Dynamic Equilibrium Demonstration for Bond Release

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Coal Section
Mining Bureau
Air, Energy, and Mining Division
Montana Department of Environmental Quality

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ACRONYM LIST

ACoE	Army Corp of Engineers
ARM	Administrative Rules of Montana
BTCA	Best Technology Currently Available
DEM	Digital Elevation Map
Department	Montana Department of Environmental Quality
DEQ	Montana Department of Environmental Quality
EDA	Ephemeral Drainage-Line Assessment
HEC-RAS	Hydrologic Engineering Center's River Analysis System
LiDAR	Light Detection and Ranging
MCA	Montana Code Annotated
MPDES	Montana Pollutant Discharge Elimination System
MQAP	Monitoring and Quality Assurance Plan
MSUMRA	Montana Strip and Underground Mine Reclamation Act
OHWM	Ordinary High-Water Mark
PMT	Postmine Topography Map
SMCRA	Surface Mining Control and Reclamation Act
USGS	United States Geological Survey

HYDROLOGIC TERMINOLOGY GLOSSARY

Bankfull	The water level, or stage, at which a stream, river or lake is at the top of its banks and any further rise would result in water moving into the flood plain.
Drainage Area/ Watershed	An area of land that drains all its water to a specified point.
Dynamic Equilibrium	A state of balance between continuing processes of erosion and deposition.
Entrenchment	The deepening process where a channel can no longer readily access its floodplain during flood flow.
Ephemeral Drainages	A stream that flows only in direct response to precipitation or to the melting of snow in the immediate watershed.
Hydraulic Radius	Ratio that measures the cross-sectional area of flow to the wetted perimeter of a channel, pipe, or river.
Perennial Drainage	A stream that flows continuously year-round.
Reach	A section of a drainage of any length along which similar hydrologic conditions exist.
Stream Order	A whole number to indicate the level of branching in a river system. A low-order stream represents the initiation of flow accumulation in channels or the headwaters.
Thalweg	The deepest park of the drainage channel.
Transect	Narrow cross section through drainage channel where observations and measurements can be made.

1.0 INTRODUCTION

Drainage basins and channels are a dynamic part of any landscape, and they have significant influences on ecosystems and hydrologic systems. The configuration of natural drainages and channels is the result of many years of variable precipitation and runoff, floods and droughts, erosion and deposition, and influenced by other factors (e.g., changes in bedrock, geologic structure, faults, etc.). The full succession of natural processes occur over long timelines. The operator must anticipate natural development and by careful planning and construction, limit the scale of erosional adjustments needed to reach an appropriate level of channel stability, meet other performance requirements set forth in the Montana Strip and Underground Mine Reclamation Act (MSUMRA), and achieve "bond release."

Reclamation targets for water quality, vegetation, and stream geomorphology are required as part of four bond release phases described by ARM 17.24.1116(6). Phase IV bond release requires that “all other reclamation requirements of the Act, rules, and the permit have been met” which encompasses ARM 17.24.634 Reclamation of Drainage Basins: ARM 17.24.634(1)(d) states, in part, that “reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to allow the drainage channel to remain in dynamic equilibrium with the drainage basin system”. To satisfy phase IV bond release, drainage channels shall be in dynamic equilibrium with the drainage basin system such that channels are functioning similar to natural drainages without excessive erosion nor deposition. This guideline was developed to outline quantitative and qualitative sources of data/evidence that may be submitted to DEQ to satisfy bond release requirements for demonstrating the dynamic equilibrium of ephemeral drainages with the goal of aiding mine companies in following applicable statues and rules. A summary of applicable statues and rules to drainage basin reclamation is provided in **Appendix A**.

1.1 DYNAMIC EQUILIBRIUM OF DRAINAGE CHANNELS

As required by ARM 17.24.634(1)(d) “Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to: allow the **drainage channel to remain in dynamic equilibrium with the drainage basin system** without the use of artificial structural controls unless approved by [DEQ]” [emphasis added]. Dynamic equilibrium is an essential component of a stabilized landscape and is necessary to be established for final bond release.

For purposes of this guideline, “drainage channels” are generally defined as landscape features that are anticipated or observed to be created by overland flow of waters that have become concentrated into more or less discernible flow paths. Drainage channels or channel reaches may be in upland or lowland areas, may be vegetated or not, and may exhibit different degrees of stability. Due to the semi-arid climate in Eastern

Montana where the coal mining is occurring, and the prevalence of lower order streams, ephemeral drainages dominate. Ephemeral drainageways are drainages that only flow in response to precipitation events or snow melt (ARM 17.24.301(39)).

Dynamic equilibrium is a balancing process associated with a set of inter-related channel physical adjustments that naturally maintain stream channels in their most efficient and least erosive form (Vermont Department of Environmental Conservation, 2011). In other words, a channel, when experiencing increased discharge and sediment load due to precipitation and runoff events, maintains its overall shape and is neither overly eroding material nor aggregating material in the channel. Generally, a drainage in dynamic equilibrium will have mature drainage features such as an established floodplain and a channel that is neither actively down cutting or widening. However, the expression of such equilibrium features depends on the climactic regime, whether the drainage is perennial, intermittent, or ephemeral, and the characteristics of each reach which vary along the length of a channel.

During mining and reclamation, a drainage's premine state of dynamic equilibrium is disrupted as the newly reclaimed drainage will always be different from premine. Changes expected from the pre-existing natural drainage to a reclaimed drainage may consist of altered slopes of the drainage channel and/or surrounding slopes, vegetation cover which influences infiltration and the rate of water reaching the channel, increased or decreased drainage area resulting in differences in discharges, and channel bed materials from natural eroding bedrock materials to spoil and salvaged soils.

While dynamic equilibrium is defined as a state of balance between continuing processes of erosion and deposition, in ephemeral drainages erosion is typically a more impactful process than deposition on the long-term success of drainage reclamation. For this reason, DEQ considers the stability of drainage channels, with the expected natural variations of erosion, a workable approximation for dynamic equilibrium. Reclaimed drainage channels for Montana coal mines are considered to be in dynamic equilibrium when they exhibit enough stability that water quality and quantity resemble, or are trending towards, premine baseline conditions and drainage basin features resemble the functionality of premine baseline conditions and/or appropriate natural analogs.

2.0 Dynamic Equilibrium and Bond Release Phases

Although the final demonstration that dynamic equilibrium has been established between channels and their drainage basin is required for phase IV bond release, success is largely dependent on considering dynamic equilibrium at all phases of bond release. DEQ oversees the implementation of four specific bond release phases for reclamation as detailed in ARM 17.24.1116(6). A summary of each bond release phase, with consideration of dynamic equilibrium is provided below.

2.1 Phase I – Backfilling, Grading, and Drainage Control

Phase I bond release is achieved when the operator has completed backfilling, regrading, and drainage control in accordance with the approved reclamation plan. Additionally, all drill holes that are not approved to be retained as monitoring wells have been plugged.

This phase provides the early groundwork for the hydrologic success of drainage basin reclamation. Of importance to the success of reaching dynamic equilibrium for later bond release is the component of “drainage control”. At phase I, the permittee should demonstrate that the drainage channel was designed and built to provide for the long-term stability of the drainage and minimize the potential for excessive erosion as laid out in ARM 17.24.634(1)(f). Excessive erosion in ephemeral drainageways can result from multiple factors including steep slopes, drainage areas too large for the built drainageway dimensions, improper in-channel gradient changes, or ineffective sinuosity, etc. (Abandoned Coal Mine Lands Research Program with Western Water Consultants, Inc. , 1993) (Bureau of Land Managment, 1985). Mitigating these risk factors will be easiest prior to phase I bond release.

The design of the regraded topography and drainage control are part of the reclamation plan’s approved postmine topography map (PMT) (82-4-222, MCA). At phase I bond release, the as-built topography should agree with the PMT. Prior to submitting for bond release, attention should be given to ensuring the layouts of drainage structures are in place and that the PMT plan has been followed. Deviations in the as-built from the PMT should be explained in the bond release package; a revision to the approved PMT may be needed to blend the as-built into the unconstructed PMT. Generally, this consists of observing how the slope of the drainage connects with drainage areas before and after the reclaimed section and channel design. For example, there should be no sharp changes in slope and the drainage profile should exhibit a concave longitudinal shape and an appropriate geomorphic habit.

Though phase IV requirements are not being evaluated during a phase I bond release, dynamic equilibrium should be considered with all applications. Assessing the design of channels and drainage bottom widths appropriate to their relative basins can, and should, be completed prior to submitting a phase I application. Attention to drainage construction details at phase I will lay the foundation for successful dynamic equilibrium establishment and subsequent bond release criteria.

2.2 Phase II – Final Topography, Soil Replacement, Vegetation Establishment

To apply for phase II bond release, at least two growing seasons (spring and summer for two consecutive years) need to have elapsed, soil replacement and tillage are complete, and soils are protected from accelerated erosion by established vegetation. Vegetation should be establishing consistent with species composition, cover, production, density, diversity, and effectiveness required by revegetation criteria ARM 17.24.711, 17.24.713, 17.24.714, 17.24.716 through 17.24.718, 17.24.721, 17.24.723 through 17.24.726, 17.24.731 and 17.24.815. Lastly, noxious weeds must be controlled, and prime farmland production is returned to the level required by ARM 17.24.815.

For phase II bond release, the subsoil and topsoil above the phase I mine spoil topography are placed and graded to the PMT. At this stage, drainage channel grades are finished, and re-vegetation has begun.

Phase II bond release provides an opportunity for operators to review the progress of stream channel establishment and stability, which is the foundation for dynamic equilibrium at phase IV. Here, after multiple precipitation events have gone through the reclaimed drainages, issues of excessive erosion should be identified and mitigated. Potential issues include the development of head cutting, entrenchment of the channel, and loss or no development of sinuosity. When left unchecked, excessive erosion features may continue to progress and place the drainage in a state where phase III and phase IV bond release cannot be met due to an unstable landscape and the channels not being in dynamic equilibrium with the drainage basin.

Additionally, excessive erosion identified during phase II bond release may lead to a failure of reclamation to meet the phase II bond release requirement that “soil is protected from accelerated erosion by established vegetation” ARM 17.24.1116(6)(b)(iv). Where drainages exhibit excessive erosion, vegetation will not be established as intended resulting in accelerated erosion of soils.

