally, removing an entire ecosystem from production is problematic for downstream water quality conditions because there are no remaining filtration zones in and along the channel. The ability to evaluate the function of a wetland ecosystem includes determining what effect the removal of various amounts of wetlands will have on the function of the system as a whole.

Scientists therefore often use **biological indicators** to measure the degrees of degradation, and use components such as key species, species diversity and water quality to determine the level of disturbance.

The use of disturbed wetlands by wildlife can sometimes be misleading because some species are actually *attracted* to disturbed sites. Moose, deer and black bears seek out recent forest fire areas, road cuts and young willow stands. Bears and wolves seek out road kill and garbage dumps. Waterfowl such as mallards, northern shovelers, American widgeon and green-winged teal, may even increase, but these are not indicator species. In fact, these ducks are common on sewage lagoons and other low water quality sites. They are generalist species that tolerate numerous types of habitat.

Consequently, the presence or absence of highly-sensitive **specialist species** are a better indicator of ecosystem change or disturbance. In Yukon wetlands, this includes species such as:

- wetland-reliant amphibians,
- herbivorous aquatic insects that need sunlight to penetrate clear water,
- fish-eating birds like ospreys,
- spawning fish like salmon and bull trout that require clean upwelling groundwater springs for egg survival, and
- cavity nesting birds like woodpeckers that require large spruce trees. [2]

In addition to using indicators to assess the degrees of degradation and level of disturbance, intermittent reaches of intact and extensive wetlands may be essential in mined areas to help offset mining disturbances. These undisturbed areas are necessary to fortify and protect the riparian corridor.

Next Steps

Wetlands are diverse, productive and vital components of healthy ecosystems and landscapes, providing numerous biotic and abiotic functions. As part of the reclamation plan, the proponent is encouraged to apply the following reclamation options in the order below.

- **Avoid disturbing wetlands**: Consider protection and avoidance strategies first before undertaking mining activities, including the building of roads, camps and other infrastructure in wetlands. Avoidance can contribute to savings in time and money during construction, and at the same time protect wetlands. To maintain wetland functions within a project area it may be necessary to leave some wetlands unmined.
- **Minimize disturbance to wetlands:** when mining in wetlands is unavoidable, every attempt by the proponent should be made to minimize the extent of impact to the wetland. This could include adjustments to the mining plan such as work planning,

[2] These types of biological indicators should be incorporated into the reclamation plan (documented in pre-mining conditions and reference sites) and monitored during reclamation and post-mining periods.

changing mining techniques, and/or using less impactful equipment.

- **Reclaim a wetland with the same class of wetland** (e.g. swamp to swamp): when mining in wetlands is unavoidable, the proponent should reclaim the disturbed wetland area with a suitable design that will replicate the original wetland type over time. The proponent should be cognizant of the fact that some wetland types are virtually impossible to reclaim.
- **Reclaim a wetland with a different class of wetland** (e.g. bog to marsh): While it is important to reclaim a disturbed wetland to the same class of wetland, this may not always be possible. A change in class of wetland may be an acceptable wetland reclamation strategy if permitted by the regulator. The regulator may decide that a larger area of lower wetland class may be required as a replacement ratio.

PART II: Mining Plans that Ensure Retention of Wetland Function

Progressive Reclamation

Reclamation transforms a disturbed environment to a state that is *different but very similar to* its original conditions, as determined by comparisons to the pre-disturbance baseline state. These pre-disturbance reference conditions are crucial for measuring wetland reclamation success.

Progressive wetland reclamation means that wetlands are reclaimed as mining activities progress, allowing reclamation to take place in areas that are no longer required for mining. Undertaking reclamation in this stepwise fashion also allows additional time for methods and techniques to be successful or adjusted (e.g., establishing pioneer and successional species), for monitoring and modification of the reclamation plan as needed, and for cost-effective use of operator time and equipment.

Additionally, one way of guaranteeing that sufficient wetland function remains in each river valley is to undertake progressive reclamation in sufficiently short increments so that wetland function is re-started within the same season. The regulator must determine timelines for progressive reclamation.

Monitoring the success of reclamation techniques during the progression of reclamation provides valuable feedback regarding the effectiveness of reclamation measures on an ongoing basis. Additionally, progressive wetland reclamation can shorten the time interval required for achieving mine closure objectives, and reduce the financial liability of the site by avoiding additional training and mobilization costs of reclamation because equipment and employees are already on the site working.

Activities such as stockpiling materials, grading and re-contouring steep excavated slopes and tailings piles, sloping and adding topographic features such as swales, depressions, ponds and islands, are all examples of activities that should be undertaken progressively after mining activities and before mining moves on to the next area. Recommended construction objectives are listed in Table 3.

Understanding Pre-Mining Conditions and Reference Sites

Equally important to knowing the quantity of minable minerals in an area, is understanding the feasibility of reclamation success in mimicking pre-mine site conditions.

Thus, before drafting a reclamation plan and mining an area containing wetlands, it is necessary to understand and document:

- morphology (land shape);
- geology;
- hydrology;
- biology;

- an estimated extent of each wetland class;
- wetland response to disturbances of flood, fire, grazing, and drought; and
- services and functions provided by the particular wetlands.

Reference Sites

In addition, to create an effective reclamation plan and to measure its ecological success over time, it is necessary to undertake a comparison of the mine site to a similar but undisturbed area. This comparison must involve measurement of the above-listed features of the exact mining site *before* operations starts, and a comparison to the same features on a nearby **reference site** that will remain as undisturbed as possible now and into the future. If the reference site's future is uncertain, establish two reference sites.

