# GUIDING PRINCIPLES FOR SUCCESSFUL MINE RECLAMATION IN BRITISH COLUMBIA

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## ABSTRACT

BC's Ministry of Energy, Mines and Petroleum Resources is developing a Reclamation Guide for Mines in British Columbia. The Guide is intended to support mine operators, regulators, Indigenous communities, and other stakeholders to improve the processes and outcomes of mine reclamation. Reclamation design is an ongoing and iterative process that begins before mine development and continues after closure. At any stage of mine life, operators generate the most detailed reclamation plan possible given available information, and document key performance assumptions and uncertainties. With each iteration, informed by the objectives and constraints of the mine plan, operators evaluate all opportunities to improve closure outcomes and achieve reclamation targets/requirements by adjusting design elements and incorporating findings from research and monitoring programs. Over the life of the mine, this design-test-do-report cycle represented by the reclamation plan iterations supports a progression of increasing information, reduced performance uncertainty and increasing confidence in the ability of designs to be successfully implemented and meet closure expectations. The Reclamation Guide focuses on five key principles for reclamation design: defining end land use targets, recognizing contaminant transport mechanisms, engaging with Indigenous communities, understanding ecohydrological interactions, and designing with the end in mind.

## KEY WORDS

mining, guidance, restoration, manual, planning, best practices

## INTRODUCTION

Provincial legislation first enacted in 1969 in British Columbia views mining as a temporary use of the land due to the non-renewable nature of the resource, with the expectation that all mining-related disturbances will be effectively reclaimed when operations cease.[1] The role of the Ministry of Energy, Mines and Petroleum Resources (EMPR) in this regard is to minimize negative environmental and social effects of mining and the costs and liabilities that could be inherited by the public. This is achieved by ensuring that appropriate plans are developed and implemented to return the land and watercourses to conditions that are protective of the environment and the health and safety of the end land users. Mines should be designed and built to minimize disturbance, and

[1] Reclamation and closure may involve ongoing monitoring and maintenance to mitigate specific disturbances related to mining for a period after operations cease, possibly in perpetuity.

reclaimed to restore site-specific land capabilities, prevent or mitigate potential adverse effects, and minimize long-term liabilities. In order to assist operators in achieving these objectives, EMPR is developing a Reclamation Guide.

EMPR's Reclamation Guide is intended to support mine operators, regulators, and other stakeholders to enhance the processes and outcomes of mine reclamation in the province. It provides background information and key concepts, and technical guidance on reclamation design, reclamation planning, and effective adaptive management including monitoring. The technical component of the Guide focusses on ecological aspects of mine reclamation and closure – such as landforms, soils, vegetation, and end land uses – and on outlining current best practices in planning for mine reclamation throughout the life of a mine, including in closure and post-closure. It does not address in detail engineering, geochemical, or contamination-remediation aspects of mine reclamation and closure, although guidance on some of these topics is referenced.

<u>The importance of reclamation</u>

With any proposed mining project, there is an expectation that mitigation planning occurs in predictable steps at an appropriate scale. Reclamation is a component of the mitigation hierarchy intended to minimize negative environmental effects from mining and ensure that land used for mining can be returned to productive uses at the end of mine life. The mitigation framework illustrated in Figure 1 is hierarchical in that it is sequential, with earlier components emphasized and achieved to the extent possible. That is, it is assumed that mine operators will do everything possible to avoid negative effects through careful location of facilities, they will then do everything possible to further minimize negative effects through optimized footprint design or other actions, and then they will reclaim to mitigate remaining negative effects to the extent possible.[2]

In general, the earlier actions of avoidance and minimization have higher certainty of successful achievement of mitigation goals: we are more certain of our ability to mitigate unwanted effects if we avoid these effects in the first place, rather than having to repair them later. However, the Reclamation Guide assumes that mining has occurred or is occurring – with actions already having been taken to avoid and minimize effects to the extent possible – and that reclamation is necessary to repair any remaining negative effects and to return the land to productive post-mining uses. Effective reclamation is a critical element of the mitigation hierarchy, and an important contributor to achievement of provincial goals for mining.

