Indiana Department of Natural Resources
Division of Reclamation

Submits

# Indiana AML Site # 297
# Enoco Mine
# Knox County, Indiana

For the

## 2010 Abandoned Mine Land Reclamation Award


**Submitted By**

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**Project Information**

Construction Start: July 17, 2009
Construction Complete: November 13, 2009
Expended on: FY 2009
Construction Cost: $726,399.95

**Organizations Responsible for the Reclamation**

Indiana Department of Natural Resources
Division of Reclamation – Design / Project Management
Aigner Construction – Contractor
Knox County Soil and Water Conservation Board
Knox County Parks Board
Natural Resources Conservation Service

**Date Submitted**

April 16, 2010

**Introduction:** The State of Indiana has a rich legacy of both surface and underground coal mining, extending as far back as the late 1830's. In the early days, coal was mainly excavated from exposed (outcropped) coal seams along river banks and hillsides. As coal mining technology progressed, surface mining became the favored method of mining shallow coal seams. Thus, areas with shallow reserves of high quality coal such as Pike and Warrick Counties were heavily impacted by historic coal mining activities. The resulting impact of historic coal mining in some areas of Indiana was a decimated landscape with areas completely devoid of plant and animal life, dangerous sections of highwall, mine spoil seeping acidic water (pH < 3), and areas impacted heavily by metals contamination. An example of a region impacted by historic coal mining is Knox County, Indiana, located in the southwest portion of the state, along the Indiana – Illinois border.

"Since 1900, coal mining has played a significant role in the economic development of Knox County, especially near the towns of Bicknell, Bruceville, and Wheatland, Indiana. Records indicate coal mining to have taken place on very small scales prior to 1900; however, it was not until the 1920's that coal mining became widespread throughout the county. For many years, coal mining was contained primarily to underground mining within Knox County. This practice can be attributed to poorer quality seams of shallow coal and the availability of thick underground reserves. However, from the period of 1920-1930, more efficient methods of coal preparation became widespread, thus making surface mining of shallow coal seams profitable. After a brief slump in coal production from 1969 – 1973, coal mining in Knox county still plays a significant role today. [1]"

Despite the heavy and often undesirable consequences of historic coal mining in Indiana, the heavily altered landscapes have led to unique habitat for wildlife. For instance, Sugar Ridge Fish & Wildlife Area, located directly in the heart of Indiana's coal mining region, is property managed by the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife. Sugar Ridge Fish & Wildlife Area consists of six separate sections encompassing approximately 8,000 acres of mostly pre-Surface Mining Control and Reclamation Act of 1977 (SMCRA) mined land. Much of the area was leased from Amax Coal Company from 1964 to 1980. After this period, most of the land was donated to the Indiana Department of Natural Resources Division of Fish and Wildlife. Sugar Ridge is a great example that not all pre-SMCRA surface mining effects can be considered adverse; large spoil banks and approximately 100 final cut strip-pits have come to create a tremendous recreational destination for Indiana residents and visitors. The state endangered bobcat and river otter also make their home in the woods and waters of this property.

The primary intent and the focus of this award submittal is a former underground mine and coal processing area located south of the town of Bruceville in north central Knox County. The site is referred to as Indiana abandoned mine land (AML) Site# 297 Enoco. More specifically, it is the area formerly operated as Knox Consolidated #5 Mine (1942 – 1948) & Enoco Mine (1948 – 1962). The Enoco mine reclamation site is unique in the sense that AML reclamation activities and maintenance at this site have been conducted over a long period of time (from 1986 until present). The result is a project area allowing those within the AML

community to see former reclamation methods used successfully as well as those used with less success. It is reclamation activities conducted in 2009 at the Enoco project site that are being nominated for this award.

The primary intent of the 2009 reclamation project was to address a lingering issue regarding high volumes of Acid Mine Drainage (AMD) discharging from the site. In order to treat AMD originating from the site, the Indiana Division of Reclamation (IDoR) employed a "Sulfate Reducing Bioreactor" (SRB). A SRB system is a passive treatment system designed to convert AMD-producing sulfates to sulfides, which will then precipitate out of the solution and deposit in a settlement basin.

**Problem Areas:** The site is located in Knox County, Indiana, at the following topographic location: T. 4 N, R. 9 W, Donations 73 & 74. Topographic maps within Knox County, Indiana, are referenced using the term "donations" instead of "sections" as the area was settled and mapped by pre-Revolutionary War French colonists and not updated when the USGS topographic mapping system was created by the US government. The Enoco project site is located northeast of Vincennes and north of Fritchton, Indiana. It is important to note that reclamation at this project site was first conducted in the construction year 1986 and has periodically received funds to conduct maintenance projects over the last 24 years.

