# STREAM RESTORATION: PAST PRACTICES – CURRENT BENCHMARKS[1]

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**ABSTRACT** To facilitate large scale surface coal mining in southern Illinois during the late 1970's -1980's, temporary diversion and eventually relocation (restoration) of perennial streams was required. Illinois' first stream restorations incorporated geomorphologic and ecological principles in their designs and construction to enhance their function and value as lotic and riparian habitats. IDNR's Office of Mines and Minerals (OMM) - Land Reclamation Division required (Federal Surface Mining Control and Reclamation Act of 1977) pre-disturbance stream restoration designs as well as post-disturbance monitoring of physical, chemical, and biological components of the stream community. The OMM interdisciplinary Stream Restoration Committee reviewed plans and provided technical input to ensure compliance with regulations and maximization of habitat enhancement opportunities. The Cooperative Wildlife Research Laboratory of Southern Illinois University Carbondale (CWRL) initiated stream restoration research in the early 1980's to evaluate restoration practices. CWRL, IDNR, and private biologists assessed ~ 7 miles of diversions and 16 miles of restorations associated with a 40-square mile surface mining complex in Perry County during ~ 1981-1994. These early pre- and post-construction investigations of stream relocations and restorations provide an extremely valuable benchmark to evaluate the long-term geomorphologic and biotic recovery processes in previously restored stream habitats, despite their relatively short 5-year post construction monitoring period. This presentation will highlight the extent and distribution, and establishment practices of these stream restorations initiated more than 25 years ago. A reassessment of these Illinois stream reconstructions that have undergone 10-20+ years of geomorphological adjustment and biological recovery is being planned to provide valuable guidance for future stream restoration practices.

**Additional Key Words**: geomorphic design, riparian buffer, stream diversion, hydraulic engineering

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## INTRODUCTION

The first surface mining for coal in Illinois occurred in 1866 near Danville, Illinois. Shallow coal was extracted using horse drawn scrappers. As surface mining progressed within the Illinois Basin, deeper deposits of coal were mined using larger equipment (> 180 cu yd shovels and draglines). During the late 1970's and 1980s large scale surface mines in southern Illinois extracted coal from depths of 70 – 95 + feet. These large surface mine open cuts, extending > 1.25 miles in length, often encountered small tributaries and streams that required relocation around the active mining operation. Prior to regulation (< 1976) small streams were permanently relocated around the active mining operation as straight channel diversions. As stream protection regulations became more stringent, straight line temporary stream diversions were replaced with permanent relocations either within the reclaimed mine spoil or on un-mined soils outside of the active coal extraction area.

Illinois' regulatory programs (IDNR Office of Mines and Minerals), mine operators, and staff and students of the Cooperative Wildlife Research Laboratory of Southern Illinois University (CWRL) have been conducting environmental assessments of pre-mine stream corridors, temporary and permanent stream diversions, and permanent stream restorations for more than 30 years. These early investigations of southern Illinois stream relocations and restorations provide an extremely valuable database for evaluation of the long-term hydrogeomorphic and biotic recovery processes in previously restored stream habitats. This paper highlights the extent and distribution, restoration practices, and biological performance of these stream restorations initiated more than 25 years ago. Monitoring methods used in the pre-disturbance and 5 yr post-reconnection stream assessments are documented in reports on file with IDNR's Office of Mines and Minerals (OMM) - Land Reclamation Division.

### Stream Disturbance Non- mining

Streams and rivers throughout Illinois have been severely impacted for more than 100 years by channelization and dredging practices not related to coal mining. Many streams in southern Illinois have been degraded by agricultural practices (drainage, clearing, and dewatering). Southern Illinois' smaller streams have been channelized to support drainage to enhance agriculture. Larger streams and rivers in Southern Illinois have been dredged and channelized by the US Army Corps of Engineers (< 1980) to facilitate barge transportation, reduce flooding, and promote river commerce. Channel incision and instability due to downstream channelization projects, and uncontrolled sediment and nutrients from agricultural runoff have degraded most low gradient natural streams in Illinois. In many cases streams restored by mining during the current regulatory era (post PL 95-87), support better habitat and water quality than un-mined “natural” streams that have been impacted by past agricultural practices.

