Peabody

Peabody Energy - Midwest Operating Group

Stream Restoration at Midwest Surface Coal Mines

Keys to Success

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Introduction

The goal of this overview is to better understand the benefits, challenges, and the keys to success of natural stream restoration or construction at Midwest surface coal mining operations.

What is Natural Stream Restoration or Construction?

- The concept of Natural Stream Restoration or Construction is a fairly new concept to mining operations that has precipitated from the drastic changes in the way the Clean Water Act (CWA) is being regulated.
- Natural Stream Restoration and Natural Stream Construction utilize various techniques such as those developed by Dave Rosgen and others (Applied River Morphology, Dave Rosgen 1996).
- Natural Stream Restoration is a geomorphologic approach to stream restoration based on an understanding of the valley type, general watershed conditions, dimension, pattern, profile, hydrology and sediment transport of natural, stable channels (reference condition) and applying this understanding to the reconstruction of an unstable channel (http://www.saw.usace.army.mil).
- Natural Stream Construction follows the same principles as restoration and implements a stream design that gives the stream proper belt width, meander pattern, and geometry to effectively transport the supply sediment downstream without either aggrading or degrading the stream system, while providing proper access to a floodplain in lower gradient streams.
- In the context of surface coal mining, Natural Stream Construction generally occurs in the reclamation, while Natural Stream Restoration generally occurs off-site in most instances.
Past practices in mining reclamation

- Common past reclamation practice was to minimize excess sedimentation from leaving the site through terracing, fescue-lined grass waterways, fescue-lined straight cut channels, permanent sediment basins and other best management practices.

- Most straight cut permanent channels were routed through some type of permanent open water structure before leaving the site.

- The channel geometry was designed (without a low flow channel, which eventually develop on their own) to carry large flood events in the channel without access to a floodplain resulting in low flow conditions not being capable of effectively transporting sediment downstream.

- The resulting condition promotes bar formations that re-direct flows resulting in excess near bank stress and stream bank erosion.

- The lack of in-stream structure placement did not allow for adequate grade control as well as riffle, run, pool, and glide development for proper stream stability and habitat enhancement.
Benefits of Natural Stream Restoration and Construction methods

- Natural methods are very desirable aesthetically compared to traditional linear methods.
- Natural methods introduce structure for streambed and bank stability as well as provide macroinvertebrate and fish habitat.
- Proper stream designs promote dynamic equilibrium, thus minimizing maintenance.
- Adequate access to a designed floodplain increases flood storage while at the same time decreases streambed and bank erosion in lower gradient streams.
Challenges of Natural Stream Restoration and Construction methods

- Final overburden and soil grading
  - Additional thought and engineering is required
  - Increased planning for drainage control
  - Additional surveying or equipment mounted GPS is required

- Channel Construction
  - Selecting quality equipment operators with experience
  - Getting the stream design from the computer to the ground
    - Requires extensive construction layout or equipment mounted GPS units
    - Proper installation of structure at the correct locations
  - Stream and Riparian Area Seeding
    - Preparing an adequate seedbed and incorporating some quick germinating species into the mix
    - Using erosion control matting or implement hydro seeding on stream banks to provide seed and erosion protection
    - Establishing dense vegetation on the stream banks is *critical* to successful stream mitigation
    - Establishing a stable, vegetated watershed
    - ACOE requirement to direct base flow around water impoundments
  - Temporarily diverting flow from newly constructed channel until stream vegetation is established
Challenges of Natural Stream Restoration and Construction methods

➢ Channel Maintenance as needed
  ▪ Channel repairs may be required where seeding, matting, or structure failures occur due to timing and intensity of rainfall prior to vegetative maturation
  ▪ Tree planting may need to be delayed initially to allow for any stream repairs that may be needed so that tree damage is limited
  ▪ Tree mortality rates or damage slowing tree growth may be high from voles or rabbits and may require the installation of raptor perches in some instances to maintain survivability

➢ Open Water
  ▪ Only events greater than bank full flows may be routed into open water per ACOE
  ▪ A reduced watershed hampers normal flow to maintain the pool stage
  ▪ Improves water quality from agricultural and urban land use watersheds
  ▪ Is a necessary agriculture water source
  ▪ Provides excellent flood storage and longer base flows to receiving streams
  ▪ Can provide more desirable in-stream fish species
Stream Restoration and Reconstruction Keys to Success

- Keys to success start long before actual stream construction and begins with proper mine planning and spoil grading plans
  - Spoil grade plans will need to be adjusted periodically
  - Stream and floodplain designs can easily be tweaked to accommodate grading plan revisions
Stream Restoration and Reconstruction Keys to Success

