DESIGN OF LANDFORM ELEMENTS FOR MINE RECLAMATION

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ABSTRACT

Landform design is the multidisciplinary process that builds mining landforms, landscapes, and regions to meet agreed upon land use goals and objectives. Such work starts even before mining begins, carries on through mine development and operation, and continues through closure and beyond to guide post-mining stewardship of the land. It allows mining companies, regulators, and local communities to progressively reclaim the land with confidence, managing costs, risks, and liabilities, to create beneficial landscapes. Landform elements are specific physical subcomponents of a mining landform that are designed to allow the landform to meet the overall landform-scale design goals and objectives. They are typically large enough to be featured on a detailed design drawing and be built with normal mine reclamation equipment; they are usually in the 10 to 100m scale. Some elements are exquisitely designed while some are simply field-fit. Examples of landform elements include swales, mounds, outlets, watershed berms, vegetation patches, meandering toe creeks, islands, and wildlife enhancements such as snags and rockpiles. All provide efficient and practical solutions to complex mine reclamation problems. The paper provides a list of 97 landform elements for mine reclamation for common mining landforms including waste dumps, tailings facilities, and end pit lakes.

KEY WORDS: checklist, landform design, element, drainage, tailings, watershed

INTRODUCTION AND BACKGROUND

Mine closure and reclamation planning is typically done at a variety of scales: region, mine lease/landscape, mining landform, and patch (Table 1). Much of the landform design effort is focussed at the mining landform scale (for example, a single dump, an end pit lake, or a tailings facility). From recent work designing and reclaiming mine sites, the authors recognized the practicality of cataloguing "landform elements" as features of a mining landform or within a constructed watershed. There are dozens of types of landform elements that can be employed in a design (Figure 1). Examples include watershed berms, swales, rockpiles, and access routes. Some elements are designed into the closure plan, some at the landform scale, others field fit during reclamation operations. This paper provides a useful checklist of landform elements for landform design and mine reclamation for practitioners, landform designers, and stakeholders.

Figure 1: Common mining landforms and landform elements.

Table 1. Landform design scales.

Design scale	Representative dimension, m	Description and examples	
Regional	100,000	A grouping of mines in a valley or region *Regional plan, cumulative effects assessment*	
Lease / landscape	10,000	A single mine lease / property. More generally: everywhere you can see from a particular point on the land (the Renaissance definition) *Life of mine plan, mine closure plan, landscape ecology*	
Landform	1,000	A single mine facility: dump, mined out pit, stockpile, tailings facility *Dump design, dam design, landform design*	
Macro-topography	100	A single designed feature on a landform: toe berm, bench, shoreline, wetland *Landform design (as above)*	Landform elements
Meso-topography	10	Fine tuning of topography: swales and ridges *Field fit*	
Micro-topography	1	Roughening: mounds and pits, individual boulders *Field fit*	

Adapted from McGreevy et al 2013; McKenna et al 2013; Eaton et al 2014; Turner & Gardner 2015.

Mining landforms and landform design

Mining landforms are distinct topographic and operational units (such as dumps or mined out pits) that together comprise a reclaimed mining landscape. Landform design draws from the behaviour, forms, and functions of natural landforms and applies this knowledge to design, construction, and reclamation of mining landforms (McKenna 2002).

Landform design is the collaborative and multidisciplinary effort to create mining landforms and closure landscapes that are constructed and reclaimed to meet specific design goals and objectives, create land for targeted end uses, and reduce risk, costs, and liabilities. Mining landscapes and landforms are designed to specific goals, design objectives, and design criteria using a design basis memorandum (DBM) approach (Ansah-Sam et al 2016). Many of these goals and objectives are defined by regulatory approval requirements.

LANDFORM ELEMENTS

Definition of landform element

A landform element is a specific physical subcomponent of a mining landform that is designed to allow the landform to meet the design goals and objectives. Such elements are typically large enough to be featured on a detailed design drawing and be built with mine reclamation equipment. They comprise macro, meso, and micro topographic scales (Table 1).