[2] The fourth step of the mitigation hierarchy, offset, is not discussed here as the *Mines Act* requires that the mine footprint is reclaimed to the standards outlined in the Code. Offsetting may be required in certain circumstances to overcome temporal constraints to restoring the footprint or uncertainty for achieving critical habitat values through reclamation on site, however offsets are not a mechanism to preclude the requirement to reclaim the mine footprint.


Figure 1. The mitigation hierarchy and reclamation (after Ekstrom et al. 2015).

Reclamation plans should not only be well designed and effective, but timely. Detailed reclamation designs should be developed early in a project's life, prior to construction, and initial reclamation efforts should be implemented early in the mine's life. The more the mine advances, and the further the life of a mine progresses, the more reclamation options are constrained, and costs to achieve permit requirements or other committed objectives may increase. Early (and progressive) reclamation allows reclamation assumptions to be tested, designs to be refined, and knowledge and supply chains necessary to support operational reclamation to be developed, and reduces uncertainties about the ability to cost-effectively achieve reclamation goals. It also provides important opportunities for early and ongoing stakeholder engagement, and helps to build relationships between miners, land users, and the evolving post-mine landscape.

<u>Intended audience</u>

The EMPR Reclamation Guide is intended for the following audiences:

- **mine operators** – to provide guidance for mine-reclamation planning, to inform mine designs and reclamation and closure plans, in particular for development of permit applications and life-of-mine reporting requirements;
- **stakeholders** (regulatory agencies, interested Indigenous communities, the public) – to provide information to support informed review of proposed or existing mining projects; and
- **EMPR staff** – to provide clarification when reviewing applications, and reclamation and closure plans required by the *Health, Safety and Reclamation Code for Mines in British Columbia* (the Code) or as a condition of all *Mines Act* permits.

This paper presents some of the foundational concepts of the Reclamation Guide.

## THE RECLAMATION PLANNING CYCLE

Prior to mining, and regularly throughout all phases of the life of a mine, operators must develop and update a Mine Plan and Reclamation Program, and present it for review to regulators and other stakeholders. This is updated every five years, at a minimum, over the life of a mine, and is a key document that articulates reclamation objectives, design, progress, and research results. For smaller mines with shorter mine lives, there could be only two or three of these five-year cycles during operations. However, many mines in British Columbia are large, with multi-decade mine lives, and having ten or more five-year planning cycles during operations is conceivable. Over the course of this long operating period, it is likely that mine plans, conditions, and expectations will change substantially.

Although this is presented formally as a cycle of planning and review that would support stakeholder engagement around these topics, a more ideal structure would be to use stakeholder engagement around the Mine Plan and Reclamation Program as a collaborative forum to review advances in information and develop the new Reclamation Program together.

The first of the Mine Plan and Reclamation Program submissions is advanced in the *Mines Act* Permit Application process, and the last is completed one year prior to closure (although additional updates may be required). At all phases of the mining life cycle, this planning should be as advanced and as detailed as current information allows. As an operation matures, the nature of the design-plan-implement-test cycle does not change, but the amount of information supporting this cycle increases. This approach is illustrated in Figure 2, which emphasizes the connections between design, testing, and reporting. Key elements in Figure 2 are emphasized in the text below with bold font:

1. At any given stage of the mine life, the operator develops the most detailed reclamation **design** possible, supported by the best available information, with the objective of having an executable plan available for the site at all times.
2. The design must explicitly identify key assumptions on which it is based, and **uncertainties** with respect to its performance.
3. The operator must implement a formal program to **test**/verify these assumptions and reduce these uncertainties – this program will most likely involve reclamation research[3] and collection of additional data.
4. The testing phase should lead to **reduction** in uncertainties. All aspects of the design are revisited with new information, and the design updated if necessary.