2.3 Phase III – Property Revegetation, Stable Landscape

Phase III bond release requires that ten growing seasons have elapsed and revegetation criteria in ARM 17.24.711, 17.24.713, 17.24.714, 17.24.716 through 17.24.718, 17.24.721, 17.24.723 through 17.24.726, 17.24.731, and 17.24.815, as applicable, are met. A stable landscape has been established consistent with the approved postmining land use. The lands are not contributing suspended solids to streamflow or runoff outside the permit area in excess of the requirements of ARM 17.24.633 or the permit. Management of any permanent impoundment is approved by DEQ and landowner. Lastly, lands meet the special vegetation criteria laid out in 82-4-235(4)(a), MCA.

As a part of phase III reclamation, the drainages should be functioning in line with the approved post mine land use. That is, drainage channels should be stable and preventing the contribution of excessive suspended solids into streamflow and runoff in excess of premine levels.

Similar to phase II bond release, phase III bond release provides an opportunity for operators to review the progress of stream channel establishment and stability. This can then be evaluated in the context of the review conducted during a phase II bond release to determine if drainages are trending towards stability or are exhibiting excessive erosion and require intervention. Reviewing drainage stability at phase III bond release allows for both determining the requirements of the rule have been met, and allowing for operators to identify erosional or drainage structure issues and address them prior to seeking final bond release. Dynamic equilibrium is assessed in the context of a drainage basin system; keeping the larger context in mind through phase III will aid the reclamation efforts and reduce risk of not meeting the requirements of phase IV bond release.

2.4 Phase IV – Full Reclamation

Phase IV bond release signifies the operator has reclaimed the land to meet all requirements and DEQ may release the remainder of the reclamation bond and liability for the application area. To meet phase IV bond, release the entire drainage must meet all the criteria identified in the three prior phases of bond release in addition to all other applicable rules and statues.

The requirement of phase IV bond release pertinent to this guidance is that all other reclamation requirements of the Act, rules, and the permit have been met including ARM 17.24.634 Reclamation of Drainage Basins. This regulation specifies characteristics expected of successful drainage reclamation, importantly that the drainage channels remain in dynamic equilibrium with the drainage basin. Therefore, to achieve final phase IV bond release operators must demonstrate that dynamic equilibrium has been established for the applied basin. Discussion on the types of data/evidence that can be used to demonstrate dynamic equilibrium are provided below.

3.0 Applicable Methods To Evaluate Dynamic Equilibrium

The following methods can be used to demonstrate that drainage channels have established dynamic equilibrium with the drainage basin system per ARM 17.24.634(1)(d). An operator may need to use multiple methods to demonstrate an ephemeral drainage is in dynamic equilibrium. Multiple methods in conjunction represent an effective way to holistically assess a drainage. Demonstration of dynamic equilibrium does not require the exact methods identified in this guidance document; should a mine operator decide on a different methodology, this guidance document can be used to assist an operator with understanding the level of scientific rigor needed to ensure that ARM 17.24.1116(6)(d), ARM 17.24.634(1)(d), and other relevant rules are met. Additionally, not every aspect of each method described may be necessary to convey establishment of dynamic equilibrium. The goal of this guidance is to provide examples of the tools mine operators can use to evaluate reclaimed drainages for dynamic equilibrium determination. Mine operators are encouraged to reach out to DEQ to develop a methodology to evaluate dynamic equilibrium for their phase IV bond release submissions. An example submission is included in **Appendix D**.

A report should be provided to DEQ that supports the phase IV bond release. The report should include the data and a narrative detailing how the data supports the conclusion that the drainage has established dynamic equilibrium in accordance with ARM 17.24.1116(7) and MCA 82-4-232(6)(a). This can be structured however the operator sees fit, but the comparison should at least include a target range for the data, typically represented as an undisturbed drainage.

Note that this guidance focuses on bond release requirements for dynamic equilibrium and drainage reclamation as they pertain to surface water hydrology; other criteria such as vegetation establishment and minimization of disturbance to the hydrologic balance as it pertains to groundwater are required but not addressed here. DEQ recognizes that vegetation plays an important role in erosion mitigation in all systems, however, there are separate bond release requirements pertaining to vegetation cover outside of the scope of ephemeral drainages (ARM 17.24.711, 17.24.713, 17.24.714, 17.24.716 through 17.24.718, 17.24.721, 17.24.723 through 17.24.726, 17.24.731 and 17.24.815). Data reporting on vegetation exceeding those needed to meet these requirements is not required to show dynamic equilibrium. While DEQ recommends operators consider the soils of their drainage channels in designing and reclaiming channels, there are no specific recommendations for soil sampling in the context of sediment loading of ephemeral channels. For example, clay and sandy soils are less likely to erode than silt and therefore can affect the erosion potential of a drainageway.

There are several ways to provide data demonstrating that a stabilized landscape in dynamic equilibrium has been established for phase IV bond release. It should be noted that demonstrations of dynamic equilibrium based on the methods described below can be used as a guide. However, the operator is responsible for providing the necessary data and evaluations to DEQ as part of an application for phase IV bond release.

3.1 GEOMORPHIC DATA

A qualitative way of evaluating channel equilibrium consists of making visual observations of a drainage reach and looking for physical evidence of the channel in disequilibrium (i.e. erosional or depositional features). Operators can utilize documentation of stability and instability features to help evaluate if reclaimed drainages are in dynamic equilibrium and meet the requirements for phase IV bond release.

A channel in dynamic equilibrium will transport sediment downstream during runoff events in a way that is balanced such that neither erosion nor deposition dominates within a typical reach. A clear indication of a channel in disequilibrium is excessive erosion such that the channel is disconnected from its floodplain which will further exacerbate erosion during large storm events. Excessive erosion is expressed through channel bed erosion or downcutting (**Figure 2A**) and channel widening with bank erosion (**Figure 2B**). Additional examples of erosion and depositional features are provided in **Appendix C.**

Figure 2: (A) Example of a native ephemeral drainage in disequilibrium where the channel bed is currently downcutting. Note the steep slopes and lack of a floodplain. Photograph from (Homan, 2024a). (B) Example of a native ephemeral drainage in disequilibrium with erosive banks and widening. Note widened channel bed but bound by steep slopes and disconnected from its flood plain. Photograph from (Homan, 2024a).

Key features of a drainage in equilibrium consist of a drainage channel with adequate vegetation on its banks and the channel floor indicating minimal erosion is occurring, the presence of a flood plain accessible by the channel, and lack of excessive erosional features. An example of ephemeral drainages in dynamic equilibrium are provided below (**Figure 3**).

The inventory of stable and unstable features along a drainage utilizing a single photograph, and if possible utilizing a time series of photographs over time, is one way to document the stability of drainages. The photographs can be used by the operator to make an assessment whether erosional features are worsening overtime or healing, indicating if the drainage is trending towards dynamic equilibrium.

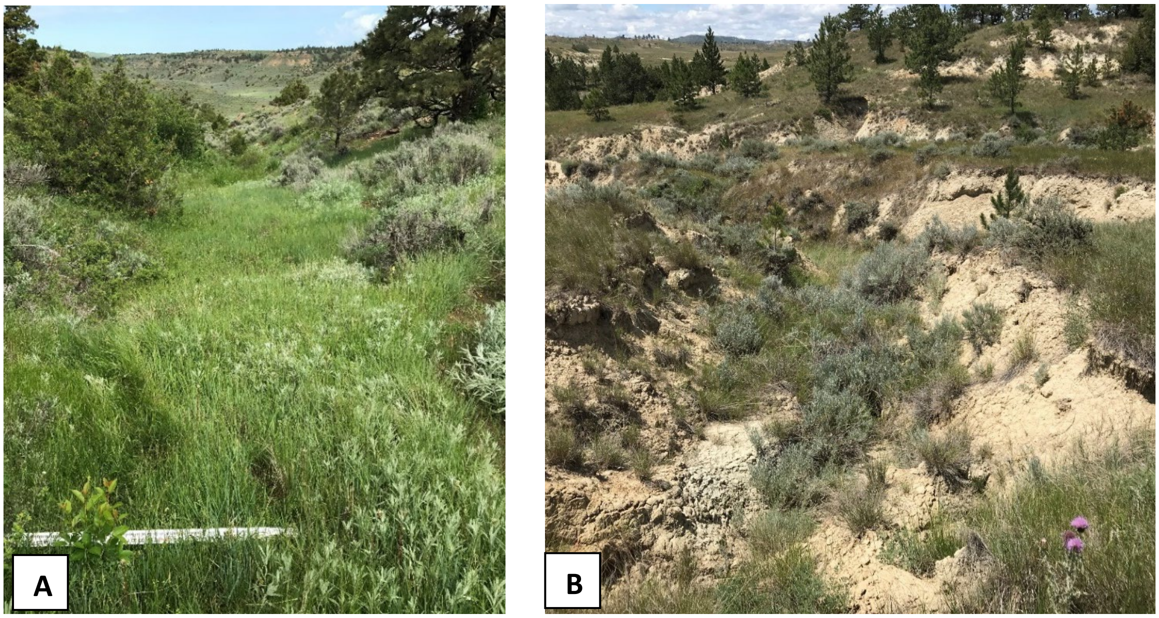

Figure 3: (A) Example of a native drainage with more depositional features. Note the lack of erosive features and strong vegetation growth in a low slope zone. (B) Example of a native Montana drainage with more erosive banks. Note that shrubs and trees are growing within the channel and that vegetation stabilizes banks where possible. Both A and B are subsections of a healthy channel in dynamic equilibrium with the drainage basin, and neither area shows excessive erosion or deposition.

3.1.1 Geomorphic Data for Submission

One of the most efficient ways of evaluating the geomorphic features of a drainage is to take photographs of the drainages. Photographs may be collected on representative reaches of reclaimed channels to evaluate the presence/absence and severity of erosional features. The points below outline a strategy for collecting and evaluating photographs along reclaimed drainages.

- Photographs can be taken from predetermined transects and taken up-stream and down-stream. The location of the photograph should be recorded so that subsequent photographs can be taken from the same viewpoint. In addition to submitting photographs, any notes on particular attention to points of interest: slumps, sloughs, cut banks, sand bars, and other potential erosional/depositional features identified while walking the drainage should be submitted. Examples of erosion and depositional features are provided in **Appendix C**.

