CHAPTER I
HYDROLOGIC IMPACTS OF MINING

Coal mining and reclamation operations alter the equilibrium of ground- and surface-water flow systems. The type and degree of hydrologic impacts vary with the size of the operation, the method of mining, and the manner in which the site is reclaimed. For example, a small contour surface mine would have different impacts on the hydrologic system than would a large longwall underground mine. Also, on a mine-specific basis, impacts will differ during the various stages of mining and reclamation. Therefore, the proposed mining method and type of reclamation must be taken into consideration when developing plans for the collection of baseline data. The following is a brief general discussion of different types of mining and mining-related activities and typical impacts. This discussion is included for reference.

A. Surface Coal Mining Operations

Surface coal mining operations break up the overlying rocks (overburden) to remove the coal. The reclaimed spoil (e.g., fragmented overburden) will have higher ground-water storage capacity and higher transmissive properties than in the original rock. These differences will alter ground-water flow in the reclaimed spoil and may affect neighboring aquifers that are hydraulically connected to the disturbed zone. As defined by the Federal regulations, *aquifer* means a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use. Removal of water from the mine pit during mining may, at least temporarily, reduce the amount of water available to both up- and down-gradient wells in the immediate vicinity of the pit.

The breaking and crushing of overburden rock in the surface mining process creates an abundance of fresh, rock surfaces. These freshly broken rock surfaces may impart high levels of total dissolved solids impart to percolating water. The oxidation and hydrolysis of minerals in the spoil material could result in the production of acid or toxic drainage containing elevated concentrations of metals and sulfate. The quality of underlying or down-gradient aquifers can be affected by recharge to the ground-water system infiltrating improperly handled or amended spoil. Spoil-water discharges and seeps that develop in backfill areas can also pollute surface-water bodies.

Surface mining alters basic watershed characteristics such as area, slope and vegetative cover resulting in changes to runoff and infiltration. Stream-flow characteristics, especially during critical periods such as peak flow, can be affected by alterations in channel geometry or gradient, changes in the composition of channel material or the amount of water contributed by impoundments. During mining the open pit, spoil banks and sediment ponds tend to detain runoff. This usually lowers the peak flow of streams. However, the removal of vegetation, the construction of roads and the removal of ponds can increase the peak flows of streams.

The surface mining method itself also influences impacts. The effects on ambient hydrologic conditions of particular types of surface mining are discussed below.

The **area mining** method is commonly used to mine coal in flat to moderately rolling terrain. In this mining method, the overburden is excavated down to the coal seam and the mining area is enlarged horizontally to expose and remove the coal. These mines are usually large and operate for many years.

Area mines often occur in close proximity to streams, ponds, lakes and other surface-water bodies. Streams are sometimes relocated, either temporarily or permanently, as a result of the surface coal mining activity. When a large area is disturbed, surface-water courses must be re-routed or otherwise disturbed, and some surface-water flow changes will occur. The magnitude of the effect upon the surface-water system in large part is a function of the size of the mine and, hence, the amount of disturbed area created with different hydraulic properties.

Area surface mines can impact the underlying ground-water system. The effect will be most distinctly observed in shallow, unconfined aquifers that are directly recharged by infiltration from the surface. Subtle changes in the hydraulic characteristics of the surficial material can result in either more, or less, water reaching these aquifers. While operations conducted in compliance with existing mining regulations are required to minimize hydrologic impacts and to restore approximate pre-mining recharge capacity, large area mines could impose a moderate impact on underlying aquifers. The degree of impact to ground-water will be a function of the size of the disturbed area, the depth of coal seam, the local hydrogeology, and the nature of the backfill material.

The **contour mining** method is typically used in the mountainous terrain of the eastern U.S. where coal seams are exposed in outcrops on hillsides and mountainsides. The mining operation usually consists of one or two cuts that start at a coal outcrop and follow that outcrop along the hillside. These mines occupy a little more area on the hillside than the coal itself, and disturb a small area relative to the surrounding undisturbed area.

Although contour mines occupy narrow bands that are small relative to the surrounding undisturbed areas, impacts to the shallow ground-water system can be large through interception of the local stress-relief fracture system. This is because the stress-relief fracture system tends to extend 100 feet beneath the ground surface. Shallow wells located immediately down-slope from the mined area are often completed in this fracture system. Other potential hydrologic impacts are increased sediment load, principally during the active mining phase, and chemical contamination, principally from acid-or toxic-forming materials, both during mining (short term) and after reclamation (long term).

The **block-cut mining** method incorporates contour mining and area mining and is used predominantly in the eastern and midwestern states. Large cuts are made along the contour and all spoil material is hauled back to the previous cut. Impacts tend to be larger than contour mining because block-cut mining disturbs larger areas or blocks and material from the initial box cut must be stored until the end of mining.

Mining in the mountains generally refers to three types of mining operations: (1) mountaintop removal mining operations in which all or a large portion of a coal seam or seams running through the upper fraction of a mountain or ridge are removed and the land is reclaimed to support the approved postmining land use requirements with a variance from approximate original contour (AOC); (2) multiple seam mining in which all or a large portion of the coal seams running through the upper fraction of a mountain or ridge are removed and the land is reclaimed to AOC; and (3) steep slope mining in which the surface mining occurs in areas having topography with natural slopes greater than 20 degrees and the land is reclaimed with or without an AOC variance. The spoil that is not returned to the mined area for any of these three mining activities is placed in fills in adjoining valleys.

