

[Mines, pits & quarries](#)

[View](#)

historical Flambeau Mine documents [exit DNR].

Metallic mining

- [Overview](#)
- [Permitting process](#)
- [Projects](#)
- [Reclaimed Flambeau mine](#)
- [Regulations and publications](#)

Related links

- [Ferrous \(iron\) mining](#)
- [Nonmetallic mining](#)
- [Recreational gold panning \[PDF\]](#)
- [Air permits](#)
- [Storm water runoff permits](#)
- [WPDES permits](#)

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Reclaimed Flambeau Mine

While there are other examples of successfully operated and reclaimed metallic mines in Wisconsin, the Flambeau Mine near Ladysmith in Rusk County is the only example of a metallic mine that was permitted, constructed, operated and reclaimed under the state's existing regulatory framework.

The open-pit, copper-gold mine began operations in July 1991, and reclamation activities were completed by the end of 1999. As specified in the Reclamation Plan and Mining Permit, the open-pit was backfilled. The backfilling process involved blending the stockpiled waste rock with a prescribed amount of limestone. Limestone, because of its neutralization capacity, was used to minimize the potential for the development of acid conditions prior to reflooding. Once reflooded, the threat of acidification was largely eliminated.

The DNR gained valuable experience in its review and oversight of the Flambeau Mine, and will continue to learn as monitoring of the reclaimed site continues for the next several decades.

- [View historical Flambeau Mine documents \[exit DNR\]](#)
- [History](#)
- [Project description](#)
- [Reclamation](#)
- [Monitoring](#)
- [Industrial outlot](#)

History

Project history

Late in 1968, based on favorable indications from an airborne geophysical survey, Great Lakes Exploration Company, a subsidiary of Kennecott Minerals Company, drilled the first exploration drillhole into the Flambeau deposit. During the next several years, more than 100 additional holes were drilled into the deposit, which helped define a copper-gold deposit that was nearly vertical and tabular shaped in size, approximately 50 feet wide, 2,400 feet long and extending to a depth of about 800 feet. The deposit contained more than 50 percent sulfide minerals, primarily pyrite (iron sulfide), with concentrations of the copper-bearing minerals chalcocite, bornite and chalcopyrite. In addition, the weathered upper portion of the deposit contained higher grades of copper and significant concentrations of gold.



An aerial view of the Flambeau Mine during active mining operations. The Flambeau River is located at the southwest corner of the photograph.

Beginning in 1974, Kennecott Minerals Company initiated the process to obtain a mining permit in accordance with the newly adopted Metallic Mining Reclamation Act. The project, as proposed in the mid-1970s, involved mining the ore body in two phases, an 11-year open pit phase followed

by an 11-year underground mining operation. The plan called for concentrating the ore on site with a tailings facility located two miles to the south of the ore body.

Upon completion of mining, the open pit would be allowed to fill with water and the remainder of the site would be revegetated. The company submitted an Environmental Impact Statement to the DNR and approved. During the final permit hearing in 1976, Rusk County officials indicated they would not grant zoning approvals due to various concerns regarding the mining project and the state's mining laws. From this indication, and due to the poor global economic conditions related to mining, the permitting process was terminated and Kennecott put the project on hold.

In 1986, Kennecott officials reevaluated the project and determined that a redesigned, scaled back project could be viable. Under the revised plan, only the enriched upper 225 feet of the deposit would be mined through a small open pit mining operation. Because of the high grade of this material, it was determined to be economically feasible to ship the ore to facilities in Canada for further concentration and smelting, thereby avoiding the need for construction of a tailings disposal facility. In addition, the company proposed to completely fill the pit with waste rock stored on the surface during the mining operation. Limestone would be blended with waste rock prior to backfilling.

Flambeau Mining Company, another subsidiary of Kennecott, restarted the permitting process for the project in 1987. After a three year process involving baseline data gathering, negotiations and project design and review, the DNR issued the Final Environmental Impact Statement for the project in 1990. A permit hearing was held amid a high level of public input and controversy. However, all permits were issued and construction at the project began in 1991. Ore shipments from the site began in 1993 and continued for more than four years. Backfilling of the pit took about 1.5 years and reclamation activities at the site were completed by the end of 1999.

Project description

Project description



Haul trucks removed ore from the Flambeau Mine.