Checklist of landform elements

Table 2 names 97 landform elements. The list will be useful to designers as a cafeteria-style checklist of possible elements to add to the mining landscape to achieve specific functions (see below). The list will be of use to local communities, stakeholders, and regulators.

In establishing the landform element checklist, the authors identified a number of variations for each of the landform elements. For the purposes of the checklist, these varieties have been grouped together where possible. For example, a horseshoe berm typically used to delineate a watershed on a dump plateau was considered a variant of a watershed berm and therefore was not separately identified in the checklist. An outlet for a wetland, dump, or pit lake and many other surface water bodies were all classified under the single term "outlet". A similar decision had to be made for 'as known as' (aka) terms for the same landform element; the use of the terms berm, bund, divide, or embankment for the same long-low topographic landform element is a good illustration.

Functions of landform elements

In developing a landform design, different design specialists (geotechnical, surface water, groundwater, soils / covers, wildlife, wetland, limnologists etc) work together to decide which landform elements are required to achieve the landform design goals and objectives outlined in the DBM, based on the function of each element. Each element typically has a primary function that fits one of these categories:

- Geotechnical and mining
- Water (management, drainage, quantity and quality)
- Operations and infrastructure
- Ecology (soils, vegetation, and wildlife)

Table 2. Checklist of 97 landform elements.

MINE FACILITIES (DUMP, TAILINGS, PIT)
Watershed berm (bund)
Ridge
Mound
Microtopography mounds
Depression/ Hollow
Soakaway (infiltration gallery)
Intermediate slope
Bench
Toe berm
Lateral berm channel
Downslope channel
Outlet channel
Spillway
Fall
Toe ditch
Central swale
Sedimentation pond
Attenuation pond
Water treatment pond
Outlet pond
Containment berm
Wetland
Rock drain
Diversion channel
Levee
Cover
Stockpile
Pit wall
Retaining wall
Rock face/cliff
Dam
Dam crest
Cap
Upland zone
Riparian zone
Wetland (marsh, fen, bog, open-water wetland, swamp)
Lake
Inlet
Outlet
Island
Peninsula
Shoreline
Portal
Gloryhole
Spring

END PIT LAKE
Inlet channel
Shelf
Littoral
Cove
Beach
Groyne
Riprap shoreline
Breakwater

SOILS, VEGETATION, WILDLIFE
Reclamation cover
Vegetation patch
Brush pile
Rock pile
Snag / wildlife tree
Nesting box
Corridor
Remnant stand
Vegetation island
Shelterbelt

DRAINAGE NETWORKS*
Creek
Confluence
Bench (bankfull)
Meander
Oxbow
Point bar
Step pool
Plunge pool
Riffle section
Bank stabilization
In-stream structure – cross, j-hook and rock vanes
Flow control structure – low head dam, weir, pier

INFRASTRUCTURE
Buildings – visitor centre, village, maintenance sheds, office
Historic workings
Access roads - haul road, light vehicle road
Access controls – fence, barrier rocks, gate, moat
Tunnel
Trail
Boardwalk
Laydown, pad, parking lot
Boat launch, pier
Bridge
Culvert
Ford
Sign
Lookout
Water treatment facility
Pump house
Pipeline
Power line
Landfill
Monitoring instrumentation
Research plot
Test pond

** Drainage network elements adapted from USDA (2007).*

Geotechnical and mining type elements provide stabilization of a remnant natural or mining feature or support the bulk mine waste placement activities. The water function category comprises elements whose primary function is to control drainage and manage water quantity and quality. Infrastructure and operations is a broad category which comprises elements where the primary functions are to undertake activities such as providing access, trafficability, health and safety, and operations to support post-reclamation end land uses). The ecology category comprises elements which are directly related to the soils, vegetation and wildlife disciplines.

One of the benefits of providing topographic elements (for example, ridges, mounds, and depressions) on mining landforms is the creation of enhanced topographic diversity. By providing a variety of slopes, aspects, and soil moisture conditions, both biodiversity and resilience is enhanced (Pyper et al 2013). Practical methods and examples of this landform grading are provided by Schor and Gray (2007).