The problems located at the project site were the direct result of pre-SMCRA underground mining. As noted above, reclamation activities conducted under the Fiscal Year 2009 grant were considered maintenance of the original reclamation project. Prior to the most recent reclamation activities, IDoR conducted the following reclamation efforts at the site: reclaimed three open mine shafts, demolished mine buildings, and capped 100 acres of gob / coal slurry.

Several of the buildings associated with the former mine are still located on-site. It is the desire of the Knox County Parks Board to leave them in place as a historical representation of former mining operations. It is interesting to note that the local community has had a long standing interest in seeing this area reclaimed. While reviewing historical information contained within IDoR's files regarding the site, a January 16, 1973, letter was found expressing interest in reclaiming the area. The letter was prepared by members of the Knox County Park & Recreation Board and expressed interest in creating a "recreational reservoir" within the Smalls Creek Watershed. However, AMD originating from the Enoco mine complex made this goal impossible. Although IDoR had attempted to correct AMD originating from the site during the initial reclamation efforts, these attempts proved relatively unsuccessful.

In 1986, when reclamation efforts began at the site, the standard approach to reclamation called for grading of coal refuse, hauling and covering the refuse with soil material, and replanting vegetation in all disturbed areas. Effective AMD passive treatments were in their infancy and unrefined; treatment with sodium hydroxide ($NaOH^{+}$) was the best method available to treat AMD at the time.

The greatest challenge originally faced during the initial phase of reclamation was heavy sedimentation into Smalls Creek. The sediment washing into Smalls Creek originated from a dam constructed of coal refuse used to contain coal slurry onsite while the area operated as an active mine. The dam had breached, and the slurry was allowed to flow into Smalls Creek. In order to prevent sedimentation, IDoR engineers constructed a

1,200 ft. dam with a 3:1 slope along the northwest portion of the site to contain the slurry. During the initial phase of reclamation in 1986, two drains were placed within the dam to capture surface and ground water: a category #5 drop structure to capture surface runoff and a toe-drain at the base of the dam to capture groundwater. Though the reclamation efforts at the site have been mostly successful, AMD continued to be a persistent problem at the site. In 2004 IDoR conducted a maintenance reclamation project that involved installing drain tile to intercept a seep that had developed along the southwest corner of the previously reclaimed gob / coal slurry area. Over time however, the seep grew too large, overwhelmed the seep drain, and AMD ultimately began seeping into an unnamed tributary of Smalls Creek. Prior to reclamation activities in 2009, water quality results indicated that AMD originating from the site possessed water quality parameters of the following: ph – 2.90, Acidity- 12,610 mg/L, Alkalinity – Below Detection Limit (BDL), Aluminum – 71.10 mg/L, Iron – 4,224.37 mg/L, Manganese – 1.08 mg/L, Sulfate – 77 mg/L.

**Reclamation Objectives & Activities:** Reclamation at this project site has progressed for many years. The reclamation conducted in 2009 to establish a Sulfate Reducing Bioreactor (SRB) at the site to capture and treat AMD originating from the seep located along the southwest edge of the gob / coal slurry area is the specific project being submitted as the award nomination.

Once again, IDoR utilized a relatively new technology, called a Sulfate Reducing Bioreactor (SRB), to remediate AMD. In the past, IDoR has attempted many different approaches, such as the application of materials like sodium hydroxide ($NaOH^{+}$) and alkaline bottom ash (waste material from coal fired power plants), to eliminating AMD at reclamation project sites. A SRB is a system that relies on the metabolic activities of a certain genus of sulfate-reducing bacteria named *desulfovibrio sp.* SRB's capitalize on the ability of *desulfovibrio* bacteria to convert sulfates ($S0_4^{-2}$) that produce AMD into a sulfide ($S^{-2}$) ion. The conversion enables the sulfide ion to combine with metals dissolved in solution. The reaction concurrently allows for the production of bicarbonate ($HCO^{-3}$) in the process. This reaction allows the dissolved metals to precipitate out of solution as highly insoluble compounds while the concurrent generation of bicarbonate adds alkalinity, raising the pH of the acidic water.

SRB's are constructed within the existing flow path of the AMD. First, a drainage system consisting of Schedule 40 perforated pipe is placed at the base of a "bioreactor" cell. Next, an organic layer of compost to supply a carbon source to the bacteria is placed within the cell; the piping system is beneath the compost. AMD entering the system percolates downward through the composted material where the anaerobic sulfate reducing bacteria feed on the organic material, converting sulfates into sulfides in the process. Within the SRB treatment cell, the metals begin to precipitate out of solution before exiting the cell through the buried piping system as treated water.

The significance of SRB technology is that IDoR now has an inexpensive, highly effective, and ecologically beneficial method of treating AMD. The area required for an SRB is considerably less than that required for other passive treatment systems such as wetlands, vertical flow ponds, or anoxic limestone drains (ALD). Excavation efforts are limited to those needed to establish a suitable depth and grade for the system to function properly. The primary source of material used within the bioreactor is often unwanted cellulose based composted material (yard waste) collected from local municipalities.

