Northern Plains Resource Council

August 9, 2023

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Re: **Stillwater Mining Company – East Boulder Mine Major Amendment 004 Draft EIS Comments**

Mr. Grosvenor and Mr. Jones:

Cottonwood Resource Council and Northern Plains Resource Council (the Councils) welcome the opportunity to comment on the June 2023 East Boulder Mine Amendment 004 Draft Environmental Impact Statement (DEIS) prepared by the Montana Department of Environmental Quality and the United States Forest Service (the Agencies). The Councils have participated in meetings and discussions related to this amendment with both Stillwater Mining Company (SMC) and the Agencies as parties to the Good Neighbor Agreement (GNA). The GNA is a legally binding contract between the Councils and SMC, which has been successfully implemented for over 20 years as a tool that allows for responsible economic development at the Stillwater and East Boulder Mines while working to minimize mine related impacts, and maintain baseline water quality downstream of mine facilities. The Councils and our Technical Advisors have reviewed the Draft EIS and offer the following comments to summarize our key concerns your consideration.

Reference to the GNA in the DEIS

The GNA is referenced in several places throughout the DEIS, including discussions related to traffic impacts, noise impacts, and tailings storage facility design. As accurately described in Section 1.4.3 of the DEIS, the GNA is a legally binding contract between SMC and the Councils with focus areas including water quality, tailings facility design, traffic restrictions, and others. This section could further clarify that the GNA does not have regulatory authority. Please note the GNA should not be relied upon within this analysis as a substitute or mechanism for the Agencies to minimize adverse impacts to the affected environment related to the proposed action.

Section 3.11 of the DEIS describes the Affected Environment and Environmental Consequences for each alternative. The GNA is referenced throughout this Section in descriptions of impacts associated with mine-related traffic including Big Game Species, Transportation Safety, and Cumulative Effects. In these discussions the DEIS references and describes the GNA Busing and Traffic Reduction Plan, concluding that existing traffic patterns are not expected to change as they would continue to be limited by the GNA traffic program. This conclusion is concerning to the Councils, and we would like to see this EIS more clearly describe the terms of the GNA as part of a private agreement and clarify that additional stipulations are not recommended as part of the DEIS.

Please describe how the DEQ and USFS will ensure no change to the current transportation conditions and public safety as referenced throughout this DEIS in the event the GNA fails, and the specific requirements for busing, private and commercial vehicle limits, monitoring, and reporting are no longer enforced privately.

Chapter 2 – Description of Alternatives

<u>Dismissal of Alternatives</u>
Section 2.5 of the DEIS describes the Alternatives Not Carried Forward for Detailed Analysis, and simply references Appendix B for a description of alternatives not carried forward and the rationale for dismissal. The final EIS should include a brief description of these alternatives and rational for dismissal within the body of the document (Section 2.5), in addition to referencing the detailed discussion provided in Appendix B.

<u>Filtered Tailings</u>
The DEIS Appendix B, Section B.2.2, concludes that the filtered tailings storage facility alternative is not technically or economically feasible citing several reasons including the reliability of the filtration process and resulting stability, acknowledging this evaluation would require scaling from laboratory results, and increased capital and annual operating costs without a corresponding reduction in environmental risk.

The DEIS notes that the economic feasibility of filtered tailings is also uncertain and that the company as part of the GNA will continue to evaluate the alternative. The GNA has a Responsible Mining Practices and Technology Committee that is committed to continued evaluation of filtered tailings for future tailings disposal, and in the event that the filtration technology improves and/or future mine development allows for the filtration of whole tailings.

The Councils requested this DEIS consider an alternative for the application of filtered tailings for the Lewis Gulch TSF in our scoping comments, and we concur with the conclusion in this DEIS and supporting documentation which provides the rationale for dismissal of this alternative. The rationale provided within the DEIS itself indirectly references the supporting information contained in the Custer Gallatin National Forest (CGNF) Filtered Tailings Memo, the Tech Memo 3 Tailings Management Alternatives, and the Rough Stock analysis. The DEIS should more clearly summarize the conclusions, and refer the reader to the additional detailed information regarding filtered tailings to ensure the public is informed of the solid rationale for this position.