- Hydrologic data to determine the bankfull depth and other meaningful relationships for a given watershed is critical in determining the proper geometry of the stream
  - Regional curve data produced from extensive research is available on-line
  - Determining which curve to utilize can become a challenge without field checking streams in the specific area of interest
  - Determining one’s own regional curve or mini-curve not only provides a great learning experience about the relationships of stream dimension versus watershed but provides sound data for stream designs specific to your region
Stream Restoration and Reconstruction Keys to Success

- Adequate stream design software or other methodologies such as Rosgen’s dimensionless ratios should be used
  - Stream design software such as Rivermorph (Rosgen Approach) and Carlson’s Natural Regrade work well to speed up the design process
  - Calculating dimensionless ratios by hand is beneficial to understand the process but takes significantly more time
Stream Restoration and Reconstruction Keys to Success

▶ Extensive surveying or equipment mounted GPS is required
  ▪ Adequate surveying and flagging is required for the equipment operator to be able to follow the meandering design if no equipment mounted GPS is utilized
  ▪ GPS surveying versus traditional surveying is a necessity due to the large scope of projects
Stream Restoration and Reconstruction Keys to Success

- An experienced equipment operator is a key component in getting the stream design from the computer to the ground
  - The stream dimensions (width, depth, side slopes, stream slope) must be excavated
  - Stream features such as riffles and pools require attention to detail
  - Stream structure such as rock cross vanes, Newbury riffles, rock j-hooks, log vanes and root wads also require attention to detail
  - With experience, a good operator will understand how and why structure is located as designed and how water interacts with the structure to produce the desired effect
Stream Restoration and Reconstruction Keys to Success

Stream Restoration and Reconstruction Keys to Success

- Stockpile suitable stream structure during the mining process
  - Save trees with root wads
    - Fan size dependent on stream size
  - Save trees with straight logs for log vanes
    - Generally 1’ to 3’ diameter depending on stream size
  - Save whole trees with limbs for raptor perches
  - Save suitable non-toxic limestone or sandstone rock
    - Perform chemical testing for verification
Stream Restoration and Reconstruction Keys to Success

- Temporary berms or diversions constructed to bypass water from the new stream construction allows time for the maturation of herbaceous species
- Survey to ensure proper grade and flow capacity
Stream Restoration and Reconstruction Keys to Success

➢ Grade control structures are critical
  ▪ Newly placed soils have a higher erosion potential and are more prone to stream bank erosion and headcutting
  ▪ No bedrock is present to prevent head cutting
Stream Restoration and Reconstruction Keys to Success

➢ Rock Cross-Vanes structures
  ▪ Provide grade control
  ▪ Increase sediment transport
  ▪ Provide near bank stability by removing excess near bank stress from the banks and direct the energy towards the center of the stream for pool development
  ▪ The developed pools provide energy dissipation and excellent fish and macroinvertebrate habitat
  ▪ Increase oxygen content to the stream
  ▪ Installing a semi-permeable to non-permeable fabric on the upstream side of the rock along its length keyed into the ground prevents scouring and undercutting of the structure
Stream Restoration and Reconstruction Keys to Success

- Mechanical Rock Riffle structures
  - Provide grade control
  - Increase sediment transport
  - Provide pool development for energy dissipation and excellent fish and macroinvertebrate habitat
  - Increase oxygen content to the stream
Stream Restoration and Reconstruction Keys to Success

- Mechanical Rock Riffle structures
Stream Restoration and Reconstruction Keys to Success

- Rock J-Hook structures
  - Re-direct high velocity energy in the near bank stress area away from the out-bank
  - Provide out bank protection along a zone both upstream and downstream of the structure reducing stream bank erosion
  - The j-hook areas promote pool formation providing energy dissipation and excellent fish and macroinvertebrate habitat
Stream Restoration and Reconstruction Keys to Success

- Log Vane structures
  - Re-direct high velocity energy in the near bank stress area away from the out-bank
  - Provide out bank protection along a zone both upstream and downstream of the structure reducing stream bank erosion
  - Promote shallow linear pool formation providing energy dissipation and excellent fish and macroinvertebrate habitat and work well in combination with root wads
  - Attaching a semi-permeable to non-permeable fabric on the upstream side of the log along its length keyed into the ground prevents scouring and undercutting of the structure
Stream Restoration and Reconstruction Keys to Success