In this way, two types of 'measuring sticks' are available to monitor the success of reclamation efforts for the pre-mine conditions, on the mine site itself, and the adjacent reference site, where mining is not taking place.

Reference sites are critically important because without clear descriptions of desirable post-mining conditions, it is impossible to know if reclamation was successful or not. Substantial disturbances and loss of wetland function occur in every mining excavation that takes place in a wetland. These effects are obvious immediately following mining because even with ideal reclamation efforts, it will take time to recreate many of the benefits wetlands provide. The worst-case scenario is an inadequate reclamation plan that will never get the wetland on the path of returning these benefits. Setting measurable reclamation goals against reference wetlands is absolutely necessary.

Writing a Wetland Reclamation Plan

A **wetland reclamation plan** lays out how functioning wetlands will be re-established as part of the landscape, including upland features, wetland areas and open water. This plan explains how the conditions will be created, encouraging recolonization and establishment of native wetland vegetation species and wildlife. Typically, this plan will be written by a scientifically trained employee or consultant.

The wetland reclamation plan is part of the mining plan and needs to be a living document that allows for modifications as approved by regulators, and that adopts best practices. Best practices become better understood as progress unfolds with mining activity and reclamation investments at each unique site.

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The plan should address each of the following:

- A set of proposed reclamation goals and description of the post-mining site conditions that will be achieved (see Table 1);
- Maps and a site description (see Table 1 or *Understanding Pre-mining Conditions* section for details) showing and describing:
    - the project's placer claims,
    - location of wetlands and their classifications on and near these claims,
    - where mining will take place and where reclamation measures will be undertaken,
    - which habitat components will be relocated, and
    - areas where wetland disturbance will be deliberately avoided for conservation;
- A clear description of the classes and extent of wetlands within the mine area and the specific services provided to the surrounding landscape by the wetlands (see Table 1);
- A clear description of an undisturbed reference site (including location and why it was selected) that will be used for comparison of wetland conditions during both progressive reclamation and post-mining periods (see Table 1);
- If applicable, a summary of any protection/avoidance strategies that will be used for intact wetlands (see Table 1);
- A clear description/maps of mining activities (Table 2) and how these will incorporate progressive wetland reclamation, including the methods planned to design and construct reclaimed wetland areas (see In the wetland reclamation plan, the proponent must describe site-specific, ground-based activities that will be undertaken to recreate suitable wetland conditions. Table 3, and the above section, contain information on particular techniques and expected reclamation outcomes to assist the proponent in planning how to reclaim their site. or *Environmental Considerations for Yukon Wetland Reclamation* section for details), and a schedule of progressive reclamation periods;
- If applicable, a description of any landscape characteristics that could potentially limit or affect achieving wetland reclamation objectives (e.g., large or multiple pockets of permafrost, lack of accessible surface water, etc.) and proposed mitigations;
- A clear description of how of progressive and post-mining wetland reclamation success will be monitored (e.g. monitoring schedule for comparison with pre-mining and reference site conditions, and reclamation goals);
- Adaptive management strategies available if reclamation problems are encountered (Table 4).

Table 1. Wetland reclamation planning: describing goals, pre-mine site characterization and reference sites

Pre-mine Site		
Subject	**Content**	**Standards for Content**
Goal setting	Statement of reclamation goals for overall site and each class of wetland on site.	Plan's reclamation goals display detailed understanding of the pre-mine site and how to re-establish self-sustaining wetlands.
Maps	Maps of claim areas, include aerial photos, showing pre-existing features, general landforms, proximity to waterways and sensitive areas to avoid (specify protected areas and ensure no ingress or operation within a 30 m buffer). A modern mapping tool should be used to characterize the spatial arrangement of sites including elevations, slope angles, topography, open water bodies and percent of cover of vegetation.	Plan includes thorough, professional maps, detailing the site, including distribution of existing wetland classes.
Geology	Describe bedrock geology, overburden, surficial outcrops, chemistry, density/compaction and weathering status across the full depths of excavation to allow reclamation to similar status and layering.	Plan includes detailed description of geologic conditions.
Surface soil	Collect at least two augured soil and peat cores per hectare to characterize topsoil conditions, permafrost lenses, layer arrangement and organic matter.	Plan includes documented surface soil description.
Hydrology	Examine groundwater (and permafrost lenses) at the same time as soils are cored. Map surface water in lakes, ponds, streams or rivers in both spring and fall (if a particularly wet or dry season, review of series of older aerial photos can help indicate typical surface water conditions).	Plan includes a hydrologic description (or maps), with direction of flows in creeks and drains, and the chemistry, particularly pH, of the groundwater.

Vegetation	Inventory the plant community, including submersed species, in mid-summer in the form of a species list (with notes on rare plants) to define the target for restoration.	Plan includes a species inventory and percent plant cover by area and species is mapped.
Wildlife	Undertake breeding bird survey, and examine site for use by terrestrial mammals, aquatic mammals, fish, amphibians and insect productivity. List biological indicators/specialist species found in and around wetlands.	Plan includes a comprehensive bird and mammal species list with common, rare, and accidental rankings.
Reference sites	Identify reference site conditions by characterization of comparable undisturbed wetlands that are: • similar size, stream type/gradient and substrate; • within the same eco-region; • will remain un-disturbed by industrial activities; and • have long term records of environmental conditions.	Plan includes an established degree of similarity to reference site before mining and goals for return to this similarity after mining.
Proposed mining and reclamation areas	Describe/ map where mine activities (cuts, pits, tailings ponds, etc.) and infrastructure will take place and progress in relation to landforms, particularly wetlands. For example: • Cuts – locations, sizes, access, timing, direction of progress. • Stockpiles – locations, footprint, access and approximate volumes of topsoil, peat and overburden to be stored during mining. • Roads – location, borrow sources • Land forms - specify final contours and elevations that mimic original landscape as closely as possible.	Plan includes logical sequence and placement of activities for best reclamation results, including detailed timing for all activities.