Closure and Post-Closure Reclamation

The DEIS and supporting information provides inconsistent descriptions of the closure and post-closure periods for the Lewis Gulch TSF and Dry Fork WRSA. To clarify, the DEIS should consistently reference SMC's East Boulder Mine Closure Plan (Table D.1 and D.2) which states the closure phase for these facilities is anticipated to last up to 15 years, and the post-closure phase is anticipated to last approximately 10 years following the closure phase. Both phases (closure/post-closure) are to be reassessed at five-year intervals.

The Councils recommend this language is clarified in the final EIS to ensure consistency between the EIS and the East Boulder Mine Closure Plan when referring to the anticipated closure and post-closure timeframes.

Long-Term Care and Maintenance

The DEIS (Section 3.5.3.7) summary of active Operating Permit stipulations addresses long-term care and maintenance stating that, "After mine closure and release of the joint reclamation bond, additional financial assurance is warranted to minimize post-reclamation liabilities." The DEIS describes that potential liabilities include maintenance of storm water infrastructure, monitoring and maintenance of the reclaimed TSF, and vegetative success. The Councils support this approach, and would like to see the CGNF work with SMC and other stakeholders to develop and finalize a long-term care and maintenance fund as described in the DEIS for incorporation into the Operating Permit.

Agency-Modified Alternative - Geomorphic Reclamation

The agency modified alternative incorporates aspects of geomorphic landform design including expanded stormwater channels for the Dry Fork WRSA, and incorporation of agency-required design criteria (Section 2.3.2) for constructed embankments of the Lewis Gulch TSF and reclamation cover of the Dry Fork WRSA. The DEIS (Section 2.3.2) describes that if this alternative is selected, SMC will submit detailed designs for the Lewis Gulch TSF and Dry Fork WRSA and a revised Plan of Operations incorporating the design requirements within 30 days of the Record of Decision.

The Councils support the incorporation of geomorphic landform design concepts for these facilities to improve long-term stability and stormwater management, and would like to see the design criteria expanded to address and minimize visual impacts from the constructed facilities during operation and closure. The recommended design criteria should include objectives to mimic natural topography to minimize visual impacts to the extent possible, and require engagement with a professional landscape architect in the development of the design for the Lewis Gulch TSF and Dry Fork WRSA facilities. In addition to these objectives, the Agencies could consider recommended principles and guidelines of landform reclamation, and their application to waste rock facilities in the attached memo (Kuipers and Miller 2015).

The Councils are concerned with the short timeframe of 30 days suggested in the DEIS for incorporation of final design modifications for both the Lewis Gulch TSF and Dry Fork WRSA. The Agencies developed this alternative with the assistance of SMC's consultant, Knight Piésold, based only on conceptual descriptions and visual renderings as contained in an Appendix E to the DEIS. The agencies could consider a longer timeframe for design development that allows for multi-disciplinary stakeholder participation, and accounts for estimated construction timeframes of each facility. This timeframe should focus on the design development, review, and approval for the Dry Fork WRSA in advance of the Lewis Gulch TSF.

Chapter 3 – Affected Environment and Environmental Consequences

<u>Surface Water and Groundwater</u>
Sections 3.3 and 3.4 of the DEIS describe the surface water and groundwater hydrology, chemistry, and physical characteristics for the area potentially impacted by this proposal in a comprehensive discussion; however, the DEIS does not adequately describe current water quality conditions and ongoing influences from current mine water discharge sources. The Agencies could expand this discussion to include a quantification of estimated load from known mine water discharge sources, and anticipated groundwater and surface water quality change below mine facilities.

As parties to the GNA, the Councils are in a unique position to have a robust understanding of mine operations, mine water discharges to the environment, and their ongoing impact to groundwater and surface water quality. While past and current mine related discharges to groundwater are no longer violating groundwater quality standards, groundwater nitrogen concentrations downgradient from mine facilities are still elevated above natural, pre-mining conditions.