Permit Requirements - Regulations

Implementation of stream restoration guidelines and regulations during the late 1970’s ended the era of channelized permanent stream diversions on reclaimed mined lands. Streams affected by mining would be required to “be put back” the way they were before mining. Stream restoration regulations and guidelines adhere to the Surface Mining Control and Reclamation Act (PL 95-87) permanent program administered by the Illinois Department of Natural Resources Office of Mines and Minerals Land Reclamation Division (IDNR OMM).). Section 780.16 of OSM’s regulations requires site specific resource information and protection and enhancement plans for “important” streams. Section 816.97(f) requires coal operators to avoid disturbances to riparian vegetation and to enhance where practicable, or restore, riparian vegetation.

Post-law stream restoration practices emphasize the design, construction, and maintenance of a “natural” meander channel within a restored riparian corridor protected by a vegetated buffer zone (Sec. 1816.43). Design components of restored streams include the reconstruction of a natural stable channel that supports a cross section profile, upstream downstream gradient, and channel meander ratio similar to the pre-mining condition. A well vegetated riparian corridor established within the reconstructed floodplain is required to provide sediment control as well as flood storage. Floodplain wetlands ranging from intermittently to seasonally inundated herbaceous or forested plant communities can be included in stream restoration plans to enhance wetland associated wildlife habitat. In-stream habitat features such as riffles and pools are included to increase diversity and enhance the aquatic habitat. Recognizing that restored streams must also provide the same hydraulic functions as pre-mine streams, flow capacity within the channel and floodplain storage must be designed to prevent both upstream and downstream flooding during a 100 year 6 hour precipitation event. To maintain the hydrologic balance (Sec. 1816.57) and ensure long-term protection of the restored stream channel and in-stream habitat features, a vegetated stream buffer zone extending from the top of bank to a minimum of 100 feet on both side of the floodplain is required.

Pre-construction geomorphic assessments are conducted to establish baseline conditions for designing hydraulic features such as bank height and angle, streambed width and profiles, upstream and downstream gradients, meander ratios, riffle and pool sequences, etc. Early stream restoration projects required pre-construction monitoring of water quality and the in-stream aquatic invertebrate and fish communities. Post construction monitoring to document successful restoration of the stream and its floodplain habitat was also required. Bond is released when all provisions of the approved plan have been implemented, the area is stable, and all regulations have been complied with. Early stream restoration projects of the 1980's and 1990's demonstrated that the coal industry was capable of restoring important hydrologic and biologic functions of streams after mining through the original channel. More recent permit approvals have not required the intensity of monitoring, since success of stream restoration techniques has been proven by several decades of past practices.

## STREAM RESTORATION, MONITORING, AND ASSESSMENT-ILLINOIS

Streams diversions and restorations associated with surface mines in Illinois have been assessed for more than 30 years. Pre-mine assessments and post –restoration monitoring has been conducted since 1979 by staff of the IDNR Mining Program-Streams Section (Pat Malone, Doug Carney, Randy Sauer). The IDNR Mining Program conducted pre-mining stream assessments as well as semiannual monitoring of the stream biotic community and water quality. Coal operators also conducted independent pre-mining assessments of the chemical, biological, and physical stream habitat conditions. Operators also monitored post-construction conditions for a minimum of 5 years to comply with state and federal regulations. Students and staff of the CWRL have conducted research to assess the recovery of stream restoration and diversion assessments since 1979. Collectively CWRL, IDNR, and Illinois coal operators have been compiling stream restoration baseline and post-construction data for 8 distinct streams during the past 30 years (Table 1). Despite the availability of fairly complete data sets for some Illinois streams, most of these short term assessments only represent "snapshots in time" providing a 2 or 5 year slice of data that focused on the pre-construction conditions or the immediate 5 years post-construction. Although the streams listed in Table 1 represent the majority of streams that have undergone diversion or restoration in southern Illinois, a full compilation of stream restoration sites in Illinois is needed to provided a baseline for future restoration efforts. However, these streams do provide an excellent opportunity to review stream restoration practices from both a historical and ecological perspective.