- Photographs of the representative reaches should be captured during the summer months after spring runoff and precipitation. The photograph interval can be reduced with consultation from DEQ if it can be shown the drainages have reached a stabilized state in dynamic equilibrium.

- Photographs of a natural drainage basin of comparable characteristics should be captured for a comparison to the natural stability of drainages in the region.

- The photographs should be used to compare the channel shape over time. This can be used to determine if the channel is trending towards excessive erosion or if the erosion is similar to what is expected from natural premine basins in dynamic equilibrium with their respective channels.

- Photos can be utilized in conjunction with other data forms such as LiDAR or models, such as the Tongway Ephemeral Drainage Line Assessment (EDA).

Data submitted to DEQ should contain both photos and a narrative describing why the drainage is in dynamic equilibrium with its drainage basin.

3.2 Ground Surface Elevation Mapping

Recent advancements in surface elevation mapping provide an opportunity in collecting quantitative measurements to monitor erosion and deposition in reclamation. With the increased utilization of drones and the improved technology of LiDAR (Light Detection and Ranging) and photogrammetry, the ability to provide high resolution Digital Elevation Models (DEMs) of drainage basins is possible.

Aerial imagery and DEMs can be a useful tool where limited sampling data was collected due to small drainage areas, or remoteness. Additionally, DEMs can also be used to find problem areas early.

The following is a list of ways DEMs can be utilized to evaluate the stability of drainage channels and satisfy requirements of ARM 17.24.634 Reclamation of Drainage Basins.

- Channel dimension data can be obtained from DEMs and used in the models described in **Section 3.4**.

- The longitudinal profile of a drainage basin can be evaluated for concavity. Knick points in a drainage can potentially be identified and remedied prior to phase I or phase II bond release and prior to the development of extensive downcutting erosion of the channel.

- The longitudinal profile of nearby or similar natural drainages in dynamic equilibrium can be compared to the reclaimed stretch. Reviewing the concavity of natural nearby drainages can be used to help shape reclaimed drainages and see what natural variations in a stream channel profile may look like.

- Lastly, channel formation over time can be observed. Evolution of the drainage channel DEM overtime can be evaluated to identify where changes in elevation, such as downcutting and widening, are occurring out of equilibrium. If the channel is downcutting, out of equilibrium, the DEM would show direct significant loss in elevation in the channel. The DEMs could also show if the channel is exhibiting relatively equal areas of erosion and deposition or staying relatively stable.

Site specific conditions will affect the selection of technology used to create DEMs. For example, orthographic drone imagery may be used in situations where the use of LiDAR is cost prohibitive. While drone photography can be highly precise, there are some limitations where the use of such a technology would be inappropriate. For example, in densely heterogenous vegetated areas, especially riparian zones, this type of mapping has difficulty producing accurate high resolution ground surface elevation. Even though imagery-based elevation mapping may be able to *precisely* assess the surface elevation through vegetative cover, it may not be able to do so *accurately*. Mine operators should reach out to DEQ if they have any questions regarding specific drainages.

It should be noted that measurement-based surface elevation methods should be used in a phase IV bond release application. PMTs or outdated as-built drawings (if there has been significant landscape change since their last collection) may not be sufficient to determine if a drainage has achieved dynamic equilibrium.

3.2.1 Ground Surface Elevation Data for Submission

DEQ recommends operators consider collecting 1-foot contour Digital Elevation Model (DEM) of drainage channels and their floodplains yearly. One-foot contours of the ground surface elevation are the level of detail needed to delineate channel formation and migration through time. The DEMs should be captured during the summer months after spring runoff and the majority of large precipitation events have passed. The points below outline a strategy for collecting and evaluating surface elevation data along reclaimed drainages.

- A DEM of a natural drainage can produce transects and profile information that can be compared to reclaimed drainage characteristics to evaluate likeness and provide a natural analog baseline.

- DEMs collected over several years can be used to compare changes in elevation and drainage evolution to evaluate the stability of drainages in the context of precipitation trends. It is recommended that elevation data of the as-built landscape be collected as a starting point with subsequent years for comparison. Problem areas can be flagged early for observation during an inspection or reviewed by the operator.

- If a reach is showing extensive loss of elevation and not widening it can be assumed that down cutting is occurring, and the channel is in disequilibrium.

- An elevation profile of the drainage that is not changing drastically or appears to have equal areas of erosion and deposition along the channel after multiple flow-generating precipitation events provides supporting evidence that the system may be in dynamic equilibrium.

3.3 Surface Water Monitoring Data

ARM 17.24.646(4) states that after disturbed areas have been regraded and stabilized the operator shall monitor surface water flow and quality to ensure the runoff is consistent with the requirements of this rule to minimize disturbance to the prevailing hydrologic balance; to demonstrate that the drainage basin has stabilized to its previous, undisturbed state; and to attain the approved postmining land use. This rule also specifies that modeling data, in conjunction with monitoring data, may be used to support bond release. Monitoring data is a significant line of evidence required for final bond release, and it can also be used to support that dynamic equilibrium and a stabilized drainage basin has been achieved for reclaimed drainage basins. However, sampling data alone will not completely capture the dynamic equilibrium of the system.

Conceptually, a reclaimed channel in dynamic equilibrium with the drainage basin will function similarly to and will have water quantity and quality comparable to that of an analogous premine channel and basin. This functional similarity would ensure that the mine operation has minimized the disturbance to the hydrologic balance. Therefore, the data evaluated needs to demonstrate either the reclamation is similar enough to a pre-mine drainage channel and basin, or that the channel is in dynamic equilibrium with the drainage basin. Each mine has an approved Monitoring and Quality Assurance plan (MQAP) that must be followed. The MQAP dictates sampling locations, equipment, frequencies, and rationale for collecting such data. It may be necessary to update MQAPs with regard to capturing samples for dynamic equilibrium determination. Such factors to consider would be sample locations for premine water quantity and quality of the drainage basin that can be comparable to the postmine basins, and timing and placement of sample locations to collect postmine water quantity and quality data with regard to the reclamation schedule. Note that any deviations from a mine’s approved MQAP will require DEQ approval.

The semi-arid climate of east central Montana presents a challenge to mine operators to accurately sample and provide a thorough analysis of surface water conditions. Most drainages being sampled consist of ephemeral channels and occasionally intermittent streams which are largely influenced by variations in precipitation. Rainfall commonly occurs in isolated highly variable thunderstorms where precipitation may create runoff in one portion of a drainage basin and yet there may be no runoff in another portion.

Additionally, a precipitation event large enough to sample might only occur once every several years.

One of the largest obstacles to sample collection is physically collecting the samples. Consistent sample collection, as precipitation events and trends allow, and a representative location will be necessary to provide a large enough sample size for the operator and DEQ to evaluate if the data demonstrates that dynamic equilibrium has been achieved. To ensure sufficient data collection for dynamic equilibrium determination, the following should be considered with regards to monitoring surface water.

- Implement the proper sampling device (i.e., single stage sampler, auto-sampler, grab samples) based on flow and drainage basin characteristics.
- Use flumes with wing walls at sampling locations to increase the likelihood of a successful sampling event. A flume could simultaneously help determine the flow as well as making a clean grab sample easier to obtain.
- Set up sample sites that are accessible during rain events if possible.

Where ephemeral drainages dominate permit areas, water quality samples predominantly consist of sediment samples from single stage siphon samplers. Therefore, most of the evidence that may be used to determine dynamic equilibrium is from the use of sediment samples and stage measurements. Sediment samples vary widely; often these samples have more to do with the time of year and intensity of precipitation events than the stability of the drainage making sediment sampling alone potentially problematic for determining dynamic equilibrium in ephemeral drainageways.

3.3.1 Sampling Data for Submission

Premine data can come from all premine stations or from stations that do not have coal mining upstream of the monitoring point at the time of sampling. Premine sampling data from other basins may be used if they represent a comparable condition and setting to compare to the reclaimed drainage. Sampling for the postmine condition may generally begin as soon as phase II has been reached in a significant portion of the of basin, excluding those features exempt from the 10-year responsibility period in 82-4-235(3), MCA: water management and other support facilities comprising less than 10% of the bond release area. All sediment control structures should be removed from upstream of sampling locations for the water quality samples to be used for evaluation.

Monitoring should be sufficient to evaluate a relationship between precipitation, climate conditions on the ground (frozen and snow melt vs nonfrozen runoff), ephemeral runoff, and sediment loads for undisturbed and disturbed drainages. Bankfull flows typically have a recurrence interval of 1.5 to 2 years and therefore a minimum of several years of monitoring is needed to characterize flows in ephemeral channels over a wide range of climate and precipitation events. The magnitude of precipitation event and the corresponding sediment and discharge should be evaluated for trends similar to that of premine undisturbed basins.

The postmine surface water sampling locations should be placed within the fully reclaimed drainage basin at a point that is high enough in the basin to accurately evaluate the stability of the channels within but also where enough flow is present during precipitation events. Additionally, the postmine sample points should be able to correspond to premine sample locations for applicable comparison, where possible. This can be achieved by having similar drainage areas. Please consult with DEQ if any questions arise when selecting monitoring locations.

3.4 Modeling Data for Dynamic Equilibrium

Modeling can and should be used to support if a channel is in dynamic equilibrium. Generally, parameters derived from a combination of geomorphic stream dimensions, sediment characteristics, and climatic data are used to model the stability and hydrologic characteristics, such as discharge and sediment loading, of a channel. Although, several watershed models exist (SEDCAD, RUSLE2, HEC-RAS, and Homan glm_20 model (Homan, 2024b)), the Ephemeral Drainage-line Assessments (EDA) model (Tongway & Ludwig, 2011), was created to evaluate stability and erosion specifically in mine reclamation on ephemeral drainages. The stability of a drainage, especially when considered with the natural variability of drainage stability in the region, is an important aspect of dynamic equilibrium. A description of the Tongway EDA is provided below. Mine operators using a model to demonstrate dynamic equilibrium can use any model they see fit, but it must be measurement based and display scientific rigor.