The 181-acre mining site was located about one mile south of Ladysmith and bounded to the east by State Highway 27 and to the west by the Flambeau River. Prior to construction of the mining facility, the site consisted of active agricultural lands, old farm fields and forested areas. Several intermittent streams flowed through the site to the Flambeau River, and about eight acres of wetlands were located within the project boundary.

The Flambeau deposit existed at very shallow depth. Depth to bedrock at the mining site ranged from about 15 to 40 feet. Glacial sand, gravel and till overlaid Cambrian sandstone, which in turn sat above the weathered Precambrian metamorphic rocks containing the Flambeau deposit.

Mining of this shallow ore body was accomplished through a 35-acre open pit. The pit faced in a northeast-southwest direction and was 2,600 feet long, about 550 feet in width, and reached an ultimate depth of about 220 feet.

The first step in the mining process was to remove all topsoil from the mining site and place it into a stockpile for use during site reclamation. Hydric, or wetland, soils were also removed and stockpiled separately in a pond while being kept saturated before use during wetland restoration. Glacial overburden, sandstone and weathered bedrock were then stripped from the pit area using scrapers and other excavating equipment.

Material was hauled out of the pit using 55-ton trucks and deposited in appropriate stockpiles. Once bedrock was reached, operators drilled and blasted the ore and waste rock prior to hauling. Ore was crushed on-site and shipped by rail to facilities in Canada for concentrating and smelting. The open pit mine operated two ten-hour shifts per day, five days per week. Material was removed at a rate of about 6,500 tons per day.

Over the course of the mining operation, about 1.9 million tons of ore containing about 9.5 percent copper and 0.175 ounces of gold per ton were mined and shipped from the site. The mine produced approximately 181,000 tons of marketable copper, 334,000 ounces of gold, and 3.3 million ounces of silver.

Material removed from the pit was directed to one of several stockpiles on the site. A separate stockpile was created for the glacial overburden, sandstone, weathered bedrock and low-sulfur waste rock containing less than 1 percent sulfur. These materials were stored in an unlined 40-acre facility just north of the open pit. High-sulfur waste rock and other material containing greater than 1 percent sulfur, which was capable of generating acid drainage, was stored on a lined 27-acre stockpile area south of the pit. The high-sulfur stockpile was underlain with a plastic membrane liner and leachate collection system to prevent migration of potentially contaminated water from entering the groundwater system.

Groundwater flowing into the open pit was collected in sumps and pumped to holding ponds on the surface. Runoff from the ore stockpile/crusher area and waste rock piles as well as leachate from the high-sulfur waste rock storage facility was also directed to the same holding ponds. This water was then transported to a wastewater treatment facility and ultimately discharged to the Flambeau River upon meeting DNR state permit limits. The water treatment facility used lime neutralization, sulfide precipitation and filtration as the main treatment technologies. Over the life of the mining operation, discharge from the treatment facility averaged about 300 gallons per minute.

During the active mining period, Kennecott employed approximately 70 employees, most of whom were from the Rusk County area.

Reclamation

Mine reclamation



View, looking southwest, of the Flambeau Mine during operations.

The approved Reclamation Plan for the Flambeau Project specified that the open-pit, upon completion of mining, would be completely backfilled with original rock material that was separated from the ore. Reclamation of the pit began in early 1997 and was completed in late 1998.

In accordance with the reclamation plan, stockpiled materials were backfilled according to their pre-mining position. High-sulfur waste rock was blended with a prescribed amount of limestone and placed into the pit first. The limestone served as a buffering materials, and waste rock was sampled and tested prior to its removal from the stockpiles to determine the appropriate amount of limestone needed for neutralization of actual acidity and potential acidity in the backfilled pit.

Once the crushed limestone was added, the material was hauled to the pit and backfill then placed in the pit and compacted. The high-sulfur waste rock was overlain by low-sulfur waste rock, weathered bedrock, sandstone and glacial till. The site was graded to the approximate pre-mining condition and provide for adequate surface drainage. Topsoil was reapplied to the site and revegetation and wetland restoration efforts began.

The post-mining land use for the site was light recreation and wildlife habitat. To achieve that goal, the Reclamation Plan envisioned creation diverse habitats on the site by reestablishing forested areas, various native grasslands and wetlands. The majority of revegetation activities at the site took place in 1998 and 1999. Grassland areas were seeded with a mixture of cover crop, native grasses and wildflowers. In addition, seeding in upland areas was supplemented with transplanting of live plant materials.