Table 1. Southern Illinois stream assessments[1]

| | Stream | Assessment Dates |
|---|---|---|
| Diversions | Galum | 1981-1982 |
| | Panther Creek | 1981-1982 |
| | Pipestone | 1983-1994 |
| | | |
| Restorations | Pipestone | 1990-1994 |
| | Galum ARCH | 1981-1998 |
| | Galum CONSOL | 2002-2006 |
| | Bonnie | 2001-2006 |
| | White Walnut | 2002-2005 |

[1] Assessments conducted by IDNR, CWRL, and /or coal operators.

Most importantly, the passage of time from active mining to 30 years post-construction provides stream ecologists and regulatory agencies the unique opportunity to view the ecological development within the restored riparian corridor that has occurred during the past 20 to 30 years. Stream restoration is a slow process that begins with the permit application process and requires extensive planning and patience that often requires 20 years from initial engineering and design to channel reconnection( (Fig. 1 a and 1b).

As exemplified by the CONSOL Burning Star 4 Galum Creek restoration (Fig. 1 a and b) stream restoration does not wait until after mining. The entire restoration process of channel design and realignment must be integrated with the active mining processes of overburden removal and replacement. Rough and final grading must be conducted 'in the dry" while the normal stream flow is diverted through a temporary channel outside of the active mining area. The temporary diversion can only be reconnected after all of the restoration channel units and in-stream habitat features such as riffles and pools have been constructed; and, the riparian floodplain plant community has been established. Although, post reconnection monitoring

Figure1a. BEFORE - CONSOL Burning Star 4 Mine. Galum Creek restoration integrating meander channel construction with active mining. (Photo Date1985)

Figure1b. AFTER - CONSOL Burning Star 4 Mine. Galum Creek restoration incorporating diverse reclaimed land use (rowcrop, forest, wetlands) with channel relocation (Photo Date2005)

begins after stream flow returns to the restored channel, this 5 year liability period provides only a brief glimpse of the actual stream restoration process. A "time lapse" perspective of the natural succession occurring within the riparian community and the restored channel is now available for more than 16 miles of southern Illinois stream meander channels that have been restored during mining and reclamation (Table 2).

During a ~ 20 year period from 1979 to > 1990 four southern Illinois streams located within a 40-square mile area of active surface mining in Perry County were restored to approximate pre-mine conditions (Table 2). Restorations encompassed more than 51,000 feet of channel reconstruction supporting average meander ratios of 1.66. Riparian buffers within the restored floodplains ranged in width from 300 to > 750 feet. Stream relocations in the 40 square mile area of active mining also included more than 37,000 feet of temporary and or permanent diversions. The permanent stream restorations occurred during Illinois' regulatory era of topsoil replacement and wetlands reestablishment. Consequently the permanent restorations represent some of the best examples of integrated land use in which reclaimed rowcrop agriculture adjoins forested and emergent wetlands that were established within the protected floodplain buffer zone.

Stream Restoration – Case Studies

ARCH of Illinois: Galum Creek. The ARCH of Illinois Captain Mine was the largest operating surface coal mine east of the Mississippi River when Illinois' first stream restoration was initiated in 1979. To facilitate mining, ~ 3.5 miles of the original channel of Galum Creek was moved east of the active operations and relocated in unmined soils (Fig. 2). The ARCH Galum Creek project represented the first stream relocation permit pursued by an Illinois coal operator under the IDNR permanent program. Stream restoration plans were developed by ARCH of Illinois' engineering and environmental staff and presented to the US Army Corp of Engineers and IDNR for review and comments in 1979. This early restoration plan encompassed less than 13 pages (including comments and responses) and 3 basic technical drawings illustrating channel features (bank height, width, buffer zone, riffles and pools), and floodplain tree planting specifications (Table 3)

Table 2. Southern Illinois - Stream channel restorations and diversions.

| Site | Channel Length-ft | Meander Length -ft | Meander Ratio | Buffer Width (ft) |
|---|---|---|---|---|
| **CONSOL 4** | | | | |
| Galum Restoration | 13,443 | 22,702 | 1.72 | 300-500 |
| Bonnie Restoration | 11,842 | 19,311 | 1.63 | 500-750 |
| Galum (perm.) Diversion | 16,400 | | | |
| **ARCH Captain** | | | | |
| Galum Restoration | 9,135 | 18,480 | 2.02 | 125-250 |
| Pipestone Diversion (permanent) | 11,342 | | | 85 |
| **AMAX Leahy** | | | | |
| Pipestone NW Diversion (perm.) | 5,808 | | | |
| Pipestone Restoration | 16,685 | 24,288 | 1.45 | 300-750 |
| Pipestone SE Diversion (perm) | 4,115 | | | |
| Pipestone Diversion | 22,704 | | | |
| **Restorations** | 51,095 | 84,781 | 1.66 | |
| **Diversions Permanent (*n=4*)** | 37,665 | | 1.0 | |


Figure 2. ARCH of Illinois Galum Creek restoration. Meander channel (4.3 miles) rerouted through unmined soils east of active mining area.