It should be noted that the DEQ Montana Pollution Discharge Elimination System (MPDES) program also uses watershed modeling to show that a mine’s Sediment Control Plan (SCP) prevents an increase of sediment loading above premine levels. This modeling may be useful in evaluating the dynamic equilibrium of a drainage. However, the modeling should be representative of the postmine landscape and validated through postmine sampling as specified by ARM 17.24.646 Surface Water Monitoring.

3.4.1 Ephemeral Drainage-line Assessments (EDA): Indicators of Stability

After field testing several methodologies, DEQ has determined that the most easily deployable and effective model for evaluating the success of ephemeral drainages in Eastern Montana coal mine reclamation is the Tongway EDA (Tongway & Ludwig, 2011). This analytical model, developed to assess ephemeral drainage stability in Australia, provides a points-based system for evaluating drainage stability. In its essence, the Tongway EDA identifies a set of 8 parameters associated with drainage health and has the evaluator score each one of these parameters, see **Appendix B** for EDA method.

Some of the main benefits of the Tongway EDA is it is time effective, does not require in-depth training, and proved effective at typical Eastern Montana site conditions during field testing by DEQ.

The 8 parameters of the Tongway EDA are slope steepness, slope surfaces, ephemeral drainage-line wall vegetation, ephemeral drainage-line floor vegetation, ephemeral drainage-line cross-section, ephemeral drainage-line longitudinal-section, ephemeral drainage-line wall erodability, and ephemeral drainage-line floor erodability. These parameters are then each given a defined score which are added and scaled to 0-100 and given classification on their potential stability including very unstable, unstable, potentially stabilizing, stable, and very stable.

When testing the Tongway EDA, DEQ modified the field procedure to utilize predetermined evenly spaced transects along the drainage to complete the measurements. DEQ recommends utilizing this approach to reduce potential biases and create a more randomized sample. It is recommended the number of transects to be measured along a drainage be spaced no further than 300 ft apart.

3.4.2 Modeling Data for Submission

While there are many models assessing erosion and stability, the Tongway EDA considers a multitude of factors other models don’t and is trained on ephemeral drainageways in mine reclamation areas. The process below illustrates an example of data collection that can be performed to demonstrate compliance with ARM 17.24.634, ARM 17.24.1116(6)(c)(ii) & (iii), and (6)(d)(iii).

- Data may be collected for the drainage and the model run shortly after phase II bond release has been met. This will allow the operator and DEQ to have a starting reference point and to identify areas in the channel design that may need additional work early to reach stability.

- The model can then be run intermittently for a sufficient time after phase II and/or III bond release to support the assertion that the reclaimed drainage has reached or is trending towards stability and dynamic equilibrium. “Sufficient time” in this context refers to a temporal span that includes, where possible; channel forming events, periods with and without flow, and at least one complete water year. This will likely require several years of data depending on the area and precipitation trends.

- The model can also be run on a nearby analog undisturbed drainage. This data can be used to set a baseline for stable conditions, and to show reclamation has reached a state comparable to un-mined natural drainages.

The Tongway EDA has no required frequency of transects to evaluate stability of a channel. DEQ recommends the distance between transects does not exceed 300 feet. In general, larger drainages with variable drainage characteristics will require more data points to accurately determine the stability of the system than more homogenous channel reaches. Every major portion of the drainageway should have enough transects so the reach can be encapsulated in its entirety.

3.5 Comparison With Natural Drainage Channels

An additional way dynamic equilibrium can be demonstrated on reclaimed drainages is to compare drainage data to similar natural drainages with no mine influence. A natural drainage is generally considered to be in dynamic equilibrium; although, consideration should be given to changing climactic regimes and land use as heavy grazing can negatively affect the stability of channels. Data from drainages with no mine influence may be used to satisfy requirements from ARM 17.24.634 (f) “provide for the long-term relative stability of the landscape. The term "relative" refers to a **condition comparable to an unmined landscape** with similar climate, topography, vegetation and land use” [emphasis added] in addition to dynamic equilibrium. Therefore, the data discussed above can also be applied to unmined drainages and compared to reclaimed drainages to evaluate the success of reclamation and establishment of natural dynamic equilibrium in the region and is recommended by DEQ.

Operators should exercise care when extrapolating drainage characteristics from natural analogs to reclaimed drainages. Reclaimed drainages have different geologic controls of unconsolidated uncompacted overburden materials, where natural drainages have formed over extended periods of time from heterogenous layers of bedrock, with established vegetation and channel dimensions reflecting the dominant climate regime. Natural drainages do not need to be identical to their post mine counter parts, so long as they are roughly comparable and fit within scope of the operator’s model, some degree of variation is acceptable and expected. Please reach out DEQ with questions about specific drainages.

4.0 Conclusion

Phase IV bond release requires, in part, a demonstration of ARM 17.24.634(1)(d) which states that “…drainage channels must remain in dynamic equilibrium with their drainage basin…”. Mine operators are encouraged to utilize the methods provided above, but DEQ will consider other proposed methodologies that demonstrates that the statute and rule have been met as they pertain to dynamic equilibrium for ephemeral drainages. Many of the methods described above are most useful when comparing results across time to draw conclusions on how stability is trending. An example data submission for dynamic equilibrium determination is provided in **Appendix D**.

5.0 REFERENCES

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Appendix A RULES & LAWS

The rules and laws included in the table below highlight the primary authority for drainage reclamation.

Rule / Law	Category	Description
82-4-203(6)(b), MCA	Drainage Pattern	The reclaimed area blends with and complements the drainage pattern of the surrounding area so that water intercepted within or from the surrounding terrain flows through and from the reclaimed area in an unobstructed and controlled manner.
82-4-203(6)(c), MCA	Drainage pattern	Postmining drainage basins may differ in size, location, configuration, orientation, and density of ephemeral drainageways compared to the premining topography if they are hydrologically stable, soil erosion is controlled to the extent appropriate for the postmining land use, and the hydrologic balance is protected.
ARM 17.24.301(14); 82-4-203(6), MCA	Definition	"Approximate original contour" means that surface configuration achieved by backfilling and grading of the mined area so that the reclaimed area, including any terracing or access roads, closely resembles the general surface configuration of the land prior to mining and blends into and complements the drainage pattern of the surrounding terrain, with all highwalls, spoil piles, and coal refuse piles eliminated.
ARM 17.24.301(55); 82-4-203(26), MCA	Definition	"Hydrologic balance" means the relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, or reservoir, and encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground water and surface water storage.

Rule / Law	Category	Description
ARM 17.24.313(1)(e)(i)	Drainage Design	Each reclamation plan must contain […] a description of postmining drainage basin reclamation that ensures protection of the hydrologic balance, achievement of postmining land use performance standards, and prevention of material damage to the hydrologic balance in adjacent areas, including […] a comparison of premining and postmining drainage basin size, drainage density, and drainage profiles as necessary to identify characteristics not distinguishable on the premining and postmining topographic maps.
ARM 17.24.313(1)(f)(i)	Drainage Design	Each reclamation plan must contain […] drainage channel designs appropriate for preventing material damage to the hydrologic balance in the adjacent area […] including detailed drainage designs for channels that contain critical hydrologic, ecologic or land use functions not already addressed in this rule such as alluvial valley floors, wetlands, steep erosive upland drainages, drainages named on USGS topographic maps, or intermittent or perennial streams. Detailed drainage designs include fluvial and geomorphic characteristics pertinent to the specific drainages being addressed[.]
ARM 17.24.313(1)(f)(ii)	Drainage Design	Each reclamation plan must contain […] drainage channel designs appropriate for preventing material damage to the hydrologic balance in the adjacent area […] including for all other channels [not described in ARM 17.24.313(1)(f)(i)], typical designs and discussions of general fluvial and geomorphic habit, pattern, and other relevant functional characteristics[.]
ARM 17.24.314(1)(a)	Water Quality	[…] The measures must minimize disturbance of the hydrologic balance sufficiently to sustain the approved postmining land use […] and must provide protection of […] the quality of surface and ground water systems, within both the proposed mine plan and adjacent areas, from the adverse effects of the proposed strip or underground mine operations.

Rule / Law	Category	Description
ARM 17.24.314(1)(b)	Water Quantity	[…] The measures must minimize disturbance of the hydrologic balance sufficiently to sustain the approved postmining land use […] and must provide protection of […] the rights of present users of surface and ground water.
ARM 17.24.314(1)(c)	Water Quantity	[…] The measures must minimize disturbance of the hydrologic balance sufficiently to sustain the approved postmining land use […] and must provide protection of […] the quantity of surface and ground water within both the proposed mine plan area and adjacent areas from adverse effects of the proposed mining activities, or to provide alternative sources of water.
ARM 17.24.631(1)	Hydrologic Balance	The permittee shall plan and conduct mining and reclamation operations to minimize disturbance to the prevailing hydrologic balance and to prevent material damage to the prevailing hydrologic balance outside the permit area.
ARM 17.24.631(2)	Water Quality Water Quantity	Changes in water quality and quantity, in the depth to ground water, and in the location of surface water drainage channels must be minimized so that the postmining land use of the disturbed land is not adversely affected and applicable federal and state statutes and regulations are not violated.
ARM 17.24.631(3)(b)	Water Quality Erosion	Practices to control and minimize pollution include, but are not limited to, stabilizing disturbed areas through land shaping, diverting runoff, achieving quickly germinating and growing stands of temporary vegetation, regulating channel velocity of water, lining drainage channels with rock or vegetation, mulching, selectively placing and sealing acid-forming and toxic-forming materials, and selectively placing waste materials in backfill areas.
ARM 17.24.634(1)(b)	Drainage Pattern	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] approximate original contour[.]