[3] Reclamation research can be conducted through formal replicated testing of techniques and assumptions, and/or through rigorous monitoring of commercial-scale reclamation. Each approach has advantages, but operators need to ensure that planned reclamation techniques are feasible using commercial equipment on large areas.

5. On a five-year basis, updated designs are provided to regulators in the form of the **Mine Plan and Reclamation Program**, which is reviewed and may be approved through the Mines Act Permit. The designs must also be updated in the form of the final reclamation and closure plan.
6. Over the life of the mine, this design-testing-reporting cycle should support a progression of **increasing information, reduced performance uncertainty and increasing confidence** in the ability of designs to be successfully constructed and to meet expectations with respect to closure outcomes.

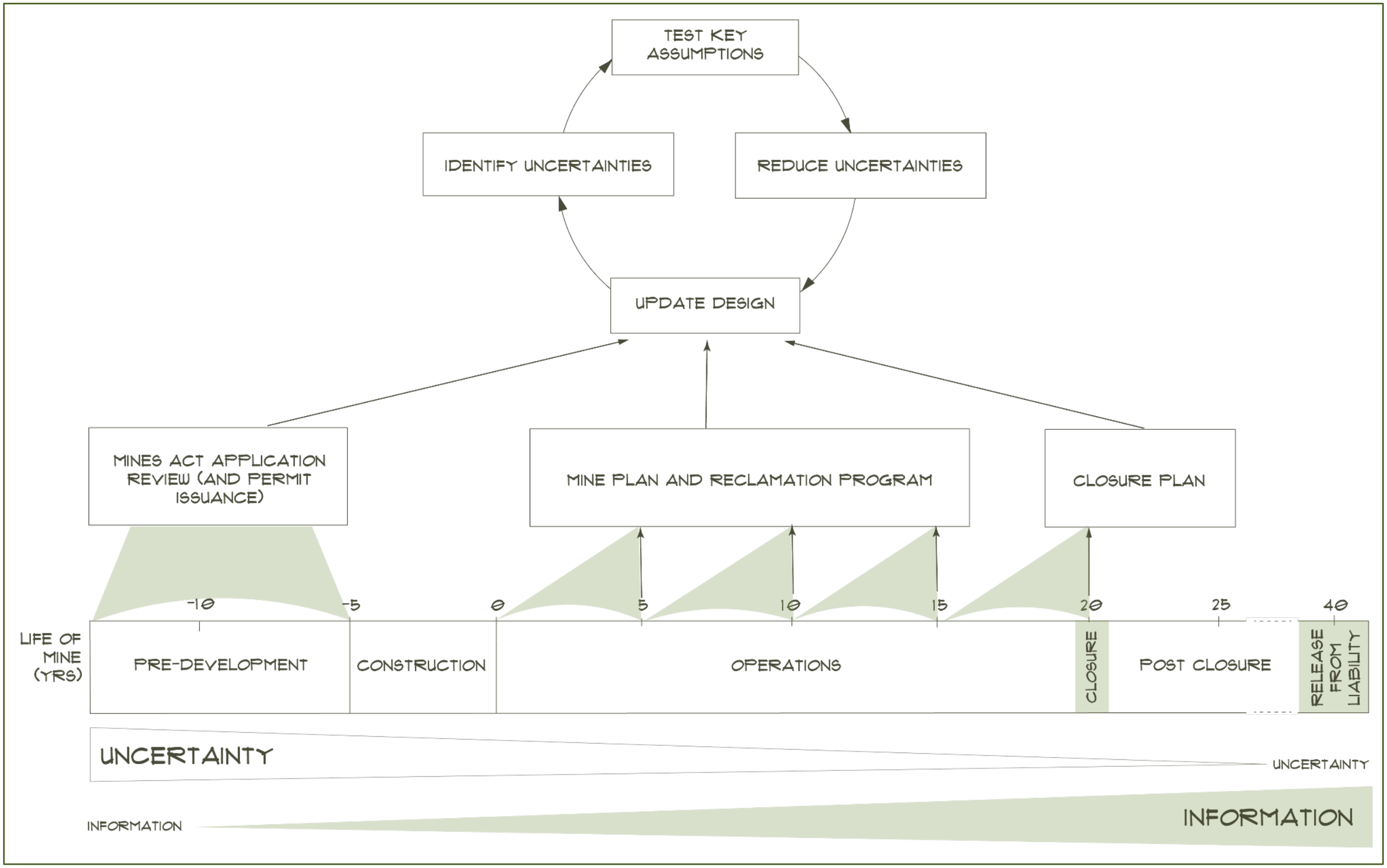


Figure 2. The cycle of design, testing, and reporting over the life of a mine.

## DEFINING END LAND USE TARGETS

Understanding land use before and after mining ("end land use") is a core concept underlying standards for mine reclamation in BC. A mine's Reclamation Program must include an End Land Use Plan (ELUP) for approval under the *Mines Act* that considers previous and potential uses. Both pre-development and post-closure landscapes can simultaneously or sequentially support more than one end land use – e.g., wildlife habitat and Indigenous traditional land uses – and areas of land use may overlap or be spatially separate across the mine footprint.

There are primary two overarching goals for reclamation based on land use and land capability:

- the mining footprint is to be reclaimed to achieve end land uses that consider previous and potential uses, and
- post-closure capability for these uses should be equivalent to the capability that existed prior to mining.

These requirements, coupled with the fact that most mining in BC has occurred on natural landscapes with few people, lead to the following key points:

1. Land capability is linked to end land use – it is not a generic capability, but the capability to support the specific proposed/approved end land use(s).
2. For the most common end land uses – those like wildlife habitat, forestry, and agriculture that rely on natural ecosystem functions and cycling of water, energy, and nutrients – capability is defined by both biological (soil) and physical (climate, topography, soil) characteristics.