Having characterized the site and understood how the distribution of wetlands functions within the landscape fully surrounding the project, the proponent can then generate **a site-specific description** of where mine activity and infrastructure will occur and interact with wetland locations and function. Table 2 outlines the type of information for this section.

Table 2. Wetland reclamation planning: describing locations of activities on the mine site

Mine Site Layout		
Subject	**Content**	**Standards for Content**
Site layout	Describe and map where mine activities and infrastructure (cuts, pits, camp, roads, etc.) will be located and progress in relation to landforms, particularly wetlands. For example: • Cuts – locations, sizes, access, timing, direction of progress. • Stockpiles – locations, footprint, access and approximate volumes of topsoil, peat and overburden to be stored during mining. • Roads – location, borrow sources.	Plan includes logical sequence and placement of activities for best reclamation results, including detailed timing for all activities.
Water management	Concurrently with mine layout, describe and map site water use and management activities. For example: • settling ponds; • diversion channels; • intake and outlet channels; and • mitigations for flooding.	Plan considers local hydrology, such as inflow and outflow of surface waters, sources of groundwater and timing of saturation and flooding.

Note that it may be acceptable and logical to describe actions for progressive reclamation (see Table 3 and the following section for detailed description) in concert with descriptions of the planned mining activities.

Environmental Considerations for Yukon Wetland Reclamation

Reclamation specifics are helpful. **Appendix II** provides on-the-ground considerations and options to assist developing a reclamation plan. In the wetland reclamation plan, the proponent must describe site-specific, ground-based activities that will be undertaken to re-create suitable wetland conditions.

Earthworks and Grading

Slopes: Final slopes should mimic adjacent natural sites and pre-mine conditions. Unstable and actively undercutting banks, abrupt cliffs and high walls, need to be safely decommissioned. The ecological function of a stabilized shoreline is to redirect the water toward the opposite riverbank. It is important to note that when banks cave in or erode, this can cause dynamic shifts in river morphology and will result in alterations to fish habitat.

Major land forms: Replace terraces or benches in their previous locations. Typically, in riverine systems there will be at least three surface elevation zones:

1. **River bed** bottom of flowing water during normal river stages;
2. **Annual floodplain terraces** that regularly experience flooding either as over-surface flows or as active sub-irrigated hyporheic flow. This is a very important filtration system for spring freshet conditions;
3. **Extreme event flood plain** where water levels reach into terrestrial borders causing major channel re-working and transport of cobble and even small boulders. Extreme flooding may occur infrequently at the decade or century frequency, yet, the changes they cause are often substantial.

Reclamation plans must accommodate each of these events without system collapse because the power of moving water can fundamentally change the morphology of unstable streams. Transported sediments can fill important depressions needed by migrating and spawning fish and mining in the streambeds predisposes such sorting and levelling of the river topography.

> *Attempts to reclaim the hydrologic regime of a river usually failed in Alaska placer streams if the gradients was greater than 1%. Streams tended to become sandy bottomed and braided initially, then resulted in razing and undermining plants which affected reclamation attempts for shoreline stabilization.*

Surface stabilization: Plantings, decomposable geotextiles, or spray-on sticking agents may help stabilize slopes and control erosion. While this may help greatly in the early stages of reclamation, if substrates are made of sand and topsoil instead of heavier rock where bends or overflow channels occur, the water is likely to remove the erosion control efforts. Channel erosion effects are three-fold: the channel is cut; the sand and cobble is deposited elsewhere in the stream; and the fines are released into the water column.

Physical erosion control may require multiple attempts to stabilize the material. For example, if a reclaimed terrace is established yet destroyed by the first minor flood, alternative materials and stabilization methods must be used in repair work to prevent that same mistake from reoccurring. It is difficult to predict the direction of energy and bed-carving during major floods, but past experience at similar sites may be useful.

Micro topography: Soil surfaces need not be smoothed; coarse surfaces may trap more precipitation, prevent gulley washing, and provide seed capture sites or microhabitats for native vegetation. Leave reclaimed surfaces in a condition that prevents movement of large sediment loads and erosional gullying or channel-capture.

Soil strata: Wetland soils occur in layers depending on saturation, sediment grain size, and organic content and chemical conditions. The most biologically active zones of wetlands occur at the surface, water permeability is usually greatest at the upper levels, and larger cobble is typical in the deeper zones. Soil replacement sequences must mimic pre-mine conditions. For example, soil strata from the bottom up at a site could consist of cobble, subsoil, sand, mucks, peat, and topsoil. If upstream disturbances mobilize fine sediments, this could result in a sand-filled zone that does not mimic the original soil strata conditions and could result in site conditions that lead to increased challenges for reclamation. Controlling upstream sediment has the added benefit of improving fish habitat, particularly spawning sites.

Soil Management

Wetland surface soils are very valuable and deserve special handling during the excavation phase. Wetland soils usually contain dark organic matter, seeds, insects, plant fragments and abundant nutrients, all of which are difficult to replace. Thus, these soils should be set aside using the following steps:

1. Ideally, soil storage will be on previously excavated sites to minimize the total disturbed footprint.
2. Large rocks, subsoil, sand, mucks and top soils should be rough-sorted during excavation and stored in individual piles.
3. Soil volumes and storage locations require mapping to organize efficient replacement after mining.
4. Each material should be backfilled in sequential order to provide similar drainage and plant-growing conditions during the reclamation period.