Rule / Law	Category	Description
ARM 17.24.634(1)(d)	Erosion Stability	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] allow the drainage channel to remain in dynamic equilibrium with the drainage basin system without the use of artificial structural controls unless approved by the department[.]
ARM 17.24.634(1)(e)	Sizing Stability	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] provide separation of flow between adjacent drainages and safely pass the runoff from a six-hour precipitation event with a 100-year recurrence interval, or larger event as specified by the department[.]
ARM 17.24.634(1)(f)	Erosion Stability	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] provide for the long-term relative stability of the landscape. The term "relative" refers to a condition comparable to an unmined landscape with similar climate, topography, vegetation and land use[.]
ARM 17.24.634(1)(g)	Profile Shape Stability	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] provide an average channel gradient that exhibits a concave longitudinal profile[.]
ARM 17.24.634(1)(h)	Vegetation Habitat Drainage Pattern	Reclaimed drainage basins, including valleys, channels, and floodplains must be constructed to […] establish or restore a diversity of habitats that are consistent with the approved postmining land use, and restore, enhance where practicable, or maintain natural riparian vegetation as necessary to […] exhibit dimensions and characteristics that will blend with the undisturbed drainage system above and below the area to be reclaimed and that will accommodate the approved revegetation and postmining land use requirements.
ARM 17.24.638(2)	Erosion	Sediment control methods include but are not limited to:

Rule / Law	**Category**	**Description**
	Sediment Control	(a) disturbing the smallest practicable area at any one time during the mining operation through progressive backfilling, grading, and prompt revegetation in accordance with ARM 17.24.711, 17.24.713, 17.24.714, 17.24.716 through 17.24.721, and 17.24.723 through 17.24.726; (b) stabilizing the backfill material to promote a reduction in the rate and volume of runoff, in accordance with the requirements of subchapter 5; (c) retaining sediment within disturbed areas; (d) diverting runoff away from disturbed areas; (e) diverting runoff by using protected channels or pipes through disturbed areas to eliminate additional erosion; (f) using straw dikes, riprap, check dams, mulches, vegetative sediment filters, dugout ponds, and other measures that reduce overland flow velocity, reduce runoff volume, or trap sediment; and (g) treating with chemicals.
ARM 17.24.639(24)(a)	Erosion Sediment Control	Sedimentation ponds and other treatment facilities must not be removed: (i) sooner than two years after the last augmented seeding within the drainage, unless otherwise approved by the department in compliance with ARM 17.24.633; (ii) until the drainage entering the pond has met the applicable state and federal water quality requirements for the receiving stream; and (iii) until evidence is provided that demonstrates that the drainage basin has stabilized to the extent that it was in the undisturbed state.
ARM 17.24.751(2)(f)	Vegetation	Restore, consistent with 82-4-231 (10) (j), 82-4-232 (9), and 82-4-233, MCA, or avoid disturbance to wetlands, riparian vegetation along rivers and streams and bordering ponds and lakes, and other habitats of unusually high value for fish and wildlife, and, where practicable, enhance such habitats.

Rule / Law	Category	Description
ARM 17.24.1116(6)(b)(iv)	Erosion	Reclamation phase II is deemed to have been completed when soils are protected from accelerated erosion by the established vegetation.
ARM 17.24.1116(6)(c)(iii)	Water Quality Erosion	Reclamation phase III is deemed to have been completed when […] the lands are not contributing suspended solids to stream flow or runoff outside the permit area in excess of the requirements of ARM 17.24.633 or the permit.
ARM 17.24.1116(6)(d)(i), (iii), (iv), (v)	Hydrologic Balance	Reclamation phase IV is deemed to have been completed when […] all disturbed lands within any designated drainage basin have been reclaimed in accordance with the phase I, II, and III requirements; […] with respect to the hydrologic balance, disturbance has been minimized and offsite material damage has been prevented in accordance with the Act, the rules, and the approved permit; […] alternative water sources to replace water supplies that have been adversely affected by mining and reclamation operations have been developed and are functional in accordance with the Act, the rules, and the approved permit; the reestablishment of essential hydrologic functions and agricultural productivity on alluvial valley floors has been achieved[.]

Appendix B EPHEMERAL DRAINAGE-LINE ASSESSMENTS (EDA): INDICATORS OF STABILITY

The below tables are adapted from the Tongway EDA (Tongway & Ludwig, 2011). They are a quantitative approach to assessing stability of ephemeral systems. Metrics found to have high correlation with successful drainages have been parsed out into stability factor tables, see below. Each transect its scored for each stability factor table based on the quantitative or qualitative descriptions. These scores are then tallied up to provide an index score, with a higher score correlating with a higher expected stability. The source reference for the model, Restoring Disturbed Landscapes, is available at DEQ for review upon request.

Steepness of slopes above and bordering an ephemeral drainage way

Score	Description
1	Very steep, > 30 deg. enabling high flow velocities into the drainage-line over walls
2	Steep, 10-30 deg. creating moderate to high velocity flows into the drainage-line
3	Moderately sloped, 5-10 deg., generating moderate flow velocities into the drainage-line
4	Gently sloped, laterally extensive, < 5 deg., generating moderate to low velocity flows into the drainage-line over walls
5	Nearly flat, laterally extensive, generating low velocity flows over drainage-line walls

Surfaces on slopes above and bordering a drainage way

Score	Description
1	Bare slopes with side-arm channels: very high inflow rates, copious sediment
2	Bare slopes by drainage-line, laterally extensive, high inflow rates, moderate sediment
3	Sparsely covered slopes with bare-soil bank lip: moderate flow rate, some highly focused inflows, low sediment
4	Densely covered slopes: low and diffused inflows, very low sediment visible
5	Very densely covered slopes with litter and coarse woody debris: very low and diffused inflows, no observable sediment movement

Vegetation on ephemeral drainage way walls

Score	Description
1	Little or no vegetation growing on drainage-line walls
2	Vegetation present are mainly annuals with shallow root systems, allowing sediment to flow past
3	Perennial vegetation covers walls with observable sediment control

Vegetation on ephemeral drainage way floors

Score	Rating Description
1	Little or no vegetation growing on drainage-line floor; flow rates too high to permit plant growth
2	Any vegetation present is annual or short-lived: partial burial of plants by recently deposited sediment evident
3	Dense perennial plant cover, similar to vegetation on the bank of the drainage-line: or characteristic wetland species composition: no observable plant burial by sediment

Ephemeral drainage way cross-sectional shape indicator

Score	Description
1	Drainage-line walls nearly vertical; depth typically greater than width; Signs of active erosion include side-wall caving, mass wasting and tunneling. Fine sediments have been washed away from the base of the walls.
2	Drainage-line walls also near vertical but signs of erosion are less severe; depth about equal to width: slight undercutting of walls, and some sediment deposits are visible along drainage-line walls.
3	Drainage-line wall angles moderate with both bank and bed edges typically rounded and stabilizing: width greater than depth; Some deposits of sediment at base of walls.
4	Drainage-line wall angles low to moderate and clearly stabilizing; width greater than depth. Maybe some low, small sediment deposits at base of side walls.
5	Drainage-line walls gently sloping and strongly vegetated; width typically much greater than depth; Drainage-line has obviously been stable for a considerable period of time: indications of spontaneous restoration.

Ephemeral drainage way longitudinal profile indicator

Score	Description
1	Drainage way currently incised into a drainage-line channel where existing sediments are within scour holes and are deposited along the channel. Flow substantially linear.
2	Drainage-line channel flat and continuous with deposits of loose sediment and signs of slow and recent sediment movements along the channel. Flow noticeably sinuous.
3	Drainage-line channel flat but with a cohesive, fine textured and “soil-like” floor; no or only a few signs of fine sediment movement evident along the channel. Meandering bed shape, with point bars.
4	Drainage-line channel well vegetated between non-cascading chain of ponds with cohesive fine sediment /organic matter floors; no signs of sediment movement down the channel are evident. Typically, this type of channel is closely connected to its floodplain and gentle overbank deposition may occur.

Ephemeral drainage way wall erodibility indicator

Score	Description
1	Dispersive materials are exposed for greater than 1 meter of drainage-line wall height.
2	Materials that readily slake are exposed on greater than 0.3 meter but less than 1 meter of drainage line wall height (use the sum of multiple layers if they are present).
3	Materials with noticeable slaking are exposed on less than 0.3 meter of drainage-line wall height.
4	No unstable materials are exposed on drainage-line walls.

Ephemeral drainage way floor erodibility indicator

Score	Description
1	Materials on the drainage-line floor have a particle size and density similar to (or smaller than) materials in the walls; For example, fine silt or sand deposits on the floor and coarser materials in the walls.
2	Materials on the drainage-line floor are somewhat larger in particle size and denser (more consolidated) than materials in the walls; For example, gravel deposits on the floor and coarse sands in the walls.
3	Materials on the drainage-line floor are much larger in particle size and denser than materials in the walls: For example, the floor is armored with stones and rocks and the wall has coarse sands.

There are five classes of drainageway stability. The index number used to determine the stability class is calculated as Score Sum/32 x 100.

Stability Classification Grouping

Index	Classification	Interpretation of drainage way stability
80+	1. Very Stable	Drainage-line is likely to be in a durable and resilient state and able to withstand major storm events. Only minimal drainage-line monitoring is required, such as after very high flow events to evaluate whether stability has been retained.
70 - 80	2. Stable	Drainage way is stable, but it should be monitored through time to determine if drainage way is trending towards a less stable condition.
60 - 69	3. Potentially stabilizing	Drainage way is potentially stabilizing from an actively eroding and unstable state. Monitor through time to determine if drainage-line is trending to stability.
50 - 59	4. Unstable	Drainage way is actively eroding and remedial actions may be required. The stability indicators from the assessment may be used to determine the source of instability.
< 50	5. Very unstable	Drainage way is very actively eroding and immediate remedial actions may be required. The indicators may be used to determine the source of instability.

Appendix C ADDITIONAL FIGURES

Figure 6 An erosional bank with a fracture feature and slump blocks below the scour line. (Renner, et al., 2023)

Figure 7 An erosional bank with sloughing features. (Coleman, et al., 2005)

Appendix D EXAMPLE DYNAMIC EQUILIBRIUM DEMONSTRATION

1.0 DYNAMIC EQUILIBRIUM EXAMPLE SUBMISSION DOCUMENT

DEQ Comment:
The following is an example outline and evaluation of data that can be used to demonstrate dynamic equilibrium to satisfy the applicable rules and statutes. The example demonstrates how each method could be applied and describes how the data could be analyzed for submission to DEQ. DEQ provided additional context to each section in blue font to describe the evaluation DEQ would perform when it reviews a bond release application for adherence to the dynamic equilibrium requirements.

Please note, this example was created to show the elements a submission should contain but should not be considered a complete submittal. Operator bond release applications should include a complete narrative and photographic database, ideally distinct in both location and time. Submissions should contain comprehensive data to demonstrate all requirements have been met. A similar report should be submitted as part of a phase IV bond release application.