3. Post-closure land capability must be compared to pre-development land capability – to assess how equivalent capability will be achieved after mining as required by the Code. To do this, post-reclamation conditions must be assessed or projected, with the objective of evaluating the gap between pre-mining and post-closure capabilities. Reclamation prescriptions must then be developed with the objective of addressing differences between pre-development and projected post-closure capabilities.

The ELUP is a "blueprint" that guides reclamation planning, research, and monitoring throughout the life of the mine, and is expected to inform all updates to the Reclamation Program. Reclamation treatments should be clearly tied to the end land use targets identified in the ELUP, including spatially explicit information on end land uses within the development footprint.

Mining generally involves substantial changes to landforms and watersheds, and that because of these changes, post-mining land use capabilities may be different than pre-mining capabilities. A key part of reclamation planning is identifying and striving to eliminate these differences. This may include conducting research programs and optimizing mine design to address factors limiting reclamation and to maximize reclamation potential.

As with all elements of the Reclamation Program, where assumptions are made about the ability for the results of reclamation activities to support specified end land uses, reclamation research programs should be developed and implemented in a timely manner to test these assumptions and associated reclamation designs, and to reduce uncertainty with respect to effective reclamation and successful closure of mine projects. Where Valued Components or equivalent have been identified through the environmental-assessment process, these Components should be clearly highlighted in the ELUP and in associated reclamation design and treatments. ELUPs should be as specific as possible, e.g., an ELUP that includes wildlife habitat as an end land use objective should indicate the focal wildlife species for which habitat will be re-created. The ELUP should be explicitly linked to ecohydrological projections of post-closure ecosystems.

The ELUP is expected to inform all updates to reclamation and closure plans and may require adjustment through the life of the mine due to changes to the mine plan, regulation, and/or stakeholder expectations, or findings from research and monitoring.