View, looking southwest, of the reclaimed Flambeau Mine.

More than 7,000 plugs of wild strawberries, wild geranium, columbine and woodland sunflowers were planted in various upland areas. Woodland areas were planted with more than 2,500 tree and shrub seedlings and about 300 larger trees were transplanted from the on-site nursery. An 8.5-acre wetland area was constructed using wetland soils that were salvaged and stockpiled during site construction. During reclamation, this wetland was planted with more than 10,000 plants and bare rootstock of typical wetland species. Drainageways and biofilters were also planted with more than 17,000 live stakes of alder, willow and dogwood species.

In all, more than 170 different species of plants were seeded or installed on the mining site during the reclamation phase. The Flambeau Mining Company also installed a trail system through the reclaimed site, which is now available for public use.

In 1998, the approved Reclamation Plan was modified to allow the plant site and a portion of the reclaimed high-sulfur waste rock stockpile area to be designated for an alternate land use. The Ladysmith Community Industrial Development Corporation approached the mining company and requested that certain buildings and the rail spur be left in place for use by another business.

Monitoring

Environmental monitoring



Monitoring compliance with mine permit conditions required frequent on-site visits.

Throughout the life of the Flambeau Mine, an extensive environmental monitoring program was conducted to ascertain the extent of environmental impacts from the project and to determine if the project was complying with all applicable statutory, rule and permit requirements. As specified in various permits, the Flambeau Mining Company was required to regularly monitor a number of groundwater factors, including groundwater levels, groundwater quality, air quality, surface water quality, wastewater effluent quality and flow, mine inflow, wetlands, aquatic ecology, stockpile leachate quality and meteorology (see "Groundwater monitoring" section below).

During active mining operations, monitoring was conducted and the results were submitted to the DNR and local governments. In addition, as part of its inspection/surveillance program, the DNR conducted periodic independent sampling to verify the results obtained by the company. Groundwater monitoring will continue at the site for several decades to measure conditions within and around the backfilled pit.

Throughout the life of the project, the company has remained in substantial compliance with all permit conditions and applicable standards. Air monitoring indicated several exceedances of suspended particulate limits, only one of which was attributed to activities on the mining site: dust from a delivery of an uncovered load of crushed limestone. There were no exceedances of any effluent (treated wastewater) limits during the period of discharge. Monitoring of water quality and other characteristics in the Flambeau River similarly did not show any impacts from the effluent discharge. Anomalous results from some bioassay tests were reported, but in each case the company responded promptly and appropriately.

Groundwater monitoring

Monitoring results have indicated that groundwater levels have nearly returned to pre-mining conditions. Minor differences in groundwater elevations within the backfilled pit were expected because of the nature of the waste rock that was backfilled, as compared to the surrounding bedrock that was left in place.

On a volume per volume basis, the majority of the water is flowing through the till and very little water is moving through the bedrock and backfill material. Resaturation of the waste rock by groundwater infiltration is the primary mechanism by which oxidation of the remaining sulfides will be controlled and the long-term environmental stability of the backfilled materials will be achieved. This is important to reduce or eliminate potential for generation of acid drainage, which is a significant concern at many mining sites worldwide.



Groundwater monitoring wells at the Flambeau mine. Water quality within the backfilled pit will continue to be monitored in order to assess potential impacts to the Flambeau River.

The first few rounds of well samples collected in 1999 indicated that elevated levels of sulfate, copper, manganese and iron were present. These results were not a surprise and were approximately equal to or slightly greater than the concentrations originally predicted. Long-term trend analysis of data collected from 1999 to 2012 on in-pit wells suggested two wells had increasing trends in copper (MW-1013B) and iron (MW-1013C), but stable or decreasing trends dominated elsewhere within the pit wells. It is difficult to make any long-term predictions of how the site will perform, but analyses to date indicates there is no acid production in the pit (porewater is saturated with respect to calcite and gypsum), groundwater elevations have generally stabilized since recovering in 2003, and metals concentrations in the in-pit water are not at levels that pose a threat to water quality in the Flambeau River.;

In addition to the wells located within the backfilled pit, groundwater samples are collected quarterly at wells surrounding the backfilled pit. Some of these wells recorded sharp increases in concentrations of copper, sulfate and/or manganese since mine pumping stopped in 1997. However, recent data suggest levels for these parameters have steadily decreased since the wells have fully recovered. Wells MW-1000R and MW-1004 have only recently recovered (2010) enough to allow for recovery of groundwater samples due to persistent drought conditions since the mine's closure.