1.1 INTRODUCTION

Please see the included report including data and evaluation performed by MTCoalExampleCompany concerning the phase IV bond release of Reclamation Drainage 1. This drainage area is 5.51 square kilometers and has met all other requirements of bond release set forth in ARM 17.24.1116. The purpose of this document is to demonstrate that the drainage basin has reached dynamic equilibrium. A methodology was developed, in consultation with DEQ, utilizing the Montana DEQ *Dynamic Equilibrium Demonstration for Bond Release* document, and used to evaluate if the reclaimed drainage is functioning similar to the most comparable undisturbed drainage and that neither excessive erosion nor deposition is occurring. The primary assumption of this document is that the undisturbed drainage is a proper representation of dynamic equilibrium for the arid climate of Eastern Montana. With this assumption, we will demonstrate that our reclaimed channel is similar in all important aspects to the natural channel and has therefore reached dynamic equilibrium with the drainage basin, as is required by ARM 17.24.634(1)(d).

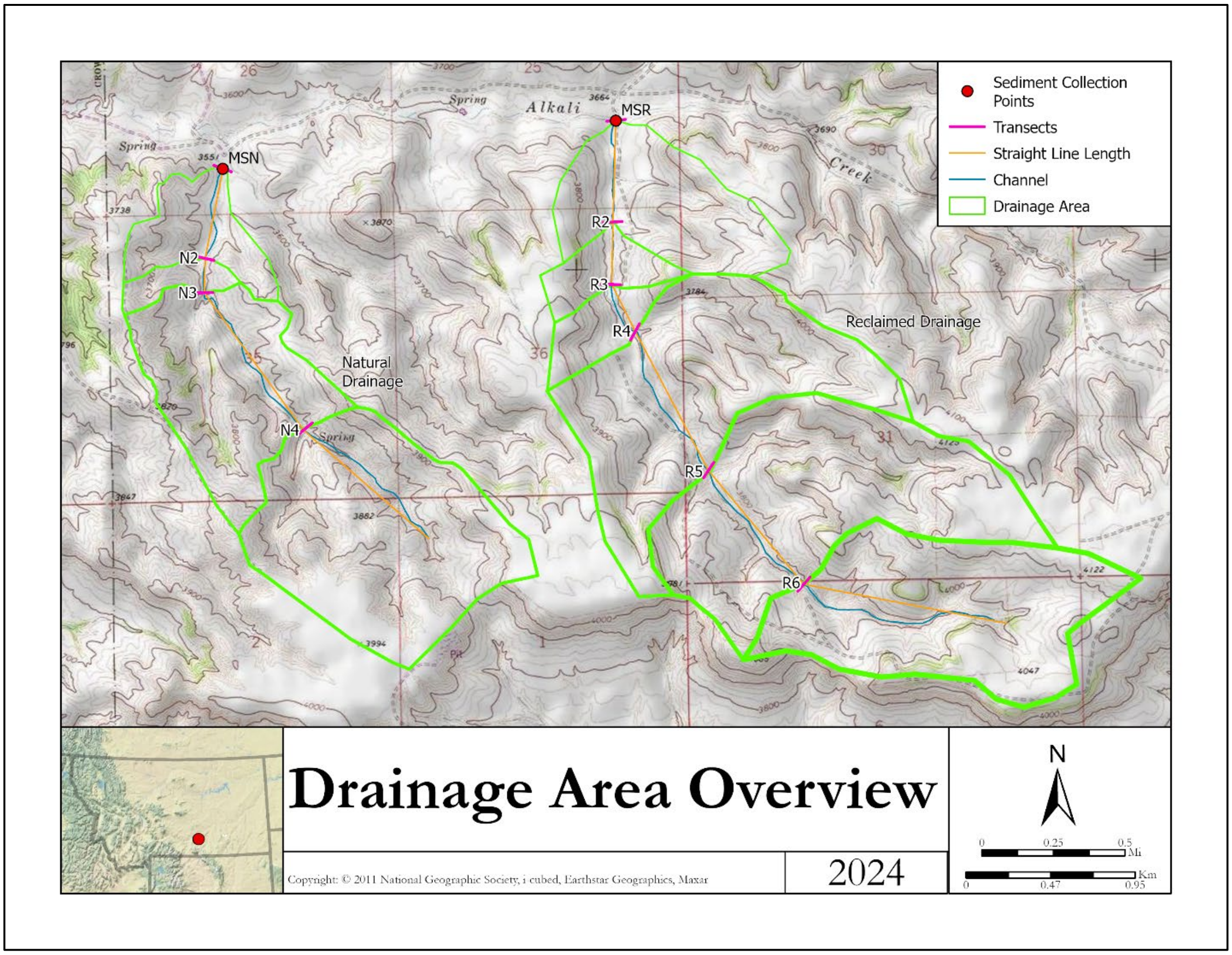

Figure 1: Overview map of drainage basins utilized for the dynamic equilibrium determination. The west drainage area denoted with N is a natural analog drainage and the east drainage denoted with R is the reclaimed drainage being evaluated for dynamic equilibrium. Green lines delineate the drainage basin area for each model transect (N1-N4 and R1-R6). The surface water monitoring locations are delineated as Monitoring Station Natural (MSN0) and Monitoring Station Reclaimed (MSR).

1.2 Model Data

We opted to use the described Tongway Ephemeral Drainage Line Assessment (EDA) for its reclamation assessment capability in similar climates and use cases. The reclamation drainage was assessed using data from six transects named R1-R6 (Figure 1 and Figure 2). The model used is described in "Ephemeral Drainage-Line Assessments: Indicators of Stability. In: Restoring Disturbed Landscapes. The Science and Practice of Ecological Restoration" by (Tongway & Ludwig, 2011). A modified procedure measuring transects instead of reaches was utilized in consultation with DEQ.

A typical cross-section from the reclaimed drainage is provided in Figure 3. Additionally, we took 4 transect measurements at our most comparable native drainage. Identical procedures were used to measure each transect in both drainages. Temporally, all data was taken within the shortest feasible span to ensure consistency. Data input into the model for the reclaimed and natural drainage are provided in Table 1 and simplified into Table 2. To provide another way to visualize the data the probability values were then mapped on the drainages (Figure 4).

Figure 2. Transect measurements were taken by hand using visual assessment and analog equipment.

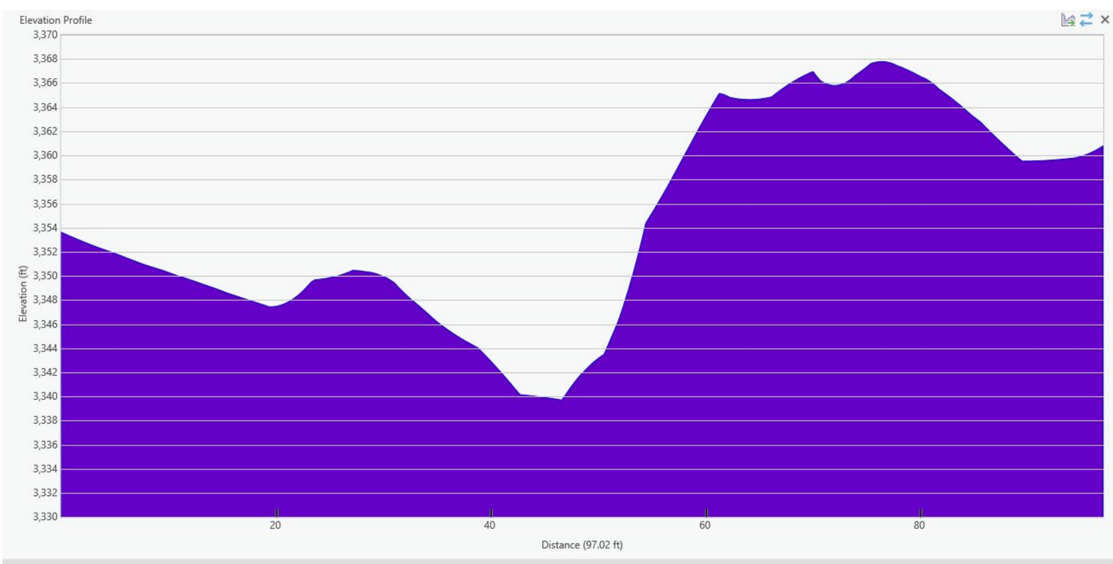

Figure 3. Typical cross-sectional transect in the reclaimed drainage. A well-defined channel with an interconnected floodplain is a sign that a healthy drainage has formed.

Table 1. Model input values collected on the natural and reclaimed drainage.

	N1	N2	N3	N4	R1	R2	R3	R4	R5	R6
Slope Steepness (1-5)	3	4	3	2	4	2	4	3	2	1
Slope Surface (1-5)	4	4	3	4	4	2	3	4	3	4
Wall Vegetation (1-3)	2	2	2	2	1	2	2	2	2	1
Floor Vegetation (1-3)	2	2	2	3	2	3	3	2	3	2
Cross-section shape (1-5)	5	5	3	5	5	3	4	4	2	2
Longitudinal profile (1-4)	4	4	3	4	3	4	3	3	4	2
Wall erodibility (1-4)	4	4	4	3	3	3	2	4	4	1
Floor erodibility (1-3)	1	1	1	1	2	1	1	2	1	2
Sum of Scores	25	26	21	24	24	20	22	24	21	15
Max Possible Score	32	32	32	32	32	32	32	32	32	32
Index (Sum/Max) x 100%	**78**	**81**	**65**	**80**	**75**	**63**	**70**	**75**	**65**	**48**

DEQ Comment:

While there are no requirements on the number of transects, sufficient datapoints should be included to support the dynamic equilibrium analysis. Transect spacing of no greater than 300 feet may be required to completely assess the channel. For large basins, this can necessitate a large number of transects. It's important to note that each transect can be assessed relatively quickly. Operators are encouraged to reach out to DEQ for help determining transect number and spacing.

Table 2. Simplified table showing results of the Tongway EDA for each transect.