The steps to developing the ELUP for a mining project start with defining the inherent ecological capability of the post-mining landscape in ecohydrological planning units, translating that capability to the related ecological uses, and then refining planning in comparison with pre-mining conditions. Required content for an ELUP is summarized in Table 1. The ELUP is expected to be a complete and logically consistent subsection of the Reclamation and Closure Program component of that submission.

Table 1. Table of contents for the End Land Use Plan.

| Section | Description |
|---|---|
| Pre-development conditions | Define and describe the pre-mining land and water capability and use, using maps and tabular inventories, with respect to ecosystems and habitats and other uses in the area of mine disturbances |
| Post-closure conditions | Define and describe the predicted post-closure land and water capability and use (based on changes that are expected to occur to topography and soil conditions due to mine development), using maps and tabular inventories, with respect to ecosystems and habitats, ability to exercise Indigenous land uses, and other uses in the area of mine disturbances |
| Measures to minimize impacts through mine planning and reclamation | Ecohydrological modelling, or other planning exercises, to reconcile or minimize differences between the pre-mining conditions (as per Section 1, above) and post-mining projections (as per Section 2, above) accounting for, but not limited to, mine design, landform design and contouring, and optimization of soil conditions |
| Documentation of optimization | Documentation of the forecasted net changes in land capability between pre- and post-mining conditions and how any opportunities to improve land capability from its previous state were considered and incorporated |
| Documentation of target conditions | Explicit documentation of mitigation targets related to end land use values – including but not limited to wildlife and wildlife habitat, vegetation, and ecosystems – and monitoring for those targets |

## RECOGNIZING CONTAMINANT TRANSPORT MECHANISMS

Mining activities have the potential to create sources of contaminants that can change soil and water chemistry and cause effects to biological receptors. Although the Reclamation Guide is focused on ecological aspects of reclamation, it is important to note that a key element of reclamation and closure planning that should dovetail with end land use planning is the development of a conceptual site model (CSM). Along with other planning, the CSM should guide mine design and the development of reclamation prescriptions with the intent of mitigating potential environmental effects and human health and ecological risk (Ministry of Environment and Climate Change Strategy 2018; Canadian Council of Ministers of the Environment 2016). A CSM should be a stand-alone document, ideally in a format accessible to a general audience, ensuring that regulators and stakeholders all have a similar context for communicating concerns and approvals. The ELUP and the CSM will work together to define the reclamation design for the mine project.

A CSM should:

- show how significant sources of parameters of concern (POCs) from the mine site have been considered and evaluated;
- assess all major exposure routes or pathways via which POCs can reach the receiving environment and receptors, including consideration of surface water and groundwater transport mechanisms;

- identify all receptors that may be adversely affected by POCs released from the mine site;
- determine the data collection requirements to validate and refine the CSM in relation to the 'completion' of pathways from sources to receptors;
- provide an overview of the potential source and pathway(s) for each POC originating from the mine site and being transported to the receiving environment; and
- indicate how POC loadings will be contained, collected, stored, and/or mitigated.

## ENGAGING WITH INDIGENOUS PEOPLES

Most mines in BC operate or have operated in areas that include local Indigenous communities, or within Indigenous traditional territories, and these communities are key rights-holders and stakeholders in reclamation planning and execution. The intent of participatory engagement with Indigenous communities within the reclamation design and implementation process, particularly in development of end land use planning, is to:

- establish an engagement approach and plan that is meaningful to Indigenous communities and that allows for active participation in reclamation planning at all stages, in order to support development and achievement of Indigenous end land use goals on the post-closure landscape; and
- identify the social and ecological processes that will foster meaningful reclamation for interested and affected Indigenous communities. The participatory approach should invite Indigenous participants into a position of direction and influence in reclamation design and implementation, including involvement in reclamation research and monitoring initiatives.

The engagement plan that will be established with Indigenous communities is overarching for the entire reclamation planning process throughout life of mine.