The DEIS should further disclose and more clearly describe existing water quality conditions, and potential future mine related impacts with respect to cumulative effects, in a way the general reader can understand. Current sources of mine influenced water include discharge from treated adit water and minor TSF liner seepage as predicted and described in the 1992 EIS; and from the waste rock used in construction of the TSF embankments, an additional source not originally predicted in the 1992 EIS evaluation. This source of seepage from waste rock is described in the DEIS as "TSF Embankment Subdrain Water" (page 3-82), with an average nitrogen concentration of 442 mg/L, however this seepage rate and load is not estimated in this analysis. The DEIS should include this additional source of nitrogen to groundwater in the discussion, and list estimated flow volumes and nitrogen concentrations similar to the sources summarized in Table 3.3-3 and Table 3.3-4.

Alternative 2 Impacts – Cumulative Effects

The DEIS predicts minor seepage from the proposed Lewis Gulch TSF and Dry Fork WRSA (Section 3.3.4.2) for Alternatives 2 and 4, and concludes there will be negligible water quaity impacts. The EIS should additionally account for ongoing seepage from waste rock sources in this analysis. The proposed action being evaluated for Lewis Gulch TSF and Dry Fork WRSA is located in the same area as current and ongoing groundwater and surface water quality change related to East Bolder Mine facilities, and it is important for the public to understand the potential for cumulative effects to water quality when there is potential for new source inputs from proposed facilities.

DEIS needs to include robust discussion including estimated loading rates from predicted seepage, and analyses to demonstrate that ongoing mine water discharge plus predicted seepage from new facilities will not result in water quality degradation/.

Agency Modified Alternative – Stormwater

The Councils support sizing of stormwater channels for the Dry Fork WRSA (Section 2.2.8.2) to convey 1:200 year, 24-hour precipitation event at closure. The Agencies should consider whether shorter duration events could result in a higher peak interval. The higher return interval is valuable to evaluate based on the likelihood it is underestimated due to climate change causing higher intensity events.

Reclamation and Closure

Alternatives 2 and 3 predict active treatment for seepage from the Dry Fork WRSA for a period of 4 years at mine closure (Section 2.2.8.2), followed by reliance on a passive nitrogen treatment system to maintain nondegradation of groundwater and surface water quality. This description is not consistent with the information provided in Tech Memorandum 1 – Review of Dry Fork Waste Rock Storage Area Nitrate Attenuation and Potential Duration of Active Water Treatment (Haley & Aldrich, October 2022), which states that “nitrate + nitrite concentrations in WRSA seepage are predicted to reach threshold concentrations between 11-15 years post-closure, allowing for release to groundwater without treatment at that point.”

The DEIS should clarify predicted timeframes for active and passive treatment from the Dry Fork WRSA, and apply conservative assumptions to avoid underestimating the timeframe and associated reclamation and bonding tasks and costs to ensure adequate funding at closure to address mine influenced seepage. Both the Hydrometrics and Haley & Aldrich analyses are based on average concentrations and a constant nitrogen removal rate, and given the uncertainty in these predictions this DEIS could be underestimating the timeframe required for active treatment.

We appreciate your consideration of these comments during preparation of the final EIS and Record of Decision. If you have any comments, questions, or would like to meet to discuss this further please do not hesitate to contact Caitlin Cromwell (Northern Plains Resource Council, GNA Manager, 406-248-1154) or Sarah Zuzulock (Zuzulock Environmental Services, GNA Technical Advisor, 406-539-0645).

Sincerely,

Kaite Howes

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Chair, Good Neighbor Agreement Task Force

Cc: Randy Weimer, Stillwater Mining Company
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Questa Mine Rock Pile Landform Reclamation Option
Jim Kuipers and Debora Miller
2015

Introduction

Members of the TWG have recommended that "landform reclamation" be considered for the Questa Mine rock pile re-sloping alternatives developed by the Design Team on behalf of CMI. Landform reclamation involves the use of geomorphic design principles for regrading and reshaping the rock piles to mimic natural local landform features. Landform grading can potentially lead to improved stormwater and erosion control, and revegetation success on the re-sloped piles. The underlying principles and examples of the approach were presented by Horst Schor to the TWG and Design Team at Meeting #5 (July 23-25, 2013). At the time, it was agreed that this approach was to be recommended, but that it did not have to be addressed as a stand-alone option for purposes of the TWG evaluations. Rather landform reclamation was viewed by the TWG as a fine grading detail that could be incorporated into any of the final options if appropriate.