Morphology

Wetland morphology refers to the shape, slope, and arrangement of land surface features. If wetlands occurred on steep slopes such as hillslope seeps or abrupt riverside shores, that is what needs to be replaced. If the wetland surfaces were benches or table-flat, that is the appropriate replacement shape. Deep pits, spoil piles and elevated placer tailings offer little natural function after mining and need to be returned to the original wetland elevations and contours.

Water Movement and Controls

The amounts of open water, flow rates, soil compaction, channel widths and quality of water produced at the end of mining should be approximately the same as pre-mine conditions. Some latitude is reasonable here to allow systems to re-establish after reclamation and for wetland health to return after disturbance. It is important to measure the return of species, water fluctuations and the functions related to wetland types listed in Appendix I.

Hydrologic control of surface water is not difficult if elevation, structure and containment are manageable. Prior to alteration or disturbance, a thorough knowledge of the on-site hydrologic regime is a necessary baseline on which to gauge irrigation management. If water berms, culverts, turn gates, coffer dams, channels, or stop-log structures are needed to control flooding or wetting, they must be planned and can be removed when the maturing reclamation system no longer needs them. Wetland processes and stabilization may occur quickly over one or two growing seasons in some cases such as mudflat annual plants; in other settings, decades may be required. For example, swamp forests may take many years to establish and grow.

Revegetation

Successful plant establishment and survival is a primary indicator that soils, aspect, slope, hydrology and disturbance patterns are configured to match pre-mined conditions.

Genetics and origins of the planting stock matter and reclamation plantings can be grouped into three broad categories:

1. **Natural colonizers**: plants growing from seeds and rootstock in topsoil, or colonizing from nearby "parent" plants.
2. **Hand or aerial seeded**: seeds should be collected on and adjacent to the disturbance site in the year before seeding. Take care to collect seeds that are ripe and ready to fall. Seeds should be stored in conditions similar to what they would experience in the field:
   - damp frozen for damp soil plants; and
   - dry and cold for upland plants.

   Both types of seeds should be kept in light-proof containers away from fluctuating temperatures and seed-eating organisms
3. Hand-planted **bare-root stock**: commercial bare-root plants are rarely available for purchase but may be collected in the region, ideally on same project site during excavation. They may be stored for a season "heeled in" to a trench covering their roots with loose damp soil until they are planted out the next spring or summer by qualified planters. Protection from browsers may require electric fencing or mesh cages to encourage establishment of roots.

It is possible to revegetate a reclamation site with plants that don't meet the system's needs, however, these plants may die in the first flood or drought, or may be quickly and permanently removed by fast-flowing water or beavers. Additionally, unsuitable plants will only survive until the planting fertilizer supply in their root container is depleted or natural competition overtakes them. Plant cover of any sort is sometimes mistaken for successful colonization, however, a dense stand of cattails, a clean stand of non-local willows, or worse yet, weedy, invasive or exotic species can create many years of undesirable conditions.

Ponds in Reclamation

Tailings ponds containing freshly dredged and washed gravels hold enough suspended solids, particularly clays and silica dust, that the water resembles chocolate milk. Settling ponds capture the heavier material and wetland or soil filtration can capture the remainder. If a settling pond rests on impermeable layers of settled clay or bedrock it may be re-filled, however the buried layers of fine, settled-out material produce a waterproof pond bottom or clay pan. If this pond is left as-is on the landscape, the clay pan bottom may change general water flow patterns by forming a barrier to water that should be flowing both over and through valley-bottom soils.

Ponds in the post-mining environment should mimic natural landscape configuration. Note that *deep ponds are rare or absent* in natural river valleys with flowing water and moving sediments. The energy of moving water usually fills depressions, similar to how a hole dug on an ocean beach refills itself: holes become “traps” for water-borne sediments and sand when the site floods.

Large ponds will attract some key wildlife species such as waterfowl, furbearers and large browsers, yet ponds do not provide the same system-wide benefits as the original wetlands they may replace. For example, the functions of carbon capture, soil stability in floods, water purification and water release in droughts are all typically lost.

One of the most important functions that risks being lost when ponds replace wetlands is the alteration of habitat providing a niche for specialist species who rely on specific habitat features found only in specific wetland types. Furthermore, the primary goal of reclamation is not necessarily to produce moose, waterfowl or beaver habitat to a degree greater than the original site, but to restore the ecosystem back to its original function, as comparable as possible.

In the wetland reclamation plan, the proponent must describe site-specific, ground-based activities that will be undertaken to recreate suitable wetland conditions. Table 3, and the above section, contain information on particular techniques and expected reclamation outcomes to assist the proponent in planning how to reclaim their site.

Monitoring and Reporting the Progress of Wetland Reclamation

Monitoring the success of reclamation techniques provides valuable experience on the effectiveness of reclamation measures on an ongoing basis. A strategy to monitor the successes and shortcomings of wetland reclamation through the life of the project is an essential component of a wetland reclamation plan.

Ongoing monitoring, and maintenance, of progressive reclamation activities during placer mining operations allows for adaptive management of the reclamation program, and ensures the reclamation plan is a living document containing modifications and discoveries uncovered during the progress of mining. Monitoring also allows for the function of reclaimed wetlands to be assessed and ensure reclamation stays in line with the proposed reclamation goals.

If scheduled seasonal monitoring occurs throughout progressive wetland reclamation, the proponent can also make the adjustments required to support natural landscaping and re-vegetation processes, as well as wetland use by wildlife species. Lastly, monitoring progressive wetland reclamation as mining proceeds indicates the effectiveness of the chosen reclamation techniques.