The USACE specified the following design criteria for the ARCH Galum restoration:

Channel Width – 30 to 50 feet
Buffer Zone – 300 feet
Channel Sinuosity – 2.0
Channel side Slope – 3H:1V
Channel (low flow) – 10- 12 ‘ wide, 2 feet deep
Riffle intervals – 700 – 1,000 feet
Pool – 1.5 to 5 feet deep

The ARCH Galum Creek project was the first meander “restoration”, although technically the stream was relocated to a portion of the watershed that was outside of its original channel corridor. Following state and federal agency review and revision, the restoration plan was presented at a public hearing in May 1979 to approximately 50 individuals who had "no outright objections" to the plan. Dr. W. D. Klimstra, Director of the Cooperative Wildlife Research Lab at SIUC viewed this initial stream restoration as a great opportunity.... "*to study man's ability to change the course of a stream and rebuild life around it* ". Early baseline data (ca 1980) from CWRL graduate student research (Bonace 1983, Busch 1990) conducted on the stream community during the first years following the reconnection, can serve as a valuable benchmark for assessing restoration success after 30 years. Currently, the mature riparian forested buffer zone provides excellent vegetative cover for forest wildlife species and roost sites for Bald Eagles which forage in the adjacent reclaimed mine areas (Fig. 3).


Figure 3. ARCH of Illinois Captain Mine. Galum Creek restoration (permit initiated in 1979, channel construction and reconnection completed 1981). (Photo Date 2005).

Table 3. ARCH of Illinois: Galum Creek stream restoration – reforestation plan.

| Floodplain | Riparian Corridor | Transition Upland Forest |
|---|---|---|
| Bald Cypress | Bald Cypress | Pecan |
| River Birch | Sweetgum | Bitternut Hickory |
| Black Willow | Overcup Oak | Shagbark Hickory |
| Green Ash | Green Ash | Shellbark Hickory |
| Hackberry | Hackberry | Water Hickory |
| Cottonwood | Black Walnut | Black Walnut |
| Pin Oak | Pin Oak | Bur Oak |
| Silver Maple | Silver Maple | Cherrybark Oak |
| | Swamp White Oak | Schumard Oak |
| | Honey Locust | So. Red Oak |
| | | Swamp Chestnut Oak |

CONSOL Burning Star 4. Located approximately 11 miles upstream from the ARCH Galum restoration, the Consolidation Coal Company engineers and reclamation staff designed and planned the nations' largest stream restoration effort to reconstruct more than 7 miles of meander channels through reclaimed mine soils at the Burning Star No 4 Mine (Anderson 1987). Unlike the ARCH Galum Creek project, CONSOL's 4.3- mile Galum Creek restoration (Fig. 4), and 3.7-mile Bonnie Creek restoration (Fig. 5) were constructed through replaced mine soils in the approximate location of the pre-mine riparian corridor.

The complexity of integrating the restoration of 2 streams into the planning, mining, and reclamation process required 20 years from initial design to channel reconnection for Galum Creek (Table 4). The CONSOL Galum and Bonnie creek restorations clearly illustrated that stream restoration is a complex, long term hydrogeomorphic process. The initial stream restoration success can be defined when bond is released within 5 years after completing post-reconnection monitoring.


Figure 4. CONSOL Burning Star 4. Galum Creek 4.3- mile restoration relocated through reclaimed soils in the approximate pre-mine riparian corridor.


Figure 5. CONSOL Burning Star 4. Bonnie Creek 3.7- mile restoration relocated through reclaimed mine soils in the approximate pre-mine riparian corridor.