Reclaimed Drainage		Natural Drainage	
IDKey	Tongway Index	IDKey	Tongway Index
R1	75	N1	78
R2	63	N2	81
R3	70	N3	65
R4	75	N4	80
R5	65		
R6	48		

As described by Tongway, the index ranges from 100 being the highest a transect can score, to 25 being the lowest. We believe that comparing the stability index between the reclamation drainage and the natural drainage results in a valid assessment of dynamic equilibrium. The comparison facilitates the use of the parameters that have been shown to highly impact erosion, while ensuring we are comparing like to like. As stated, our initial assumption is that the natural drainage is in dynamic equilibrium. Therefore, having similar results in the reclamation drainage and the natural drainage demonstrates that the reclamation drainage has reached equilibrium.

Taking the average index values for both data sets gives us an index of 66 for reclamation and 76 for natural. While the reclamation drainage does show a lower overall stability score, the difference is minimal, just over 10 percent of each other. The Mann-Whitney U test provides a U value of 4, which is significant for an $\alpha=0.05$, showing there is a statistically significant difference between the two groups. While there is one outlier, R6, the remaining transects have a very tight grouping of values; excluding R6, the difference between the most stable transect and the least stable is 12 points. This is a similar grouping to the natural drainage (with a spread of 16 points). Although transect R6 scores lower than the rest of the drainage, results of the drainage stability assessment from several years prior indicate the channel is increasing towards stability with an increase in scores relating to the establishment of vegetation. Dynamic equilibrium suggests that some transects may have some manageable erosion, what's important is that the system as a whole is functioning properly. In the context of the other submittal data, and the morphology of the system, there is strong evidence to support the drainage being in dynamic equilibrium.

The results of the stability analysis, while considering the model and sampling results, support the reclaimed drainage is in dynamic equilibrium and not exhibiting excessive erosion or deposition, especially when compared to a similar natural drainage. The reclaimed drainage values are similar to that of a native drainage and a comparison overtime indicates the channel is trending towards stability. We believe that the other methods in this document will continue to show that reclaimed drainage functions similar to that of the natural drainage, and that the reclamation drainage has reach equilibrium.


Tongway Index
Less Stable
More Stable

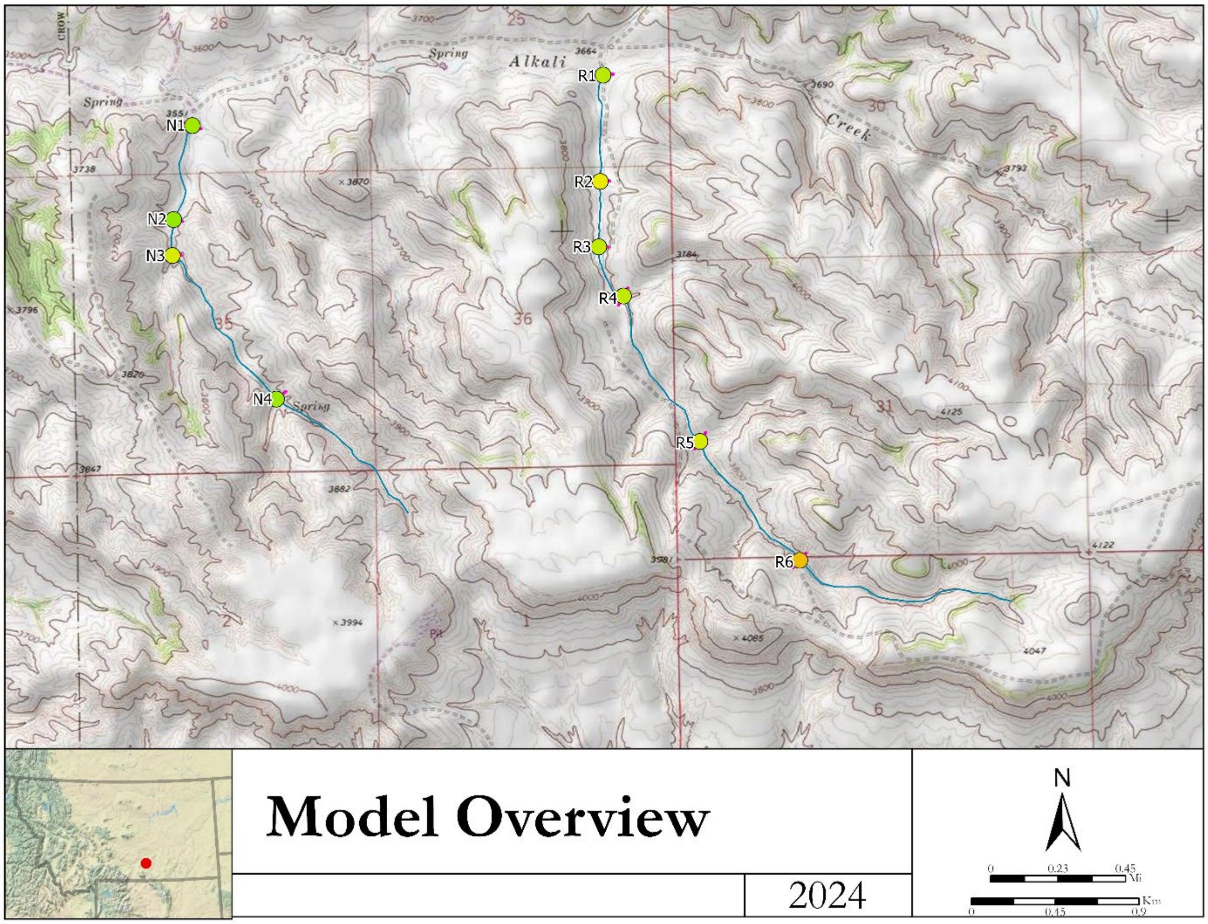

Figure 4: Tongway EDA results mapped on the drainage locations where they were collected. N1-N4 on the left are part of the natural drainage and R1-R6 on the right are part of the reclaimed. Note the majority of transect values for the reclaimed drainage resemble that of the native drainage.

<u>DEQ Comment:</u>
Looking at the data, R6 appears to be an outlier which could have a multitude of factors, in this case it's likely due to the steeper slope of the reach. Dynamic equilibrium is not necessarily stability at every single transect, but rather that the basin as a whole has a healthy balance of erosion and deposition. (However, it is important to note that stability is an important component of phase III which already needs to have been demonstrated for all areas in question.) If an operator chooses to run some of their statistics without the inclusion of certain transects, they must justify that doing so is correct and prudent. This is just an example, submittals from operators should have more transects which will allow for higher accuracy and a more robust suite of statistic tools to be used. Another addition to the model which will greatly bolter an operator's evidence is running the model several times over many years. Showing a stable Tongway EDA, or even one that improves, can add a considerable deal of defensibility to the demonstration for phase IV bond release.

1.3 SAMPLING DATA

MTCoalExampleCompany has collected water quality and quantity data at the mouth of a reclaimed drainage and a natural analog drainage system. Station locations are provided in *XXX*. The drainage area for the natural analog is 2.79 sqkM and the drainage area for the reclaimed drainage is 5.51 sqkM. Both monitoring stations consist of automatic samplers for total suspended solids (TSS) and a crest gauge for stage that was converted to flow in cubic feet per second (cfs). Data was collected for the natural drainage between years 2009 and 2020 and for the reclaimed drainage between 2001 and 2024. Data evaluated for the natural analog and the reclaimed drainage are provided in Table 4. Box and whisker plots for TSS and Flow data are provided in Figure 5 and Figure 6, respectively. TSS as a function of flow is provided in Figure 7. This data was evaluated to determine if the reclaimed drainage was functioning similar to a native analog drainage. For this evaluation, it is assumed the natural drainage is in dynamic equilibrium.

The natural and reclaimed drainage TSS data appear to be comparable (Figure 5). Considering the spread of the data, the median TSS of 780 mg/l for the natural drainage and 1020 mg/l for the reclaimed drainage are similar. Both the natural drainage and reclaimed drainage TSS data have similar overall shapes with large upper quartile ranges with a positive skew. Although, the natural drainage has a larger range of data. The reclaimed drainage TSS data includes outliers while the natural drainage does not but has a more spread-out upper quartile range.

As seen in the Figure 6 Tukey Box and Whisker plot, the natural and reclaimed drainage flow measurements appear to be comparable. Considering the spread of the data, the median flow of 4 cfs for the natural drainage and 3 cfs for the reclaimed drainage are similar. Both the natural drainage and reclaimed drainage flow data have similar overall shapes with large upper quartile ranges with a positive skew. Although, the natural drainage has a larger range of data. The reclaimed drainage flow data includes outliers while the natural drainage does not.

The natural drainage and reclaimed drainage TSS as a function of flow data show similar overall spread (Figure 7). Both trend lines are positive, although the reclaimed drainage has shallower slope. The natural drainage exhibits more variability in TSS at lower flows (<35 cfs) than the reclaimed drainage.

The higher median TSS for the reclaimed drainage may be the result of the larger drainage area and/or the increasing establishment of vegetation in the drainage bottoms, which can reasonably be expected. The overall shape of the TSS and flow data box and whisker plots are in response to increasing variability at increased values. This may be explained by the variability in hydrologic response of each basin to varying intensity and duration precipitation events. Although the median flow for the reclaimed drainage is less than the natural drainage with less drainage area, the reclaimed drainage exhibits higher outlier flow measurements. Overall, water quality and quantity data show similar trends and support that the systems function in a similar manner. Based on the analysis, the reclaimed drainage is in dynamic equilibrium.

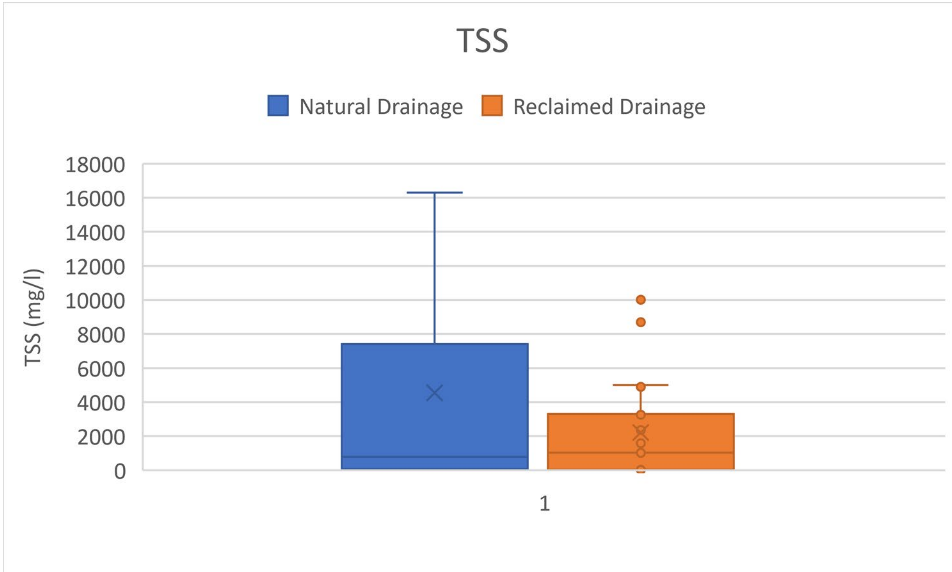

Figure 5. Box and Whisker plots of TSS data collected from a natural drainage with no mine influence and the reclaimed drainage.