With the objective that landform grading be adequately documented as a TWG recommendation for rock pile remediation, it is addressed specifically through this supplemental memo to the final TWG report. Our concern, which is the rationale for preparing this memo, is that landform grading is distinct from both the geotechnical stability issues and considerations, which were the focus of the TWG, as well as from the cover and revegetation considerations which are the focus of separate investigations by others. Landform grading is therefore in a sort of "no man's land" with respect to the conventional engineering and reclamation studies that are being done at the Questa Mine. This memo is intended to emphasize that landform grading is considered by some members of the TWG as key to the long-term success of rock pile reclamation, and to encourage its implementation on the Goathill North pilot project and ultimately on the other rock piles.

Executive Summary

The Questa Mine rock piles present a challenge from a reclamation standpoint in terms of slope length, steepness, underlying scar and steep slope areas, and lack of ideal cover material for revegetation and erosion control. These challenges are compounded by a severe southern aspect for many of the rock piles and a climate prone to high-intensity but unpredictable weather events. The efforts of the TWG have been focused on addressing geotechnical slope stability and have only tangentially addressed covers and revegetation relative to stability. In focusing on geotechnical stability, the TWG considered landform design but decided to incorporate it as a secondary consideration associated with overall rock pile reclamation design objectives. It was agreed that, for purposes of the TWG process, landform grading principles would be considered as "finish grading" details that could be deferred to final design and applied to any of the identified options carried forward following the TWG process. Given that the rock pile design approach with respect to the TWG effort is an engineered design with geotechnical stability as the primary objective, it does not necessarily achieve all the closure objectives contained in the site ARARs, particularly with respect to the New Mexico Mining Act in terms of long-term sustainability.

Landform design represents an opportunity to use state-of-the-art geomorphological reclamation approaches to achieve both better revegetation and reduced erosion by mimicking the natural environment. Under conventional, agricultural-based approaches to reclamation uniform, evenly graded

engineered slopes are typical. It has been shown, however, that the replication of mature and relatively stable natural geomorphic land forms, with all their variability and irregularity, can reduce the risk of erosion while increasing the likelihood of both successful initial propagation of plants and sustained revegetation success over the long term. The principles of landform reclamation are compatible with standard engineering approaches as well as the stakeholder approach incorporated by CMI in creation of the TWG. However, the designers require a high level of understanding of geomorphic science and could be aided by incorporation of models designed for this purpose. In addition, absent the presence of revegetation success in prior test plots and lacking truly meaningful data from the new test plots for decades in the future, the presence of existing vegetation at the Capulin pile in particular should be further researched in regard to landform design principles and what it might tell us in terms of both approach and expectations.

Ultimately, the application of landform reclamation at Questa will require some compromise of both standard engineering approaches and strict regulatory interpretations, combined with a willingness by CMI to undertake a "leap-of-faith" and take the risk in demonstrating this approach. Given the site-specific challenges at this site, some members of the TWG strongly encourage the application of landform design on a pilot scale. The Goathill North (GHN) rock pile presents an ideal opportunity to implement landform design on a full-scale project. We strongly recommend and advocate that a detailed landform design be developed and implemented as part of the GHN pilot project reclamation process.

Background

As noted by Ayres et al (2006)

> "*Historically, final landforms for waste rock stockpiles consist of linear (in plan), planar slope surfaces with unvarying gradients and angular slope intersections. Slope drainage structures are generally oriented along contours and are highly engineered, while revegetation efforts follow artificial configurations. By contrast most natural slopes are characterized by a variety of shapes (typically concave), and drainage systems follow natural drop lines with catchment sizes defined by undulating relief on the slope. Vegetation on natural slopes grows in discrete vegetation units that are adjusted to hillside hydrogeology, incident solar radiation, and other microclimate effects.*
>
> *This lends itself to uniformity of design and construction, but does not necessarily achieve the mine closure objectives of minimum erosion and long-term sustainability (Sawatsky et al., 2000). Uniform landforms represent immature topography, and are poised to evolve to lower energy states by shallow slope failures or accelerated erosion. In contrast, the development of a sustainable landscape for mine closure involves the development of landforms that replicate natural landscapes. The replication of mature and relatively stable natural systems reduces the rate and risk of accelerated erosion. It also encourages replication of the self-healing erosion control systems that help preserve the stability of the natural analogue (Sawatsky et al., 2000)*."