Table 4. CONSOL Burning Star 4: Stream restoration project timeline

| Project Phase | Date |
|---|---|
| Design and Engineering | May 1979 |
| Permit Approval | November 1982 |
| Construction (8.0mi) | June 1984 - ~1998 |
| Floodplain Restoration | 1984 - 1998 |
| Channel Reconnection | June 1999 |
| Monitoring | 2002 – 2006 |
| OSM National Award | 2002 |

However, the attainment of long term biologic success is fully appreciated after several decades when the riparian plant communities have matured and the stream channels reach a "dynamic equilibrium" similar to the pre-mine condition. The U.S. Office of Surface Mining National Award for innovative reclamation practices recognized the significance of the CONSOL Burning Star 4 stream restorations in September 2002. OSM noted that this was ... "*..........the first time in Illinois that two major streams in a minefield were diverted during mining and then restored to their original locations. ..........reclaimed as a habitat for wildlife and waterfowl......"*

The CONSOL Burning Star 4 award-winning stream restoration practices implemented at both Galum and Bonnie Creek enhanced wildlife habitat within the stream channel and the floodplain corridor. The restoration practices included construction of meander channels, riffles, pools, and deep water habitat. Deepwater habitat enhancement was provided by routing of and connection of the restored stream channel through deep water (> 75' deep) incline basins. In addition to enhancing base flow and aquatic species habitat during seasonal droughts, the connection of restored channels with deepwater pools and basins provided sediment control from unmined upstream rowcrop fields. The deepwater basins as well as the design of floodplain forested and emergent wetlands provide storm water retention for flood events passing thru the restored channel. Storm water retention capacity was designed to maintain upstream water level increases below 0.5 ft. Floodplain reclamation in the Galum Creek restoration provided forested wetland habitat that was designed to be inundated by a 2-year design storm. These storm water retention functions were provided by the design of a protected floodplain buffer zone in the Galum Creek corridor that ranged from 300 to > 500 feet wide. Similar to previous steam restoration plans, IDNR staff recommended the hand planting (7' x 7") of flood tolerant or adapted bare root forest seedlings in the floodplain (Table 5).

Table 5. CONSOL Burning Star 4 Stream restoration. Floodplain forest seedling recommendation (IDNR).

| | | |
|---|---|---|
| Bald Cypress | Ash | River Birch |
| Pecan | Sweetgum | Cottonwood |
| Silver Maple | American Elm | Beech |
| Pin Oak | Red Maple | American Plum |
| Swamp White Oak | Hackberry | Box Elder |
| Sycamore | | |

Following the reconnection of the unmined upstream Galum and Bonnie creeks with the downstream restored sections, semi-annual (spring and fall) monitoring of water quality and stream biota was initiated in 2002 and continued through 2006. The 5-year Galum Creek (2002 - 2006) and Bonnie Creek (2002-2006) monitoring reports submitted to IDNR by the operator represent excellent baseline documentation for a future 20+ year re-assessment of long term stream restoration processes.

<u>AMAX Leahy Pipestone Creek</u>. The ~ 4.6-mile reconstruction of meander channels and riparian corridor of Pipestone Creek at the AMAX Leahy Mine in Perry County was the longest single stream restoration project on a reclaimed surface mine in southern Illinois. Similar to other (Galum and Bonnie Creek) post-law stream restorations, the Pipestone restoration followed the approximate original pre-mine floodplain location. Construction of the Pipestone Creek meander channels began in ~ 1979 with a small dragline, following grade and centerline profiles established by standard engineering practices of the 1970-80s. Meander channel segments of the Pipestone Creek restoration were constructed between 4 incline haul roads and vegetated as the active pit advanced beyond the future riparian corridor (Fig. 6). .