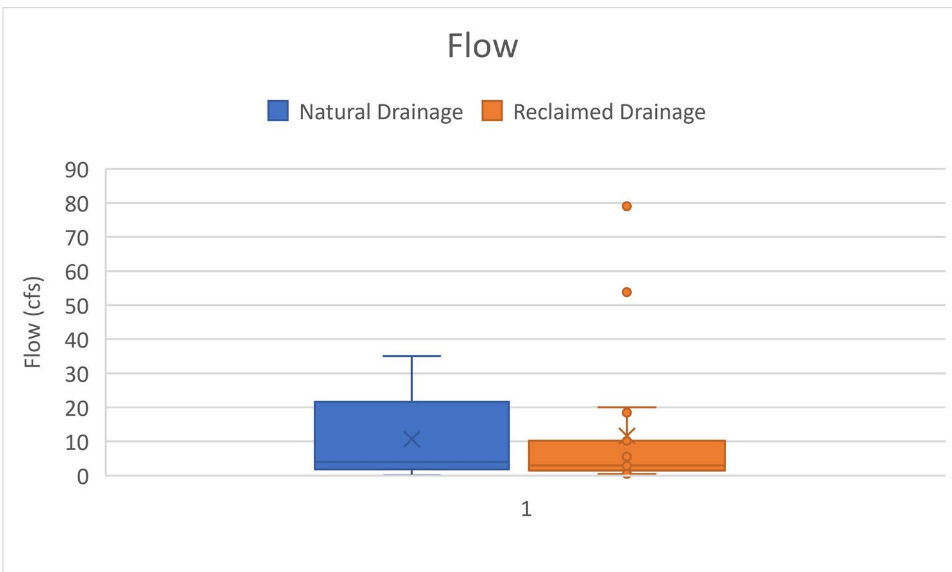

Figure 6. Box and Whisker plots of flow measurements collected from a natural drainage with no mine influence and the reclaimed drainage.

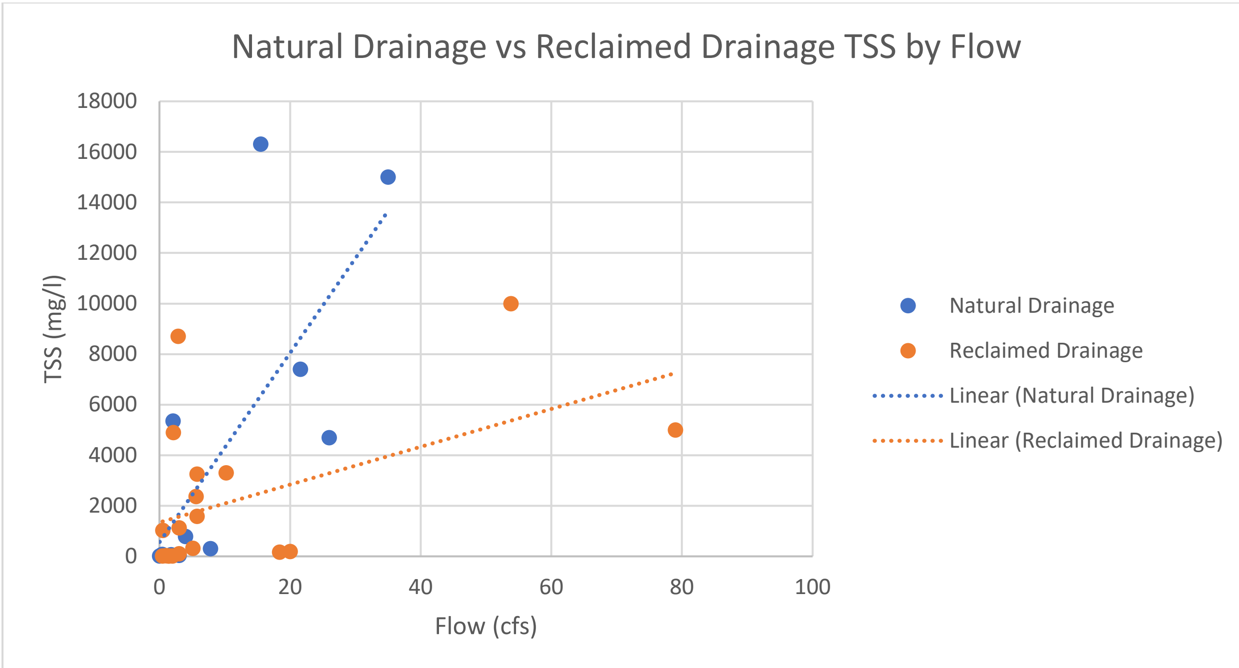

Figure 7. Scatter plots of TSS as a function of flow for a natural drainage with no mine influence and the reclaimed drainage.

Table 3. TSS and Flow data used for dynamic equilibrium evaluation.

Location	Sample Date	Flow (cfs)	TSS (mg/l)
Natural Drainage	8/7/2009	15.5	16300
Natural Drainage	6/23/2010	26	4700
Natural Drainage	7/28/2010	35	15,000
Natural Drainage	8/4/2010	21.6	7400
Natural Drainage	8/20/2010	2.1	5350
Natural Drainage	2/25/2012	0.03	8
Natural Drainage	6/3/2015	4	780
Natural Drainage	3/19/2018	3	34
Natural Drainage	3/12/2019	1.8	60
Natural Drainage	2/29/2020	7.8	310
Natural Drainage	3/24/2020	0.44	80
Reclaimed Drainage	6/11/1997	5.6	2360
Reclaimed Drainage	7/21/1997	0.5	1020
Reclaimed Drainage	8/19/1997	79	5000
Reclaimed Drainage	7/22/2002	10.2	3300
Reclaimed Drainage	3/12/2003	53.8	10,000
Reclaimed Drainage	7/14/2004	5.78	3250
Reclaimed Drainage	5/18/2005	5.14	312
Reclaimed Drainage	1/19/2009	1.5	13
Reclaimed Drainage	6/10/2010	2.13	4900
Reclaimed Drainage	7/15/2010	2.875	8700
Reclaimed Drainage	3/10/2011	1.36	8
Reclaimed Drainage	5/23/2011	18.4	170
Reclaimed Drainage	6/1/2011	20	187
Reclaimed Drainage	8/11/2011	5.78	1580
Reclaimed Drainage	1/31/2012	0.47	17
Reclaimed Drainage	2/18/2014	2	11
Reclaimed Drainage	3/4/2014	3	97
Reclaimed Drainage	6/20/2018	3	1130
Reclaimed Drainage	1/29/2024	1	21

DEQ Comment:

This analysis provides interpretation of the data collected. The main characteristics of the two drainages and data are stated (basin size, data range, and sample collection methods) and transparent. The reclaimed drainage data need not match natural drainage exactly, but it should reveal broad basin trends that explain differences in the data. Since sediment data in ephemeral drainages is highly variable, basing conclusions on sampling data alone may not be always appropriate.

1.4 GEOMORPHIC DATA

Photographs of the drainage evaluated for dynamic equilibrium were evaluated and the results are provided below. Photographs of two transects that represent the majority of the drainage are described below, and the reminder of the photos collected are also provided to DEQ.

Transect R2 exhibits a channel that is down cut into the surrounding relatively low sloped landscape ~1-2 feet, but it is wider than it is deep (Figure 8). Somewhat sparse vegetation is establishing in the channel floor and walls. The model results indicate this stretch as potentially stabilizing. Photos from previous years indicate that additional vegetation is establishing which will act to stabilize the channel. The erosive bank features appear to be trending towards stabilization.

Transect R4 exhibits a channel with steeper landscape slopes than Transect R1 but has little channel incision <1 foot (Figure 9). The surrounding landscape is well vegetated and sparse vegetation is establishing in the channel bottom. Additionally, the channel is beginning to create additional sinuosity in the channel bottom with the development of point bars.

The geomorphic features highlighted for the two transects described support that the drainage is in dynamic equilibrium. First the lower scoring transect with the model indicates trends towards stability with vegetation establishment and lack of further downcutting. The stable scoring transect (Figure 9), is exhibiting bed particle sorting and also lack of erosional features. We assert that these features support the position that the drainage being evaluated is in dynamic equilibrium.

Figure 8. Transect R2 of the reclaimed drainage. Stability analysis classifies this reach as potentially stabilizing.

Figure 9. Transect R4 of the reclaimed drainage. Stability analysis classifies this reach as stable.

DEQ Comment:

General photographs of the drainage and surrounding landscape support the evaluation. These may include aerial orthomosaics, images of erosional and depositional features at measured transects, and photographs of overall channel morphology. Reviewing stability features and comparing photographs over time helps demonstrate whether the drainage is progressing toward stability, particularly in previously unstable areas. A complete submission should include sufficient images to provide a comprehensive view of drainage stability, along with a figure indicating photo locations.

1.5 CONCLUSION

An objective determination based on the shown evidence demonstrates that it is more likely than not that the drainage is in dynamic equilibrium. By all metrics laid out by DEQ and in literature, there is little evidence of excessive eroding or depositing of sediment across the drainage. It is therefore our understanding that the reclamation drainage has met the requirements of 17.24.634 (1)(d). Assuming all other requirements for phase IV bond release have been met, we request that the drainage be released from further reclamation requirements and all remaining associated bond be returned to the Mine.

DEQ Comment:

A summary of the results of the analyses conducted should be provided to highlight and reaffirm the position that the drainage being evaluated is in dynamic equilibrium.