For example, at Questa the ROD requires the following: "Each rock pile re-contouring will be initially designed to a minimum interbench slope of 3H:1V or up to 2H:1V, with slope break lengths provided approximately every 100 to 200 feet (i.e., designed to achieve the shallowest slope practicable between 3H:1V and 2H:1V)." However, Hancock et al. (2003) noted that these type of features are prone to failure and if failure occurs water is channeled into concentrated flow paths and can lead to severe gullying and even localized slope failure. This type of failure and effect has been noted by the TWG during a 2015 site tour at the Questa rock piles on recently regraded areas both at Sugar Shack West and Goat Hill North.

Principles of Landform Reclamation

Ayres et al (2006) proposes the following general approach and guidelines for waste rock pile landform reclamation.

"The following generalized approach is proposed for developing a sustainable final landform design for existing waste rock stockpiles:

1. Determine the final land use for the rehabilitated site through consultation with all stakeholders, and an assessment of potential geologic or structural control elements for the landform;
2. Observe and collect data on a nearby natural landscape (a natural analogue) to determine hillslope forms and gradients, soil and vegetation types, drainage density, and watershed characteristics;
3. Determine the long-term eroded profile for the various slopes of the existing stockpile through erosion and landform evolution numerical modeling;
4. Based on the maximum slope length and gradient as determined from Steps 2 and 3, design a methodology for reshaping the existing stockpile to conform to these requirements (a horseshoe-shaped landform, which creates a small well-defined catchment, can be effective in reducing slope length and gradients without changing the footprint of an existing stockpile)
5. Design a surface water management system to safely convey meteoric water off the final landform, and ensure runoff reaches final discharge points in volumes and at velocities that will not cause unacceptable erosion or sedimentation;
6. Develop a final landform design following completion of Steps 2 to 5 inclusive, taking into consideration the long-term safe storage of reactive or hazardous materials.
7. Develop a revegetation plan suitable for the swales and ridges in the final landform based on data collected in Step 2; and
8. Review the final landform design with key stakeholders for general acceptance prior to implementation."

"The following guidelines are proposed to aid in the development of a sustainable final landform design for waste rock stockpiles.

- Design the final landform using natural analogues as described in Keys et al. (1995). The reclaimed landscape can be no more stable than the adjacent undisturbed landscape; therefore, the designer can assume that the reclaimed area will be less stable and design accordingly, with gentler slopes, higher density drainage and smaller drainage basins.
- Maintain the final landform height and slope angles for stockpiles in areas of low relief as low as possible. Where slopes compatible with the surrounding landscape cannot be achieved, an attempt should be made to visually soften steeper areas by avoiding straight "engineered" ridges and sharp changes of angle, and by careful planting of trees to break up views of the horizon (Environment Australia, 1998).
- The preferred reclaimed slope design is a "spur-end" slope plan with a concave or complex (convex-concave) profile. The use of terraces or contour banks should be avoided. It is very

difficult in practice, particularly for stockpiles with long slopes, to construct concave slopes with continual curvature on a waste rock stockpile. However, hillslope curvature can be obtained using a series of linear slopes or slope facets as shown in Fig. 3. Hancock et al. (2003) demonstrated through simulations with a landform evolution model that there is minimal difference in sediment loss between a hillslope constructed of linear facets and that constructed from continual curvature.