Table 3 outlines some reclamation objectives and shows how monitoring will determine if these are being met.

How to Monitor

At its simplest, monitoring is a site inspection to identify changes since the area was last visited or since actions were taken. Monitoring should include observations of positive (desirable) changes at the site and negative (undesirable) changes that will need rectifying.

It is important to take notes and photographs (preferable date and time stamped) each time a site is visited because memories are not always reliable. It may be useful to have one notebook or binder dedicated to monitoring notes. These notes will be useful for the annual report as well.

Information to record:

- site location (if there are multiple sites, they could be assigned a name or number);
- basic information like the date, current weather, and previous weather events;
- the type of monitoring (routine vs. follow up on an action) and time since last monitoring event or action at the site;
- soil or substrate: changes in compaction, erosion, gullies, depositions from water, etc.;
- water: changes in depth, rate of flow, colour, smell, algae, etc.;
- water quality: in-situ parameters (pH, temperature, conductivity, turbidity, total suspended solids, etc.) if the means to test these are available;
- changes in vegetation: growth, death, new plants, aquatic plants, invasive species, etc.;
- sightings, tracks or signs of any insects, birds and wildlife, particularly in the water; and
- anything else that seems unusual or different.

Recording the absence of an expected phenomenon or observation is also important information.

Monitoring is more accurate if it includes specific quantitative measurements (water 30 cm deep, plants 10 cm high) but these can be time consuming and sometimes difficult to take. Relative “measurements” are also useful (edge of water close to tree and last time it was past tree, plants are 30-cm tall high and last time they averaged 5-cm tall) and can be made very intuitively.

Monitoring Schedule

A repeatable monitoring schedule for the active season (approximately April to October) should be designed with the site conditions in mind. For example, for a simple, flat site with one marsh, monthly or bi-monthly monitoring of the wetland may suffice. A more complex site with multiple surface water inputs, steep adjacent topography, multiple wetland types and a rare plant species present, may require weekly or bi-weekly monitoring during the active season.

Monitoring should always take place following freshets to determine how high water has influenced the previous season’s reclamation activities. Unusually heavy rain events, persistent rain or other weather that is out of the ordinary merits an additional monitoring event. Camera monitors or water level gauges add rigor.

Winter monitoring, where possible, may provide insight on wildlife (via tracks), ice thickness (via augering), snow cover (an input to the site’s water budget) and ice-jam flooding or loss of pit contents due to overtopping.

Taking Action and Follow-up Monitoring

If anything unusual is noted during routine monitoring or an incidental observation, take the appropriate action, record it, and determine a suitable interval for follow-up monitoring depending on the severity of the event. If the problem persists, the prescribed fix will need to be changed. For example, if gullies form repeatedly despite repairs, consider using biodegradable matting and revisit the site after the next rain event to assess the success of this remediation.

Incorporating the Reference Site

Visiting the chosen reference sight at the same time of year as the monitoring events will help determine if changes at the reclaimed wetland are in keeping with natural processes in a similar ecosystem. The reference site may also provide insight on how to solve or work with any problems that occur at the reclaimed site. For example, if replanted vegetation is killed or damaged by ice or high water during freshet, that type of vegetation may not grow near the water at the reference, indicating it is not a suitable species to replant near the ordinary high water mark of the reclaimed site.

It is important to keep in mind the reference site is most likely at a different successional (developmental) stage and will not entirely resemble an early reclaimed site.

Reporting

Proponents shall submit to the regulator an annual report of monitoring and maintenance activities, including:

- Observations of succession and growth rates of natural vegetation species. Compare these plant species to those at reference sites. Describe whether any invasive species have occurred and if so, how these were removed.
- Observations of the presence or absence insects, birds, fish and wildlife, including any important indicator species compared to reference sites.
- Description of reclaimed wetlands and how these stayed saturated and/or under water (i.e., existence of ponds, marsh areas, etc.). If additional hydrological maintenance actions were taken to ensure saturation or flow, explain.
- Description of erosion control measures and the stability of edges of reclaimed wetlands. Explain if any areas required repeated maintenance (e.g. if rainfall events caused problems), and how erosion control activities changed or increased.
- Description of erosion control measures for tailing piles and overburden.
- Include any data on quality of water released such as self-testing, testing by Compliance, Monitoring and Inspections, independent testing, etc. If water releases were not acceptable quality, why not? Explain actions taken to rectify problems.

Adaptive Management

If problems are noted during monitoring of progressive reclamation, Table 4 offers some adaptive management strategies that can be employed to resolve them.

Table 3. Wetland reclamation planning: how to monitor reclamation to promote positive outcomes

Post-reclamation Monitoring		
Objectives	**Proposed Methods/Approach**	**General Performance Indicator**
Only high quality water released	Test water for suspended solids, mobilized heavy metals, and other pollutants.	No evidence of sediment plumes or fine sediment accumulation in release sites
Reconnect some groundwater flow	Boreholes or piezometers indicate that groundwater is not stagnant.	Boreholes fill at a rate at least half as fast as reference sites. Subsurface water and springs show some flow.
Re-configured land forms	Reduce height of stockpiles and depths of low areas to no more than +/-50 cm of pre-existing topography. Do not leave extensive ponds; use available fill to re-contour them.	Land surface resembles reference area
Appropriate soil placement	Topsoil and organic-rich mucks and subsoils will be stored for re-application across all surfaces that were previously vegetated.	No extensive areas of bare rock, mine waste or subsoil that is unsuitable for revegetation
Natural plant cover	Plantings with native vegetation should be photographically documented at fixed, repeatable locations to show plant spread over time. Claim stakes may help with reference photo sites. Informal walking transects spaced 100 m apart across mine area, inspection every 30 m measuring plant cover.	By year 3, the species composition and distribution will be 75% of the pre-mine condition even if sparse By year 5, 75% plant cover density will be achieved.
Accommodate indicator species of wildlife	Concurrent bird and wildlife surveys to record return of fauna. Tracks, lodges, scat, browsing or tree-felling (by beavers) is confirmation of wildlife species present. June breeding bird surveys in each major habitat will confirm use. Fish may be netted (under permit), angled, or viewed if water quality permits.	By year 3, flowing water species of insects, grayling and salmon survive. By year 5, insect-eating birds nest in shrub and emergent vegetation at densities comparable to reference site. Within 3 years aquatic mammals (beaver, muskrat, otter, and mink) are present.