Many of these topographic elements are based on returning the land to wildlife habitat / ecology land uses – the most common land uses for remote mines (Pearman 2009; McKenna et al 2015). Where the land is being returned to industrial or agricultural uses, less diversity and fewer elements may be desirable.

EXAMPLES

Figures 2, 3 and 4 present some examples of landform elements in design.

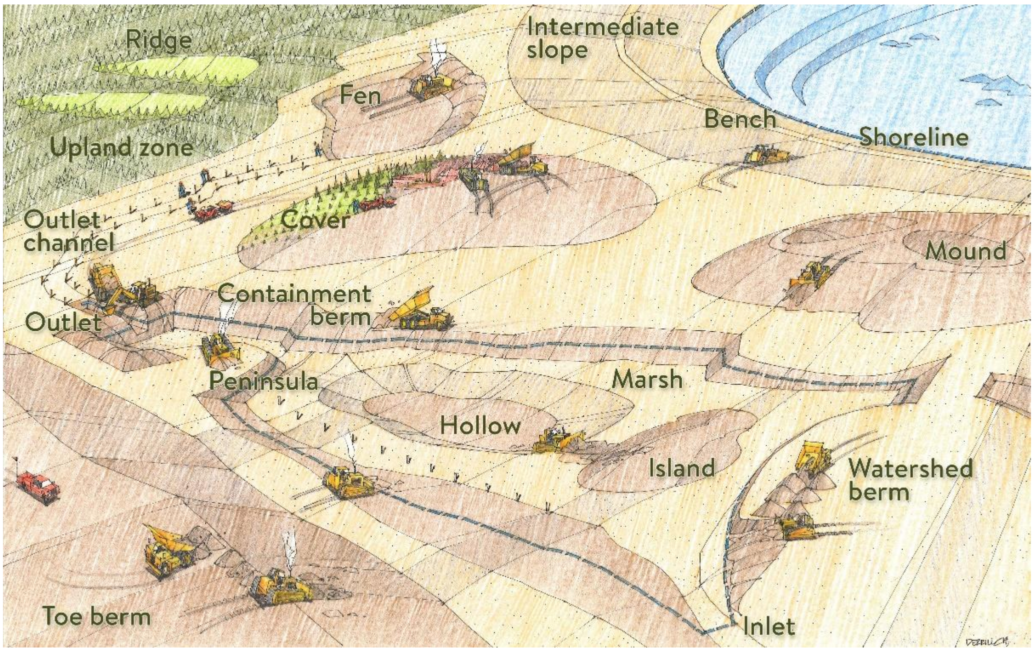

Figure 2. Landform elements and wetland construction (adapted from CEMA 2014).

Figure 3. Landform elements around a sight-and-sound dragline-spoil berm
(Highvale Mine 2009, design by Brent Hartley).