The DNR will continue monitoring conditions at the reclaimed Flambeau Mine for many years. Monitoring results will be compared to predictive analyses and modeling, and if substantial differences are observed to the extent that they may not comply with the permit conditions and applicable regulations, the company would be required to take action to prevent adverse impacts.

Vegetation monitoring

Results of vegetation monitoring conducted on the site from 1999 through 2002 indicate that the site is performing quite well. The site is stabilized, native species of vegetation are starting to thrive and survival of the woody vegetation is greater than 80 percent. Two deer exclosure areas (fences) have been temporarily established to protect woodland areas from grazing impacts. These preventative measures will allow DNR staff to monitor woodland species survival and provide a basis for comparison with grazed areas. Grassland areas on the site are subjected to periodic controlled burns to further enhance native vegetation.

Based on this reclamation success, Flambeau Mining Company (FMC) asked the DNR to concur with its assessment that reclamation had progressed enough to warrant a notice of completion (NOC) for the reclaimed Flambeau Mine. The DNR concurred with the NOC in March 2002 and set Nov. 1,

2001, as the effective date of the NOC.

On Jan. 7, 2007,, FMC petitioned the DNR for a Certificate of Completion (COC) for the Flambeau Mine site. After the DNR determined the site was still in compliance with the standards specified in the reclamation plan and mining permit and a contested case hearing, FMC was issued a COC for the 149-acre portion of the mine site that contains the in-filled pit. As the result of a stipulated agreement between the parties at the hearing, the COC does not include the 32-acre Industrial Outlot that formerly contained the mine administration buildings, wastewater treatment plant, ore loading areas and a portion of the Type II Stockpile. Based on this decision, the in-filled mine pit has been transitioned into the 40-year long-term care period. Under current law, FMC is responsible for the maintenance of the site in perpetuity.

Industrial outlot

Industrial outlot

On July 30, 1998, the DNR granted the Flambeau Mining Company (FMC) a modification of its mining permit to split the site into the main, 149-acre mine site and a 32-acre Industrial Outlot to preserve the mine operations buildings for future industrial development. The Industrial Outlot formerly held FMC's administration building, the wastewater treatment plant, the ore loading area and rail spur as well as a portion of the Type II waste rock stockpile. The Outlot currently houses the DNR's Ladysmith Service Center and Xcel Energy's power line maintenance shop.

Remedial actions and Stream C

Since the mine's closure, regular monitoring and site inspections by FMC revealed that portions of the Industrial Outlot and an associated 0.9-acre biofilter (used to collect surface water runoff from the Outlot) had elevated levels of copper. The company has taken remedial actions in accordance with the contingency plans in the mining permit to correct the problems, including removing gravel and placing clean backfill in the old rail corridor and over the former ore loading area. Much of the area that was determined to have elevated copper levels due to accidental spillage of ore and dust during site operations has also been covered with an asphalt parking lot.

It appears that these clean-up efforts have been successful in removing soils with the highest elevated copper levels in the Industrial Outlot with the exception of sediment within the biofilter. To address the biofilter sediment, FMC submitted a work plan on May 17, 2011, to address removal of the sediment and a reconfiguration of the storm water management. The plan was approved after a public hearing under Chapter 30, Wis. Stats., and implementation of the plan is scheduled for spring 2012.

To track the effectiveness of remedial actions, FMC committed to additional surface water and sediment sampling of the biofilter to better characterize discharge into a nearby intermittent waterway known as Stream C. In the Industrial Outlot, Stream C is dry most of the year but has been determined to be partially navigable during wet periods. It eventually discharges into the Flambeau River. Environmental sampling by FMC indicates there are elevated (compared to nearby streams) levels of copper in Stream C water and sediments. Unfortunately, no background sampling was performed on this waterway prior to mining activity, so it is difficult to tell if these levels are due to naturally occurring circumstances, mining or other human influences.

Department water resources staff are evaluating Stream C to determine whether aquatic resources have been impaired, in accordance with the federal Clean Water Act.

Related documents

- [Copper Park Business and Recreation Area work plan approval \[PDF\]](#)
- [Copper Park Business and Recreation Area work plan addendum \[PDF\]](#)
- [Copper Park Business and Recreation Area map \[PDF\]](#)
- [Chapter 30 permit \[PDF\]](#)

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