Table 4. Troubleshooting: potential problems with reclaimed wetlands and adaptive management responses

Problem	Indicators	Adaptive Management Strategies
Water loss (drying)	Exposed soil area Presence of salts	Increase the height of the discharge structure (if present) to prevent water discharge. Convert drier areas from wetland habitat to upland habitat with permission from regulator.
Water gain (flooding)	Higher water level than desired Diminishing aquatic vegetation	Decrease the height of the discharge structure (if present) to allow for more water to discharge. Add more stockpiled soils and organic materials into constructed ponds to reduce water depth.
Infilling with sediments	Increased turbidity Reduced aquatic plant growth	Check for and correct any slope erosion issues. Block off access to silty water. Change height of discharge structure (if present).
Shoreline erosion	Excess sediments eroding around edges Decreased vegetation on shoreline	Cover eroding shoreline with gravel or timber and woody debris. Plant willow cuttings or stakes on shoreline.
Lack of vegetation	Bare areas	Make soil surface rough and loose to reduce compaction and increase micro germination sites. Check for loss of organic soils and replace organic soils as necessary with stockpiled topsoil. Limit soil losses by erosion control measures, including biodegradable matting if necessary. Plant willow cuttings or stakes, or hand-planted bare-root stock. Hand or aerial seed with collected local seeds.
Low aquatic organism diversity	Expected waterfowl not present Expected aquatic mammals not present	Create more shallow littoral and marsh areas at the edges of ponds Increase amount of logs and woody debris in the bottom and on the slopes of the pond or peninsula. Re-introduce aquatic organisms using natural shallow water wetland soil and plants set aside from initial excavation of site.

Appendix I – Classes of Wetlands

This guide uses the five common classes of wetlands identified in the Canadian Wetland Classification System: **marshes, bogs, fens, swamps and open shallow water wetlands**.

1. **Marshes** (riparian meltwater, stream, floodplain and slope marshes) form on mostly mineral soils and support knee-high to head-high growth of sedges, cattails, and bulrushes. Water levels are variable but marshes usually have standing water for much of the year and are often found in backwaters, around small ponds and oxbows.
   Functions of marshes include stabilizing water flow, flood control, maintaining water flow during drought, filtering water, trapping sediment, and providing wildlife food and habitat.
2. **Swamps** where marshes support alders or willows they are a special form of forested wetland called swamps (riparian floodplain swamps). Swamps are characterized by well-decomposed woody peat and can be either peatlands or non-peatlands. They typically have a fluctuating water table. There are also coniferous treed swamps affected by a shallow water table and a shallow depth to permafrost. These may also be subject to flooding.[3]
   Functions of swamps include stabilizing water flow, flood control, maintaining water flow during drought, storing organic material and carbon, filtering water, trapping sediment, stabilizing soils, wood production and providing habitat.
3. **Fens** (riparian shore and stream fens)**.** In most Yukon river valleys, fens are the largest continuous wetlands in broad flat areas of river bottom. They are saturated, peat-accumulating sites that support wetland grasses, brown mosses, cotton grass and sometimes larch trees. Their water comes from mineral-rich groundwater that has a neutral to higher pH (more alkaline). The water table is usually at or below the surface and the peat is made of partially decomposed sedges or brown moss.
   Functions of fens include stabilizing water flow, maintaining flow during drought, storing organic material and carbon, filtering water, trapping sediment and providing habitat.
4. **Bogs** (riparian shore bogs and peat mound bogs) are moss-covered, deep peat areas that rarely flood or receive ground water, rather, they get their water exclusively from rain and snow-melt. The soil and water have a low pH (acidic). Bogs sometimes have stunted black spruce and low shrubs growing in them but they always have Sphagnum

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[3]Shoreline zones of riparian wetlands (riparian meltwater channel marsh) are a special zone of a larger wetland class that occurs on wet mineral soil, gravel and sand within the annual high water zone of the flowing water. These are often very narrow zones, just a few meters in width. They may be bare or recently covered with plants. Floods and scouring during ice-out mean these are naturally high-disturbance sites that may be re-colonized each year with durable or expanding plant life. Common plants include horsetails, sedges, mudflat annuals and willows.

mosses present, which increase the acidic growing conditions preventing many other plants from growing there.
Functions of bogs include storing water, organic material and carbon, and providing diverse habitat.

5. **Open shallow water wetlands**, such as ponds, have standing or flowing water less than 2 m deep in mid-summer. Shallow water wetlands are transitional between seasonally wet (i.e. bog, fen, marsh or swamp) and permanent, deep water bodies. Water levels are seasonally stable, permanently flooded, or have intermittently exposed bottoms during droughts, low flows or intertidal periods. Shallow waters undergo the aquatic processes typical of lake surface waters or shore zones with full light penetration such as nutrient and gaseous exchange, oxidation and decomposition.[4]
   Functions of shallow water wetlands include stabilizing water flows, trapping sediment and providing aquatic habitat.