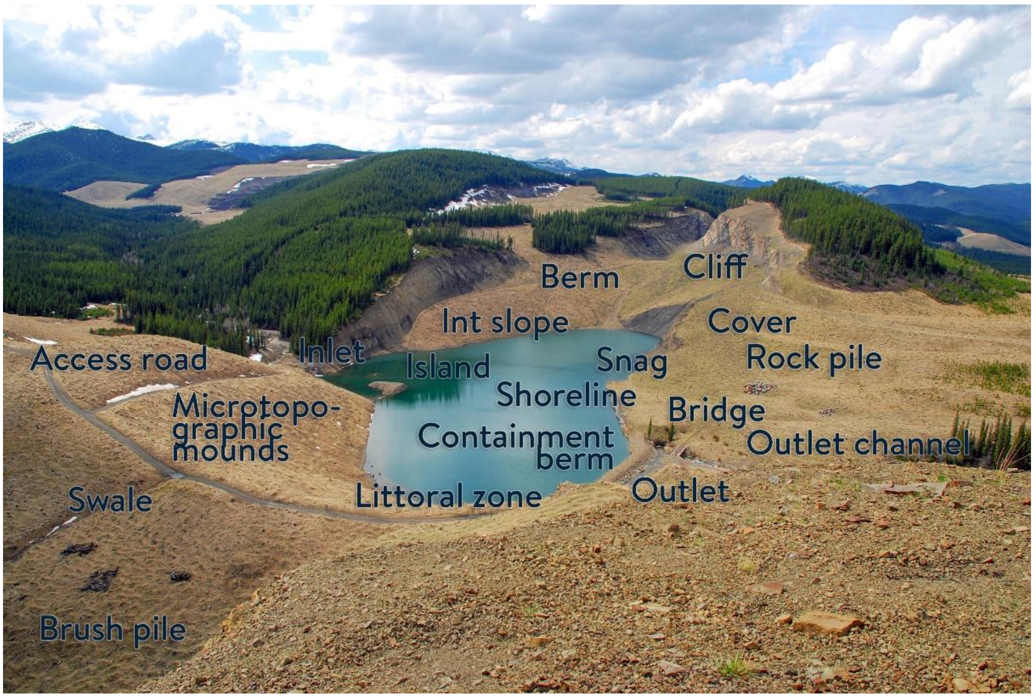

Figure 4. Landform elements around a coalmine end pit lake
(Cardinal River Sphynx Lake 2010, design by Marc Symbaluk).

LANDFORM ELEMENT – DESIGN AND CONSTRUCTION

Landform elements should be easily identifiable in a landform design drawing / report as individual functional components of the landform design. The level of detail for the design of each element will vary significantly. Some elements require a detailed engineering design; for example, dams, cap, or a water treatment plant. Some elements will be shown on a plan view map as part of the landform design and may have a standardized 'off the shelf' design; for example, a haul road. Some landform elements will be field fit; for example, a mound, some berms.

The list provides a useful starting point to develop and test generic designs. For example, Eaton et al (2014) have developed a framework for generic design of wildlife enhancement features. Their work provides an example of a generic design of snags (dead vertical wildlife trees installed in the reclaimed landscape using a telephone-pole installation rig to provide habitat for cavity nesting birds and perches for raptors – Figure 5). The framework provides details for design based on available information in a concise table, and a program for testing the efficacy of the element. This generic design template could be applied to most of the other elements in the checklist.

As part of mine closure design best practice, all topographic areas of the closure plan are apportioned to a specific landform (dump, outlet, end pit lake, tailings drainage basin). Following this best practice technique means that no areas of the lease are overlooked. In contrast, it is not considered necessary that all areas of the landform are allocated to a landform element. Although this may be the outcome, particularly if covers are used, it is not considered a necessity.

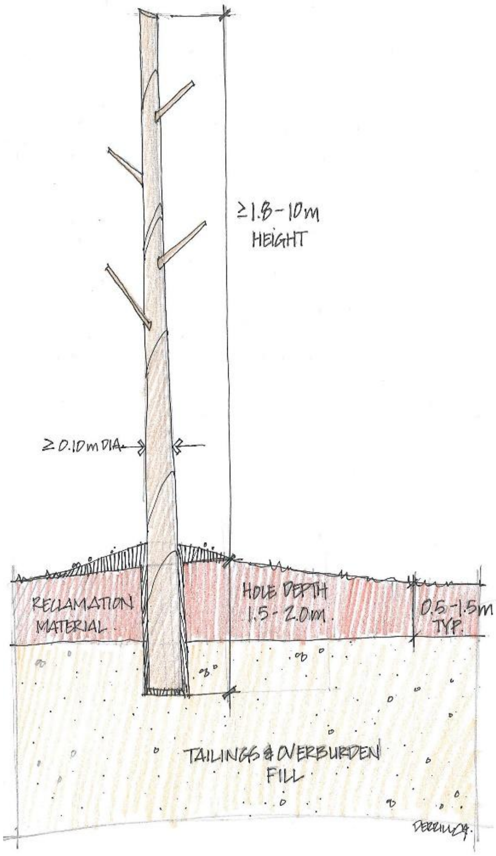

Figure 5. Example of design guidance for wildlife snag

<u>Design guidance</u>

Landform elements should be designed to be easy to construct, as part of standard mine reclamation practices. For example, a horseshoe berm on a dump plateau can be designed to be constructed from piles of mine waste material dumped tightly by trucks (Figure 6). The resulting windrow can be later graded with a dozer, then covered and planted to create the required watershed divide. The berm should be wide enough to allow efficient placement of reclamation material. The design is simply two lines on a drawing with a few survey points and construction guidance in the specs; construction supervision is minimal.