## UNDERSTANDING ECOHYDROLOGICAL INTERACTIONS

Ecohydrology is the study of the interactions between vegetated ecosystems and water: how water availability and timing influence the kinds of ecosystems that can establish in an area, and how these ecosystems in turn mediate the movement of water through the landscape. Ecohydrological analysis refers to data-driven techniques to quantify these interactions and apply results to reclamation design. This analysis provides the basis for pre- and post-mine capability comparisons, how design adjustments can be made to optimize reclamation outcomes, and for understanding how ecological reclamation decisions affect the hydrology of the reclaimed landscape. Ecohydrological analysis is used as an integrating design approach throughout this Guide.

In BC's Biogeoclimatic Ecosystem Classification (BEC) system, biogeoclimatic zones represent broad geographic areas of similar macroclimate and are recognised as influencing the biological characteristics of the resulting ecosystems (Meidinger and Pojar 1991). Biogeoclimatic zones are subdivided into subzones, with these subzones representing homogeneous climates at a finer scale

(Lloyd et al. 1990).[4] Typically, at a local scale (e.g., a mine permit area) there are relatively few subzones (e.g., a maximum of 2-3), which are delineated mainly by elevation thresholds that vary slightly by aspect.[5] Within each subzone, there are groups of distinct ecosystems called site series, a concept which describes all sites with similar physical properties and limitations in climate, topography, and soils (Pojar et al. 1987). Each site series has an assemblage of plants adapted to its edaphic conditions — a fundamental principle of the BEC system is that sites with similar physical properties have similar vegetation potential (Meidinger and Pojar 1991).

The relationship between site characteristics – or limitations in climate, topography, and soil (i.e., land capability) – and vegetation communities is conceptualized in the BEC system using edatopic grids (e.g., Figure 3), where site series (numbered, coloured boxes) are associated with particular combinations of soil moisture regime (SMR, vertical axis) and soil nutrient regime (SNR, horizontal axis). The availability of soil water (SMR) is a dominant control on the development and maintenance of a given SNR,[6] and thus in the BEC system, soil-water availability is believed to have the greatest influence on ecosystem development.

[4] Subzones may have multiple variants, where similar subzones occur in different geographic areas of the province. In this document, the term "subzone" is used to refer to the subzone/variant level of BEC.

[5] Research into current and anticipated climate changes in BC are indicating that biogeoclimatic zones and subzones are already shifting spatially, and will continue to shift with time.

[6] For example, a very xeric SMR, defined by prolonged growing-season drought, cannot naturally develop or sustain a very rich SNR due to low biomass production.