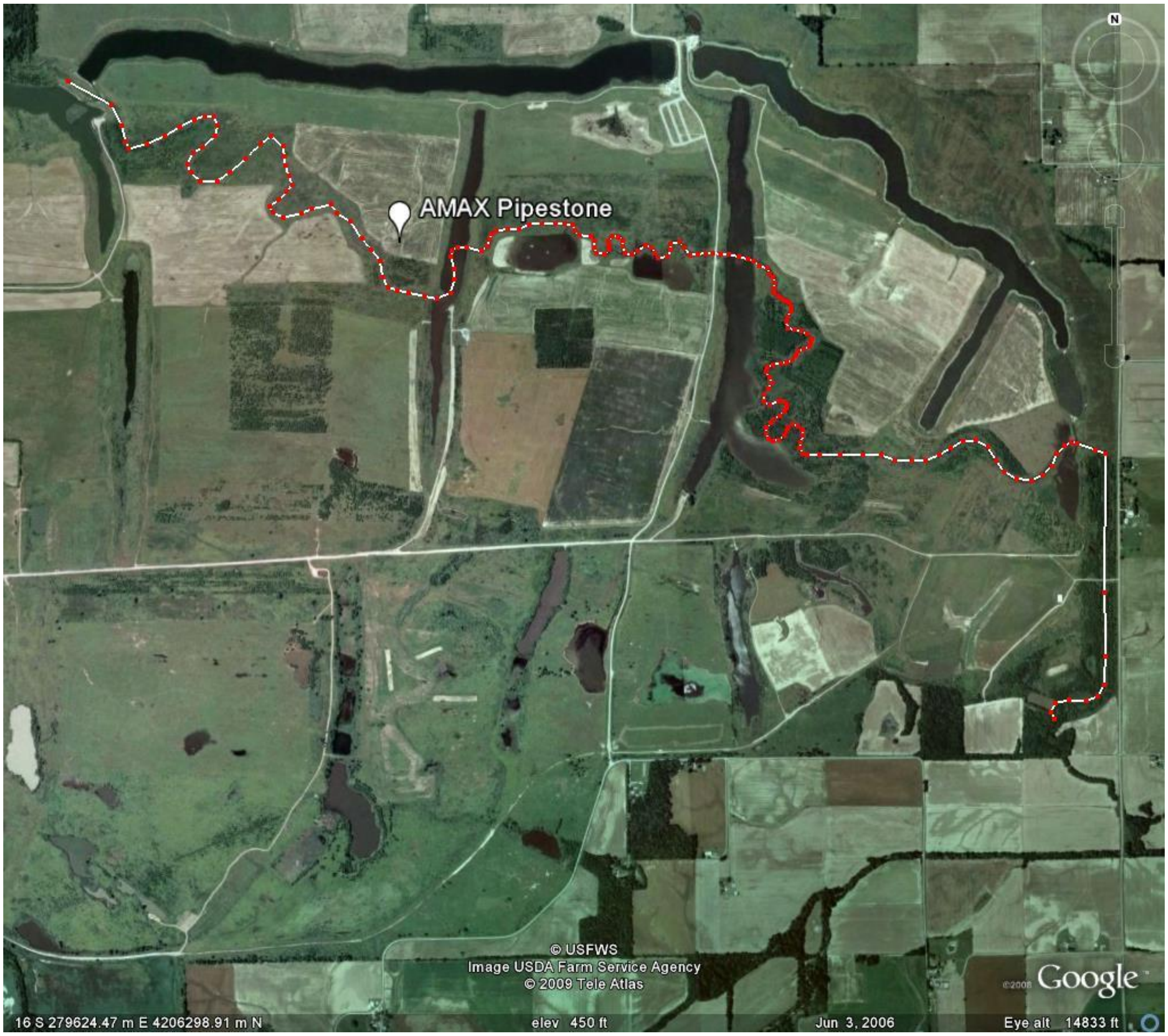


Figure 6. AMAX Leahy Mine. Pipestone Creek 4.6- mile meandering channel restoration relocated in approximate pre-mine riparian corridor.

Meander channel construction incorporated an average sinuosity (ratio of stream length (thalweg) to valley length)) of 1.45 within the 300 – 750 foot wide Pipestone Creek corridor. Stream restoration plans often identify the construction of a "stable" channel as a design feature. Ironically, channel stability conflicts with the true hydrogeomorphic definition of "meander" as a verb rather than a noun. If the restored stream is truly "restored", meandering of the channel within the floodplain should be expected to occur. A restored stream that meanders within its reclaimed floodplain is demonstrating the dynamic equilibrium that we expect to occur in natural streams. The lower reach of the Pipestone Creek restoration "meandered" within the floodplain, when storm flows rerouted the channel across the floodplain prior to reconnecting with an existing “meander” (Fig. 7). This natural abandonment of a constructed meander channel provides a desirable succession from a lotic to lentic stream channel environment that diversifies wetland habitats within a functionally restored floodplain.