Many landform elements need professional sign-off, for example where geotechnical stability, surface water drainage, or cover performance may be impacted. All the elements need to work together toward the overall design goals, objectives, and criteria (McKenna and Cullen 2008).

NEXT STEPS AND OPPORTUNITIES

There is an opportunity for mine operators and designers to add to the list by further identifying and testing landform elements. In future, it may be feasible to incorporate this approach with ecological concepts towards ecosystem succession and establishment, with the assistance of ecologists.

The concept of standardized generic guidance or designs for landform elements provides a significant opportunity for the mining industry. As part of this next step, the authors would suggest that the function of the landform element, as part of the overall landform design goals, should also be identified and explored. Identifying the primary function of the landform element enables the future performance of the individual element to be monitored (Fair et al 2014) and the design guidance updated accordingly.

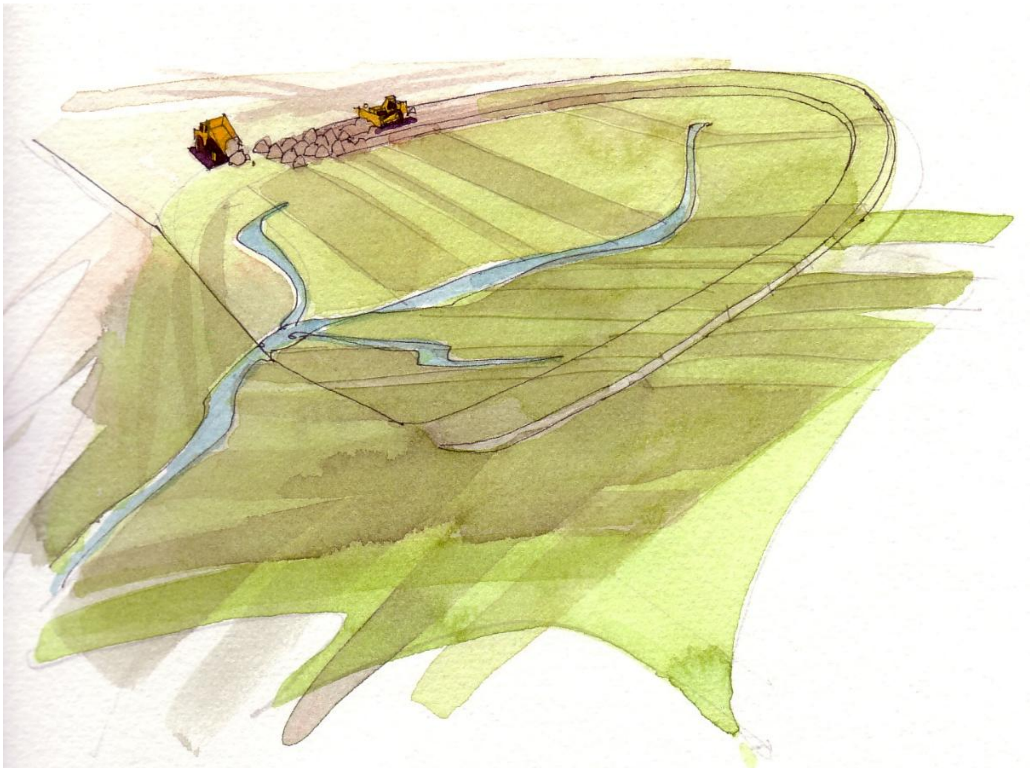

Figure 6. Practical construction is a key consideration for design of landform elements; in this case, simple design and construction of a horseshoe / watershed berm on a dump.

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