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[4]The open shallow water class excludes artificial water bodies (reservoirs, impoundments and dugouts) where water regimes are manipulated. This category excludes active tailings ponds, with controlled inputs and outputs. Abandoned tailings ponds, less than 2 m deep, subject to natural aquatic processes typical of surface waters or shore zones, are included.

Appendix II – Frequently Asked Questions about Wetland Reclamation

The following 16 questions pair with answers and performance indicators to assist in achieving successful wetland reclamation. Questions are hyperlinked to the appropriate answer.

Questions

Q1. What is the best management of excavated soil and stockpiles?

Q2. How do I design and construct to mimic natural landforms?

Q3. What is the best way to restore slopes and surface elevations to pre-mine conditions?

Q4. What is the appropriate creek channel hydrology and how can it be re-established?

Q5. What is the appropriate range and distribution of wetland sizes to leave?

Q6. Is there a place for islands, shorelines and peninsulas in the post-mine configuration?

Q7. Are deep excavation pits suitable in the reclaimed site?

Q8. What role do marshes have in wetland creation?

Q9. What role do shrubby or wooded swamps have in wetland creation?

Q10. Explain the desired surface or micro-topography to leave after mining.

Q11. Why is it desirable to leave islands of undisturbed vegetation scattered around the mine site?

Q12. What are wetland plant zones and how does reclamation encourage their development?

Q13. Where should reclamation specialists get their plants and seeds and why is this important?

Q14. How can insect life be encouraged?

Q15. What reclamation techniques attract and support a diverse wildlife community?

Q16. Are chewing mammals such as beavers, muskrats and geese beneficial?

Answers: Suggested Methods and Performance Indicators

A1. Soil and Stockpile Management

Long slopes and steep gradients encourage erosion, so shorter and more gradual are best. Native topsoil is rich in organic material and natural plant seeds and roots, thus, should be retained. The best way to do this is to make the first lift of the surface soil deep enough to capture roots and top soil but not to incorporate subsoil and rubble. This topsoil zone is visible and may extend downward between 30 cm and 1.5 meters. This valuable topsoil should be stored separately from overburden and where possible, stored by individual surface vegetation type to make it easier to replace by plant growing zone. For example, later cattail soils get replaced into low swales; aspens and willows to upper shores. The sooner topsoil and embedded plant parts can be reinstalled the better to limit erosion, aeration and decomposition and composting effects that can kill seeds and living shoots.

Performance Indicators (A1)

a. Situate and sort reclamation materials conveniently for subsequent reclamation.
b. Return excavated materials to the reclaimed sites natural contours promptly after mining.
c. Site-appropriate plants emerge from re-distributed topsoil to assist natural colonization.

A2. Mimicking Natural Landforms

Benches should be relatively level and runoff pathways should be longer and shallower to increase settling of suspended solids increase time for infiltration into the sediments. A tier of floodplains should occur above the normal high water mark to restrict overflow to true out-of-bank flood periods. Encourage rapid revegetation of banks and floodplains to stabilize surface sediments. Where slopes are steep, erosion-prone from normal precipitation, stabilize them with biodegradable matting (hemp, jute or coco fiber) to prevent down-cutting. Place check-dams or water-breaker cobble in erosion gullies and wherever channel formation down-cuts.

Performance Indicators (A2)

a. Stable landforms with no obvious erosion
b. Precipitation and mine waste water infiltrates ground or wetland beds without erosion or slope failures.
c. Excess runoff is minimal and flows toward, and is captured by, adjacent intact plant stands.
d. Floodplain benches are only occasionally (and briefly) inundated at peak runoff periods.

A3. Restoring Pre-mine slopes and Elevations

Progressive reclamation requires real-time filling and contouring sites simultaneously with ongoing mining operations. Fill material is replaced in reverse-order of its excavation, typically subsoil and cobble goes on the bottom, followed by gravel, then silt then topsoil. Temporary settling ponds should be re-filled with substrate to +/- 50 cm of grade, recognizing that some settling and subsidence is likely. Swales, low areas, and depressions should occur close to the groundwater table to encourage saturated soils, encourage wetland plant return, and to minimize invasive upland exotic plants. Wetland formation may be encouraged above the water table by the placement of fine tails and settled clays to slow infiltration and hold water for wetland development.

Performance Indicators (A3)

a. Surface elevations and slopes reclaimed to original wetland status with saturated wetland conditions.
b. Order of material replacement encourages surface insulation and encourages permafrost development.

A4. Re-establish Creek Channel Hydrology

Reconnect and return local hydrologic inflows and outflows of surface and groundwater to original conditions. If approvals and licences permit, connect wetlands to streams to supplement hydrology and keep wet-areas wet. Where constructed wetlands connect to surface water sources, create the junction at right angles to water flows and armor the junction with boulders or coarse cobble to reduce erosion and outlet closure. Keep constructed wetland sites wet, especially in fall. Release settling pond water only with regulatory approval or via filtration through groundwater.

Performance Indicators (A4)

a. Stable creek and main-stem channels resemble pre-mining form.
b. Water and ground surface elevations similar to undisturbed river valley bottoms with river-wet swales (high water overflows) and zones only overtopped by major floods.
c. Moist soils cool, assist ice-formation and increase penetration of seasonal freezing.

A5. Wetland Sizes on Site

Replace excavated materials back into pits to eliminate elevated piles and deeply excavated depressions. Ponds on reclaimed site should be of similar size, shape, depths, and distribution as exited pre-mining ponds. Understandably, the exact locations may be different.