- Erosion and subsequent evolution of the proposed final landform design(s) should be predicted over a period of at least 100 years using state-of-the-art software packages.
- The thickness of earthen covers designed to minimize the entry of atmospheric oxygen and/or meteoric water to reactive or hazardous material should not only be based on soil-atmosphere numeric simulations, but should also take into consideration the predicted long-term erosion from the final landform (e.g. see Ayres et al. (2005)).
- The design of surface water drainage courses should be based on the discharge and sediment load of the receiving stream(s). Drainage channels used to convey surface water off the top of the landform should follow the slope gradient of the final landform as much as possible. The use of imported substrate as well as man-made materials such as pipes, gabions, and concrete should be avoided whenever possible.
- Design conservatively to account for excessive erosion resulting from extreme climatic events and differential settlement in the reclaimed landform.
- Reclamation of large waste storage facilities should include the construction of small lakes and wetlands upstream of final surface water discharge points, provided they are geomorphically compatible and stable. Such features will attenuate surface runoff to reduce peak flows and increase sedimentation prior to reaching receiving streams (Sawatsky, 2004)."

<u>Landform Reclamation Examples</u>

At La Revilla in Spain the principle was applied in 1995 and thirteen years of monitoring was reported in 2009 by Duque et al. The geomorphic model used had two very different sectors and objectives:

" (i) the highwall-trench sector allows the former quarry face to evolve naturally by erosion, accommodating fallen debris by means of a trench constructed at the toe of the highwall; (ii) the concave-slope base sector, mimicking the landforms of the surrounding undisturbed landscape, promotes soil formation and the establishment of self-sustaining, functional ecosystems in the area protected from sedimentation by the trench. The model improves upon simple topographic reconstruction, because it rebuilds the sutficial geology architecture and facilitates re-establishment of equilibrium slopes through the management and control of geomorphic processes.

Thirteen years of monitoring of the geomorphic and edaphic evolution of La Revilla reclaimed quarry confirms that the area is functioning as intended: the highwall is backwasting and material is accumulating at the trench, permitting the recovery of soils and vegetation on the concave slope. However, the trench is filling faster than planned, which may lead to run-off and sedimentation on the concave slope once the trench is full. The lesson learned for other scenarios is that the model works well in a two-dimensional scheme, but requires a three-dimensional drainage management, breaking the reclaimed area into several watersheds with stream channels."

<u>Additional Observations</u>

The following information from Ayres et al (2006) is analogous to the Questa site.

“Vegetation on natural slopes grows in discrete vegetation units that are adjusted to hillside hydrogeology, incident solar radiation, and other microclimate effects. Trees and shrubs are concentrated in concave areas, where moisture conditions are higher, while grasses / legumes generally dominate the drier convex portions.

Examination of analogues like Mount Wilkinson near Wiluna, Western Australia shows there is little vegetation or topsoil to be found on the upper sections of natural slopes. It is only once the slope flattens out in the lower third of the slope that vegetation approaches the density of the surrounding flats and that topsoil is found. The upper two-thirds of the slope are characterized by surfaces that are well armored and consist of coarse particles, any fines are found below this layer of coarse material.”

“The inventory shows that the greatest physical risk to the landscapes is associated with gully erosion and re-established surface water drainage courses. Gully erosion poses the greatest environmental threat to covered waste storage facilities containing hazardous materials such as acid-generating or radioactive materials. In addition, methods to reduce and control infiltration and leaching of acid drainage products or metals from minerals often work against measures to reduce erosion, which would rather promote infiltration and reduce runoff.

“It is well known that steep unarmored slopes will flatten, planar slopes will gully, straight drainage courses will start to meander, and linear or convex slopes will become concave. Unplanned, rapid changes in the reclaimed landscape could result in unacceptably high sediment loading of streams, gully scarring, and landslides (Keys et al., 1995). The incorporation of natural slope features into the final landform design for stockpiles not only improves aesthetics, but also emulates slopes that are in equilibrium with local conditions of rainfall, soil type and vegetation cover. The relatively small increase in costs for engineering and construction for creating natural landforms are more than offset by improved aesthetic impact, decreased slope maintenance costs, and improved long-term stability.”