- Root Wad structures
  - Provide stream bank protection
  - Form large deep pools especially if the root wad fan is angled downward to further increase downward flow direction
  - Provide energy dissipation
  - Provide excellent cover for larger fish and macroinvertebrates
  - Work well in combination with log vanes
  - Installation is easily accomplished and requires no fabric
Stream Restoration and Reconstruction Keys to Success

- Large Boulder placements
  - Provide stream bank protection
  - Form large deep pools
  - Provide energy dissipation
  - Provide excellent cover for larger fish and macroinvertebrates
  - Work well in combination with log vanes and root wads
  - Installation is easily accomplished and requires no fabric
Stream Restoration and Reconstruction Keys to Success

- Large Boulder placements
Stream Restoration and Reconstruction Keys to Success

- Step Pool structures
  - Provide stream bed protection from head cutting on steeper stream slopes
  - Construct deep and shallow pools moving the water side to side
  - Pool construction provides energy dissipation
  - Work well in combination with root wads/log vanes and bank placed boulders which provide stream bank protection
  - Installation is somewhat tricky and requires more time and large quantities of rock to install
  - Fabric installation may be required in high bed stress areas
Herbaceous Vegetation

- The establishment of herbaceous vegetation is critical to stream mitigation success
- Mother nature is not always cooperative so expect some occasional re-seeding
- Seedbed preparation is a very important part of this process
  - Soil testing should be completed as necessary
  - Fertilizer should be applied as needed
  - Stream banks should be lightly worked
  - Floodplains should be deep tilled for herbaceous and tree root penetration as needed
  - Annual deep rooted, quick germinating species such as annual ryegrass, millet, or wheat needs to be included in the herbaceous seed mixture for quick cover
  - Hydro seeding is a good alternative on stream banks
Stream Restoration and Reconstruction Keys to Success

- Erosion Control Matting
  - Excelsior matting has provided the desired results
  - Matting not only provides erosion protection, but also holds seed in place and helps retain moisture for better seed germination, survival, and quick establishment
  - The placement of matting is labor intensive, but is necessary in high erosion potential areas and is more cost effective than re-seeding
  - Hydro seeding may also be effective on stream banks of newly constructed streams
Stream Restoration and Reconstruction Keys to Success

- Erosion Control Matting
Stream Bank Willow Growth

- Natural willow regeneration may occur along stream banks and increase bank stability
- Introducing live willow stakes to stream banks increases bank stability
- Willow growth along streams is generally confined to the bank region
- Willow provides exceptional stream bank protection due to their massive, fibrous root system
- Willow can provide a canopy, habitat, and detritus material much quicker than hard masted tree species
Stream Restoration and Reconstruction Keys to Success

- Stream Bank Willow Live Stakes
Stream Restoration and Reconstruction Keys to Success

- Raptor Perch structures
  - Raptor and owl species feed on voles, which kill tree seedlings, and are vital to ensure tree survivability in the stream riparian area or floodplain
  - Saved whole or partial dead trees make exceptional perches for raptors
  - Manufactured posts work as perches as well but do not get utilized as much due to their shorter heights
Stream Restoration and Reconstruction Keys to Success

- Raptor Perch structures
Summary

- Natural stream restoration is a geomorphologic approach to stream restoration based on an understanding of the valley type, general watershed conditions, dimension, pattern, profile, hydrology and sediment transport of natural, stable channels (reference condition) and applying this understanding to the reconstruction of an unstable channel (http://www.saw.usace.army.mil)

- Common past reclamation practice was to minimize excess sedimentation from leaving the site through terracing, fescue-lined grass waterways, fescue-lined straight cut channels, permanent sediment basins and other best management practices

- Natural methods are very desirable for macroinvertebrate habitat, fish habitat, and aesthetics compared to traditional linear methods

- Some of the challenges of Natural Stream Restoration and Construction include channel maintenance

- Stream restoration and reconstruction keys to success include
  - Advance mine planning and spoil grading plans
  - Hydrologic data such as regional curves to determine the proper design geometry
  - Adequate stream design software such as Rivermorph and Carlson Natural Regrade
  - Extensive surveying or equipment mounted GPS is required
  - An experienced equipment operator
- Advance mine planning and spoil grading plans
- Temporary berms or diversions
- Grade control structures
- Install proper stream structure such as:
  - Rock cross vanes
  - Mechanical riffles
  - Rock j-hooks
  - Log vanes
  - Root wads
  - Large boulder placement
  - Step pools
- Seed bed and herbaceous vegetation
- Erosion control matting to provide stream bank and seed protection
- Natural willow regeneration or live staking along stream banks
- Raptor perches are a key component to the overall tree survivability in the stream riparian area or floodplain