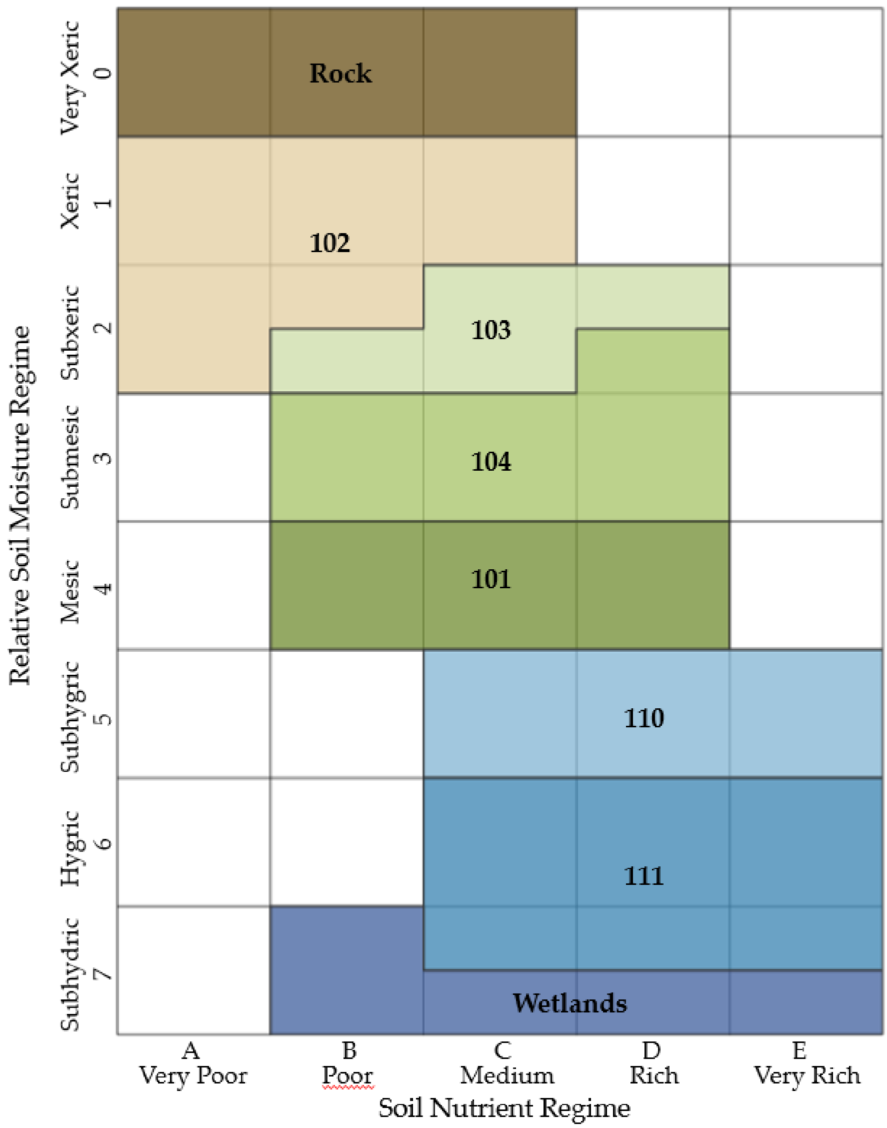


Figure 3. Edatopic grid for the ESSFdk1 variant showing the relationship between site series, soil moisture regime, and soil nutrient regime.

Together, location and landform characteristics determine the biogeoclimatic zones and subzones that occur in a post-mining landscape. Landforms and reclamation cover systems determine the occurrence of site series, which reflect climate, water and nutrient conditions in the rooting zone, and the native plant communities that are best adapted to these conditions. As discussed below, climate plus rooting zone and plant community characteristics have a strong influence on surface water balances, and so we can make ecohydrological linkages between the occurrence of post-closure site series and effects on water movement.

Because mining creates new landforms constructed out of new materials, and because landform shapes and materials influence biogeoclimatic conditions, post-mining landforms and landscapes may support specific ecosystems that are different than pre-development conditions,[7] and thus also have different capabilities to support land uses that depend on these ecosystems.

A key interaction in post-mining landscapes is that between re-establishing ecosystems and hydrological performance. Reclamation cover systems and their associated vegetation are the first parts of the mining landscape to encounter precipitation (rain and melting snow), and form a thin, active "skin" that mediates the movement of that water through the rest of the hydrological system. In most areas of BC, transpiration by vegetation is a dominant control on surface water balances, and thus can play a major role in determining the rate, magnitude and timing of water transiting mine landscapes and entering mine waste deposits. Conversely, the characteristics of mine landforms and the materials from which they are constructed have a strong influence on the performance of vegetated cover systems. One of our most important tasks as reclamation designers is to recognize and design for these ecohydrological interactions.

Water is highly mobile, connecting landforms within mines and to adjacent landscapes. Mining landforms such as waste rock dumps are often areas where water infiltrates (hydrological recharge), and can affect downstream ecosystems. Thus, in reclamation planning we must design not only for site-level requirements, such as soil water retention to support plant growth and soil biota, but also for landscape-level objectives such as limiting or enhancing runoff, or limiting infiltration to underlying materials. The decisions we make as designers about reconstructing soil water characteristics can have substantial implications for water quantity and water quality of receiving environments. We need to consider these full ranges of functions and implications in our reclamation planning, as they will occur whether we have integrated them into our designs or not.