Figure 7. Pipestone Creek restoration. Channel “meander” (dashed black line).

Similar to the CONSOL Galum Creek restoration, the restored Pipestone Creek channel was designed to enhance deep water habitat connectivity provided by 3 incline lake basins. During the construction (ca 1980 – 1990) of more than 24,200 feet of meander channel stream restoration segments within the active mining complex, the main channel of Pipestone Creek was rerouted through a 22,700–foot straight-line temporary diversion that was constructed around the northern and eastern perimeter of the active surface mine. When all segments of the permanent restoration channel were completed (fall 1991) Pipestone Creek was reconnected to the 4.6- mile restored channel; and, inactive reaches of the temporary diversion were backfilled and reclaimed. Backfill conversion of portions of the temporary diversion channel to palustrine emergent season wetlands provided habitat for Illinois threatened and unique species such as the rice rat (*Oryzomys palustris*) and least bittern (*Ixobrhychus exilis*).

Water quality and stream biota in the temporary diversion; and, eventually in the restoration channel were monitored semi-annually (spring and fall) by CWRL staff and the coal operator from 1983- 1995. Unique species of aquatic invertebrates and fish more commonly associated with clear and cool flowing streams were recorded during monitoring of the channel reaches immediately below the incline basin sampling points; and, in the clear water below the last restoration channel segment. Reductions of stream water turbidity values from 36 NTU (upstream) to 8 NTU (below incline basin) were noted in those reaches of Pipestone Creek in which brook silverside (*Labidesthes sicculus)* minnows and stonefly (Perlidae) larvae were sampled during the semi-annual monitoring program. The occurrence of aquatic species indicative of high quality streams in a relatively short time following stream restoration suggests that physical features of stream restoration practices associated with deep water reconnection can provide immediate in-stream habitat improvement prior to longer term plant community development in the adjacent riparian corridor.

The streams, floodplain forested habitats, emergent wetlands, and rowcrop reclamation associated with the Pipestone Creek restoration corridor can now be viewed, 20 years post-construction, by visitors to the 16,000-acre IDNR Pyramid State Park (Denmark Unit). The AMAX Pipestone Creek restoration demonstrates the success of the Illinois stream restoration / reclamation program.

## SUMMARY AND RECCOMMENDATIONS

The Illinois stream restorations completed in the 1980's -1990's can all provide valuable baseline data. These 16 miles of stream channel restoration represent a unique large scale reestablishment of stream communities and riparian corridors that can be used to assess future restoration success. Unfortunately, some of the early permits documenting the stream design and engineering details and data have been lost after bond has been released. Efforts are needed to recover and protect missing stream monitoring data, compile all existing data, and document site history and project locations. Fortunately, Illinois' regulatory and natural resource agencies as well as CWRL have been involved in some of the earliest stream restoration and stream diversion monitoring. Secure archival storage of these historic restoration files is essential.

Monitoring data and design information is still available for some sites. Former members (Doug Carney, Pat Malone, Randy Sauer) of the Illinois IDNR Stream Restoration monitoring program (now inactive) are now retrieving 20-25 year old stream sampling data to reestablish an archival stream restoration data set for Illinois.

Although regulations do not require long term monitoring, the 20 and 30 year- old Illinois stream restoration sites should be re-assessed through the OSM National Technology Transfer Team Applied Science Program to document the truly long term trends of stream restoration processes. A reassessment of these Illinois stream restorations that have undergone >20 years of hydrogeomorphic adjustment and biologic recovery can provide valuable insight into future stream habitat restoration practices.

The scope of the environmental challenges and engineering accomplishments of these previous stream restoration projects will probably never be repeated in the Midwest at this scale. Illinois' stream restorations represent living laboratories that should be preserved and protected. The regulations that required buffer zones during the restoration process should be strengthened to permanently protect the riparian corridor (both hydric and non-hydric plant communities) of restored streams, when feasible. Protecting these sites not only preserves and provides valuable habitat. Protection ensures that living benchmarks are available to stream ecologists and regulators. To facilitate future mining and environmentally responsible reclamation in the Midwest, regulators, engineers, coal operators, and scientists need stream restoration base-line data and long-term performance data to once again answer the invariable question ..."but can you restore the functions and values?........"

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