The SRB complex located at the Enoco project site is approximately 7.9 acres in size and consists of 3 separate cells. The SRB bioreactor located at the project site begins with a 1.2 acre bioreactor cell where the process of treating AMD begins. The mixture of organic substrate utilized in the SRB cell consists of approximately 10,000 cu. yds. of the following components by weight: 10% agricultural lime, 10% compost, 50% coarse wood chips, and 30% straw. The AMD is channeled through the substrate and into a network of PVC pipes, where it is then discharged into a 1.0 acre "polishing" or oxidation pond, where precipitates drop out of solution.

The SRB system located at the Enoco project site represents an evolution in bioreactor technology based on IDoR's experience with these systems. In the summer of 2009, IDoR experienced a malfunction of a previously constructed bioreactor / ALD system located in Pike County, Indiana. After 5 years of successfully treating AMD, the system seemed to fail overnight, and AMD was once again flowing into the South Fork Patoka River. Fortunately, it was determined that the carbon source (organic substrate) had been consumed sooner than expected, and the addition of more organic substrate quickly remediated the problem. Upon further analysis of the situation, it also became the opinion of IDoR engineers that the construction of the bioreactor cell may not have allowed for a suitable retention period for the bacteria to convert the sulfates to sulfides. Armed with this knowledge, the bioreactor system at the Enoco project site was constructed to allow for a greater retention period.

The SRB located at the Enoco project site is designed to maximize the amount of time the AMD and the organic substrate have to interact with one another. Unlike a traditional SRB where AMD is collected in a feed pond and then channeled in to the bioreactor cell, AMD seepage at the Enoco site originating from the gob / coal slurry area is channeled directly into the bioreactor cell. Unlike a traditional bioreactor cell, which has a PVC network extended throughout the entire length of the cell, the piping system associated with the bioreactor cell at the Enoco project site is not extended throughout the cell. In other words, AMD must flow throughout the organic substrate (and is thus retained for a longer period) until it reaches a network of PVC piping (located near the northeast corner of the bioreactor cell) that carries the treated water to an oxidation pond, where sulfide precipitates will continue to drop out of solution.

It is also worth noting that in the future, IDoR will make the attempt to establish a permanent source of organic material within the bioreactor cell. It is the intention of IDoR to plant wetland species within the bioreactor. As the vegetation continue to grow, it is the hope that over time they will help to create a natural organic substrate. Should this practice ultimately be successful, it will reduce (or maybe even eliminate) the need to continually replace the organic substrate within the bioreactor as it is consumed by the sulfate reducing bacteria.

After the treated water exits the oxidation pond, it encounters a small wetland created by IDoR during the 2009 reclamation project. The purpose of the wetland is to further allow precipitates to drop out of solution prior to entering an unnamed tributary of Smalls Creek. The wetland is similar to the bioreactor cell in the sense that the construction of the wetland makes it conducive to the build-up of organic material. A series of "leaky-rock dams" were placed throughout this wetland cell. Over time, it is believed that organic material

circulating throughout the SRB system will “plug up” the pore spaces within the dams, thus flooding the wetland. This process will not only create a greater retention time for precipitates to drop out of solution but it will also establish a wetland habitat for local wildlife. The table below illustrates water quality data collected from the site:

| | pH | Acidity | Alkalinity | AL | Fe | Mn | $S0_4$ |
|---|---|---|---|---|---|---|---|
| **Pre-Reclamation Data:** | 2.90 | 12,610 | BDL | 71.10 | 4,224 | 1.08 | 77 |
| | pH | Acidity | Alkalinity | AL | Fe | Mn | $S0_4$ |
| **Post-Reclamation Data:** | 7.30 | 85 | 124 | 3.34 | 13.02 | 1.08 | 77 |

* Units included in table are reported as mg/L.
*** Post reclamation samples taken on 4/8/2010, approximately 3-4 months after bioreactor began treating water.
***Samples taken at sampling location 297A, location of treated water discharging into the unnamed tributary of Smalls Creek.

**On-site Difficulty of Project:** The greatest challenge encountered while constructing the SRB system was building the bioreactor on previously reclaimed gob. As noted above, one major objective of the 1986 reclamation project was to cover approximately 100 acres of gob and slurry. In order to intercept AMD originating from the drain tile and thus meet the objectives of the 2009 reclamation project, it was decided the SRB system would need to be placed within the previously reclaimed tailings area; however, installing the SRB system required disturbing buried gob.