To more explicitly design for ecohydrological interactions, it is useful for us to consider the surface (soil/reclamation-cover-system) water balance. This water balance equation is composed of fluxes and changes in stores, and can be written as:

$$Q = P - E - \Delta S$$

where over a given time (e.g., a growing season or a year):

- $Q$ is runoff, potentially comprised of both $Q_S$, surface runoff, and $Q_G$, groundwater flow;
- $P$ is precipitation as both rain and snow;
- $E$ is evaporation from both soil and vegetation surfaces, including plant transpiration; and
- $\Delta S$ is the change in soil water storage in the soil (Davie 2002).

[7] Post-mining ecosystems are generally drier and more nutrient-poor than dominant pre-development ecosystems, as reclamation-cover materials may be lower in organic nutrients, and as waste-rock substrates in the rooting zone hold less water than most natural surficial materials.

The linkages between ecology and hydrology in mine reclamation are illustrated using these terms below. Generally, in a given climate in BC:

1. Ecosystem occurrence is largely governed by the ability of surface materials to store and release water for plant growth over the course of a growing season (related to the $\Delta S$ water-balance term).[8,9] Thus the storage capacity that we design in our cover systems is a primary determinant of the ecosystems that we will be able to establish.
2. Larger water storage capacities will support ecosystems with more evapotranspiration ($E$) over time.
3. Larger evapotranspiration values result in lower runoff ($Q$) values, including net percolation from reclamation-cover systems into underlying mine-waste landforms. The increased soil water storage ($\Delta S$) on its own does not have the potential to decrease runoff ($Q$); it is the combination of increased soil water storage and a mechanism to remove this stored water – plant uptake and transpiration – that decreases runoff ($Q$).

These linkages must be explicitly considered in reclamation design objectives. For example, if a key design objective is to limit the volume of water contacting mine waste, one mechanism to contribute to this reduction is to build well-vegetated cover systems with a large capacity to store water for plant growth. This approach will require reclamation cover materials of sufficient quality and volume. If these materials are not available, there will be implications for hydrological performance of the reclamation cover and landform.

If the design objective is instead primarily to achieve ecological targets (e.g., replacement of certain proportions of ecosystems on the reclaimed landscape to meet end land use objectives), amounts of water transiting these ecosystems will vary according to this design, and this variance should be factored into the design process, with the understanding that decisions that are made at the landform level with respect to water may have landscape-level impacts. Such trade-offs should be explicitly discussed in design documents.

**DESIGNING WITH THE END IN MIND**

A central principle of the Reclamation Guide is the imperative (and the benefit) of designing with the end in mind. Land outlives mining – the true legacy of mining is the land left behind for local communities. Most decisions that affect reclamation design and performance are made before mining even starts (e.g., the type of mining, the milling process, the location of the major mining landforms, the plan to stockpile reclamation materials). Good decisions result in good performance at reduced costs with reduced risks. Poor decisions result in reduced performance, increased costs, and increased risk. A clear design basis, with a defined program of progressive reclamation and

[8] This storage capacity is related to the $\Delta S$ water-balance term and is governed by the available water storage capacity (AWSC) of the soil, i.e., the size of its storage reservoir, which is determined primarily by soil texture and depth.

[9] Occurrence of wetland and aquatic ecosystems is largely governed by the $Q$ term, or input water from surface or groundwater sources.

research backstopped with an effective adaptive management program implemented before mining starts is modern mining's way to create successful reclamation and control costs, risks, and liabilities. Mines that design with the end in mind save costs, achieve reclamation and closure goals, and minimize long-term risk and liability. It is both practical and important to initiate meaningful reclamation planning, including defining reclamation goals, concurrent with mine planning in order to inform the decision–making process and set operations up to not only produce cost-effectively but also reclaim successfully.

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