“Various measures can and have been used in the reclamation of waste rock stockpiles that provide short-term stability, but are generally not a suitable means for long-term landform stability. These include terracing or contour banks, cross-slope or contour ripping of the surface, dozer basins or “moonscaping”, and placement of erosion control blankets in drainage channels. Provided these measures are properly implemented, they reduce erosion rates as a result of higher infiltration (i.e. lower runoff) and/or greater roughness on the surface (i.e. surface resistance). These techniques are prone to failure over the short term (i.e. 1 to 10 years), which explains why none of these measures are found on natural slopes. However, this time frame may be sufficient to allow a good stand of grasses and legumes to establish, thereby aiding in the long-term stability of a reclaimed slope.”

Models

Ayres et al (2006) describe the following models that could be used to aide in the Questa site design.

“The WEPP model provides a detailed description of the susceptibility of soils and spoils to rill initiation and transport. This aspect makes the model especially applicable to situations where soil erodibility is measured in the laboratory, and to consideration of materials (such as rocky spoils) for which erosion responses to slope length and gradient differ greatly from those of agricultural soils. However, being an agriculturally-based model, WEPP does not consider potential effects of erosion and deposition on landform development, nor does it deal specifically with gully development.”

“SIBERIA is a physically-based model for simulating the evolution of landforms over geomorphic timescales developed by Dr. Garry Willgoose at the University of Newcastle, Australia. It simulates runoff and erosion from a landform that evolves in response to predicted erosion and deposition. It is a three-dimensional topographic evolution model, which predicts the long-term evolution of channels and hillslopes in a catchment on the basis of runoff and erosion. The location and speed with which gullies develop are controlled by a channelization function that is related to runoff and soil erodibility (Willgoose et al., 1991). The model solves for two variables; elevation, from which slope geometries are determined, and an indicator function that determines where channels exist. An activation threshold governs channel growth. A surface may commence with no gullies, but when the activation threshold, which depends on discharge and slope gradient, is exceeded, a channel develops.”

Challenges

Michael et al (2010) identified the following challenges to landform reclamation:

1. Existing reclamation-enforcement regulations that are focused on civil engineering principles and not explicitly supportive of geomorphic methodologies;
2. Regulatory agencies’ current intent to limit the down-gradient reach of excess spoil fills in order to allay disruption or burial of natural streams;
3. Actual or perceived increases in reclamation costs; and
4. The challenge of designing and constructing “natural” landforms that are mature and stable in an otherwise youthful, erosional landscape.

References

B. Ayres, B. Dobchuk, D. Christensen, M. O’Kane and M. Fawcett. 2006. INCORPORATION OF NATURAL SLOPE FEATURES INTO THE DESIGN OF FINAL LANDFORMS FOR WASTE ROCK STOCKPILES, Paper presented at the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis MO.

Hancock, G.R., K.G. Evans, G.R. Willgoose, D.R. Moliere, M.J. Saynor, and R.J. Loch. 2000. Medium-term erosion simulation of an abandoned mine site using the SIBERIA landscape evolution model. Aust. J. Soil Res., v. 38, p. 249-263.

Martin-Duque, J.F., M.A. Sanz, J.M. Bodoque, A. Luda and C. Martln-Moreno. 2010. Restoring earth surface processes through landform design. A 13-year monitoring of a geomorphic reclamation model for quarries on slopes, John Wiley & Sons, Ltd.

Michael, Peter R. , Michael J. Superfesky, and Lois J. Uranowski. CHALLENGES TO APPLYING GEOMORPHIC AND STREAM RECLAMATION METHODOLOGIES TO MOUNTAINTOP MINING AND EXCESS SPOIL FILL CONSTRUCTION IN STEEP-SLOPE TOPOGRAPHY (E.G. CENTRAL APPALACHIA) Paper presented at the 2010 National Meeting of the American Society of Mining and Reclamation, Pittsburgh, PA Bridging Reclamation, Science and the Community June 5 - 11, 2010. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

Sawatsky, L., G.T. McKenna, and M-J. Keys. 2000. Towards minimizing the long-term liability of reclaimed mine sites. p. 21-36. In M.J. Haigh (ed.). Reclaimed Land: Erosion Control, Soils and Ecology. Rotterdam: A.A. Balkema.

Schor, Horst J., Gray, Donald H. 2007. Landforming: An Environmental Approach to Hillside Development, Mine Reclamation and Watershed Restoration, John Wiley & Sons.