As construction of the bioreactor cell began, thus exposing the gob to the surrounding environment, a large rain event occurred and flooded the bioreactor cell. IDoR took precautions such as building the SRB "backwards" (polishing wetland → oxidation pond → bioreactor cell) so no outlet existed (until project completion) that would allow a large flush of AMD into the Smalls Creek watershed. This practice proved worthwhile as the previously mentioned rain event could have caused a large discharge of AMD into the Smalls Creek watershed. Conditions within the rain flooded bioreactor cell showed pH levels drop below detection levels on a field pH meter (pH <1).

After the bioreactor cell was excavated to the required depth, the disturbed coal refuse was covered with a thin veneer (4-inches) of soil. The organic substrate was then placed over the top of the soil veneer, and the system was later activated. Thus far, no complications have arisen that would indicate the buried gob is causing any interference with the system.

**Benefits to the Community:** Reclamation of the former Enoco mine has long been sought by the local community for use as a public park. The Knox County Parks Board sought an EPA restoration grant as early as 1973 to remediate AMD originating from the site. After nearly 24 years, this long sought after dream may now become a reality. The 2009 reclamation project required IDOR to work closely with the Knox County Soil & Water Board in order to remediate the site. Their input allowed IDoR to design the SRB system in a manner that would meet the goals of both entities. This board continues to be very supportive of this project as evidenced by their statement::

"The reclamation project at the Enoco mine site is great for the people of Knox County for a couple of reasons. First, water quality in the properties ditches and in Smalls Creek will be greatly improved by the removal of the acid drainage problem. Smalls Creek has run red for a long time, and the stream will look much better as the iron is flushed from the system. Aquatic organisms will return to the affected parts of Smalls Creek, and wildlife will benefit as well.

Second, the project made some great improvements to the Enoco property. The wetlands will provide much needed wildlife habitat, the land will be more productive due to the lime and fertilizer applied, and the road makes the property accessible to the public and will enable them to enjoy the property.

The Knox County Parks and Recreation Department has many improvements in mind for the Enoco property, and the work done by DNR Reclamation has put those plans on a fast track.[2]"

**Exceeds the Spirit and Intent of SMCRA:** When SMCRA was originally drafted, it was in response to the disastrous legacy of the unencumbered environment in which surface and underground coal mining was allowed to operate. The Enoco Mine Reclamation Project is a prime example of the dramatic and often negative effects created by mining companies allowed to mine coal with little or no regulation. After over 30 years of implementation, time and science have worked together in numerous ways to help extend the act well beyond the original intent. For example, when SMCRA was originally drafted, who knew that an unintended consequence would be to show the power of a wetland to act as a natural "filter?"

As a result of SMCRA, time and technology have advanced to establish the use of a low cost, low maintenance, system to eliminate pollutants. The use of wetlands to improve water quality has also been recognized by other industries such as sanitation, water management, and other groups striving to improve water quality. Use of SRB wetland in such high profile projects as those associated AML reclamation allow people to gain a new appreciation for the viability of wetlands and encourage further research regarding their use as a remediation system.

## Works Cited:

[1] "Coal Mining in Knox County, Indiana" Special Report 54; Indiana University; Indiana Geological Survey, Denver Harper & Donald L. Eggert (pg.1)

[2] Hinkle, Troy, "RE: Enoco" e-mail from author, April 15, 2010

# Photo Captions

Attached are photographs showing portions of the site before and after reclamation:

- **Photo 1:** This photograph gives a general depiction of the site conditions prior to the 2009 reclamation activities. The grassy area in this photograph depicts the future location of the SRB cell. This photograph was taken from the top of the reconstructed dam.

- **Photo 2:** This photograph depicts AMD originating from the drain tile installed in 2004. AMD originating from this location impacted the Smalls Creek watershed degrading downstream water quality.

- **Photo 3:** This photograph depicts the bioreactor cell under construction. As noted above, the bioreactor was installed within the area originally reclaimed in 1986.

- **Photo 4:** This photograph depicts the future location of the bioreactor cell. This photograph is a good representation of the challenges faced by IDoR to build a successful treatment system on-top of previously reclaimed coal refuse.

- **Photo 5:** As indicated above, during construction of the bioreactor cell (and oxidation pond), a heavy rain event occurred. As the coal refuse noted in photo 4 was exposed to the open environment, AMD began to generate. This photograph depicts the oxidation pond flooded with pH < 1 AMD. The AMD seeped from the bioreactor (not pictured), which would be located to the left of the oxidation. The AMD was treated in-place (not discharged) using sodium hydroxide ($NaOH^+$).

- **Photo 6:** This final photograph is a picture illustrating the site nearly 5 months after the completion of reclamation. The water filled impoundment noted in this picture is the flooded bioreactor cell. To the right of the bioreactor cell is the primary oxidation pond. The polishing wetland, which discharges into the unnamed tributary of Smalls Creek can be noted in the upper left-hand side.