Performance Indicators (A5)

a. Topographic relief, remaining ponds and wetland zones are returned to +/- 25% areal extent of pre-mine landscape.

A6. Island, Shoreline and Peninsula Development

Overburden and tailings may be pushed or dumped from shore to create roughed-in islands and peninsulas. The inclusion of ice, snow, and coarse woody debris is permissible to increase groundwater penetration in these low-flow areas.

Performance Indicators (A6)

a. Elevated mounds and peninsulas do not exceed 50 cm above or below the average high water mark unless pre-mining conditions at that site occurred at higher elevations and contributed excess soil volumes.

A7. Excavation Pit Depths

Build shallow shoreline zones (called littoral zones) by sloping any abrupt or cliff-like walls. Overburden may be pushed or bucketed over edges to create ramp-like gentle slopes for colonization by littoral wetland plants along this gradient. Islands, irregular shorelines and variation in shallow pond bottoms are desirable.

Performance Indicators (A7)

a. Pond shores and beach edges are gradually tapered to the water.
b. Wetland plants colonize this shoreline in definable zones according to depth to ground water.

A8. Marshes in Wetland Creation

Marsh plants are the first to arrive in disturbed sites and will be favored by shallow damp slopes and depressions with fluctuating water levels between 0 and 100 cm depth. These mimic river backwaters and channels cut off from river flow. Arranging groundwater flow down the gradient will assist the development of fen vegetation over time.

Performance Indicators (A8)

a. Marsh plant appearance in open shallow wetlands
b. Soil and water movement intercepted by gently sloping vegetated zones at water-soil junctions.

A9. Swamp Creation

Swamps are wetlands with shrubby or woody plants such as willows. They tend to develop in areas with moderately high groundwater for root uptake and are not injured by periodic flooding and fluctuating water levels.

Performance Indicators (A9)

a. Shrub and tree colonization that stabilizes banks, slows over-bank water flows and helps control floodwater speeds.

A10. Micro-topography After Mining

Reclaimed ground surfaces can remain rough and non-compacted to encourage water infiltration, seed capture, and a variety of micro-sites to meet a variety of plant growing conditions. Placement of 6-10 cm of rich organic sediment from natural wetland areas previously mined can enrich colonization by native species. The organic matter often contains an abundance of dormant seeds and the water-holding nature of organic matter reduces desiccation and provides nutrients to seedlings.

Performance Indicators (A10)

a. Natural vegetation colonizes appropriate micro-sites.

A11. Reservoirs of Undisturbed Vegetation

Whenever possible, leave areas of natural vegetation in, or near, the operating area, along travel corridors and in riparian buffers around water bodies. Their seeds, micro-flora and fauna, and natural spread can aid reclamation toward original conditions.

Performance Indicators (A11)

a. Existing vegetation acts as a habitat, corridor and parent source for newly colonizing plants.

A12 Wetland Plant Zonation

Cover shorelines and wetland zones with fine soils along gradients to allow natural re-vegetation.

Performance Indicators (A12)

a. Wetland plants colonize and cover littoral zone in depth-appropriate zones perpendicular to elevational gradients.

A13. Sources of Reclamation Plants

Use stockpiled topsoil, peat, and organic matter to revegetate areas with local flora as soon as possible. Collections of seeds called "seed banks" are resident in such soils and represent a valuable resource of locally adapted and genetically appropriate plants. Distribution of bucket loads of undisturbed natural plants and underlying topsoil can provide islands of natural plants, seeds, soils, and microflora. Request permission to borrow up to 10% of standing vegetation from surrounding undisturbed areas to serve as planting stock. Collect mature seeds from dominant plant species when ripe. Collect the fall prior to planting or from nearby undisturbed areas in the same year as reclamation. Collect and plant bare-root rhizomes and stems in similar sites. Seed and plant reclaimed areas.

Performance Indicators (A13)

a. Wetland species occurrence and distribution on reclaimed sites are similar to those on natural wetland disturbance sites in the region.
b. Optimal depth of 20 cm organic rich topsoil ensures root penetration at water depths less than 45 cm.
c. No invasive plant species occur on the reclaimed site.

A14 Aquatic Insect Occurrence

Aquatic invertebrates (for example insects, crustaceans, worms) form an important component of the food chain. Place logs, root balls and woody material in the soil profile, in wetlands, and on shoreline slopes. Re-introduce aquatic organisms using the shallow water, wetland soil and plants salvaged from initial excavation. Submersed aquatic plants are particularly rich with aquatic life

Performance Indicators (A14)

a. Habitat is available and occupied by a diversity of aquatic invertebrates.

A15. Supporting Diverse Wildlife Communities

Retain some gravel in ponds, along shorelines rather than burying it all under constructed landforms. Install coarse woody debris. Place a variety of intact logs flat on the ground surface to mimic the natural floodplain log jams that provide much cover, denning habitat and safe sites for medium and small-sized mammals. Retain or install upright snag trees for cavity nesters and predator perches.

Performance Indicators (A15)

a. Site supports the same suite of resident and transient wildlife that existed prior to mining.

A16. Beavers, Muskrats and Geese

Beavers, muskrats and geese may disturb some planting efforts, however, their overall effects are usually more beneficial than harmful in the long run. Their browsing, chewing and movement of plants add diversity and complexity to sites as well as increase seed distribution. It is an option to leave very occasional ponds (one or two percent of area) up to 2 meters deep to ensure water under the ice for insects, beaver, muskrat and otter overwintering habitat.

Performance Indicators (A16)

a. Up to one small pond (2 ha) per 100 ha site may be left if beaver colonization is sought.
b. Anticipate beaver damming to block any flowing channels. This may change the water table locally.