Mining in the mountains can impact surface water by altering peak and baseflow characteristics resulting from changes in both topography and drainage patterns, and it can alter the chemical content of the baseflow contribution. Peak flows during mining (worst case when revegetated steep slopes are bare) typically are higher than ambient conditions at the toe of the valley fills; but the flow is usually attenuated through the use of sediment structures downstream. Peak flows after mining and reclamation are typically less because the gentle slopes and higher infiltration rates contribute to reduced surface runoff. Reduced runoff rates in turn decrease peak flows. This also translates into higher baseflow rates as a result of the increased ground-water discharge from the backfilled areas and valley fills. In fact, the increases in baseflow may preserve streams that might otherwise dry up completely during the low flow season. The higher baseflow rates of the more mineralized ground water (higher dissolved solids, sulfates, metals) change the chemistry of the stream. Increases in suspended solids may also occur.

Mining in the mountains can impact ground water by altering recharge characteristics and flow patterns. In steep slope areas, ground water is typically conveyed through stress-relief fracture systems from ridge tops to valley bottoms. Mining in the recharge area of these fracture systems could result in less water available in the stress-relief systems at the base of the ridgeduring active mining. The recharge is re-directed into the mine backfills and valley fills where it may discharge and sustain surface-water flow during dry weather conditions. Water quality is highly variable depending on the geochemical characteristics of the overburden. Movement of water from these spoil systems into underlying water-bearing zones can cause increases in sulfates, metals and total dissolved solids.

B. Underground Coal Mining Operations

The process of underground coal mining results in the removal of coal under broad areas. The most common impact associated with underground mining is subsidence. The potential for subsidence depends on the thickness of the coal seams mined, the geometry of the mine, the thickness and strength characteristics of the overlying strata, the mining method and the percent of coal extracted.

Subsidence can alter the hydrologic balance and affect both ground- and surface-water flow. If subsidence cracks extend to the surface, surface flow can be diverted into underground mine workings, surface flow paths can be rerouted and ground-water recharge capacity may be increased. Depending on integrity of the coal barriers between mines, there can be a direct hydrologic interconnection between adjacent mines. However, recently and actively operating mines better maintain coal barrier integrity, which greatly impedes ground-water movement between adjacent mines. Subsidence potholes and the general lowering of the ground surface may also change the normal drainage pattern causing local surface flooding. It is important to note that the area of hydrologic impacts can extend beyond the subsided area.

Fracturing of rock strata can also affect the ground-water hydrologic system. If the confining strata below an aquifer fractures, this could cause the aquifer to drain and its potentiometric surface to drop. As a result, wells could go dry and springs fed by ground-water discharge could be reduced or dry up entirely. Fractures created in the rock strata may also result in intermixing of poor quality ground water with potable ground water.

Underground mining may cause ground- and surface-water contamination. Surface water can be degraded by discharges from subsurface workings containing water with acid or toxic characteristics and elevated concentrations of metals and sulfate. Flow of degraded surface water to the ground-water system from fractures extending to the surface can result in increased mineralization of ground water. Underground mining may dewater overlying water-bearing zones and impacts may extend beyond the local surface-water drainage divide. This can result in interbasin transfer of water and gaining or losing streams. Also, pumpage of excess water from active workings can contribute to stream channel erosion and an increase in suspended solids.

After mining, the mine workings can flood and raise the water table. Effects vary with topographic location. Below-drainage mines flood completely; above-drainage mines may only flood partially. Above-drainage mines can also have outcrop barrier seepage and may be susceptible to blowouts. Methane and other gases such as hydrogen sulfide and carbon monoxide can migrate into wells from below-drainage underground mines leading to serious problems. Partially flooded workings may allow the circulation of air which induces the production of acid mine drainage.

The method of underground mining can also influence impacts. The two major underground mining methods are room and pillar and longwall. The permit area for underground mines can include either the face-up area (the area where the initial development of the mine and mine entry takes place) and in some cases the shadow area (the area overlying the coal seam or seams that will be extracted). In either case, baseline data collection must reflect the existing ground and surface-water resources and the impact that the proposed mining can have on the hydrology and existing water use.

Room and pillar mining in its basic form consists of driving entries, rooms and crosscuts into the coal seam to extract coal. Pillars of coal are left to support the overburden or for haulage and ventilation. This procedure is called "development" mining. To increase extraction of coal where the conditions allow, development mining is followed by "pillar recovery" or "retreat mining"where the pillars are systematically extracted in part or completely.

The principal hydrologic impacts associated with room and pillar mining would be the interception of fractures and the effects of subsidence on overlying water-bearing zones. Both ground- and surface-water systems could be affected from change in recharge capacity and mixing of surface and ground water. The magnitude of the impacts depend on extraction ratio, depth of cover, overburden characteristics and areal extent of mining. Subsidence impacts from room and pillar mining, even without pillar recovery, can occur for years after mining has ceased.

Longwall mining is a high-extraction mining method that maximizes the recovery of coal resources. The coal is systematically removed in parallel panels ranging in size from 500-1,200 feet wide to 4,000 to 15,000 feet in length. The mine roof above the extracted coal collapses and subsidence occurs. As the overburden continues to collapse, effects of subsidence progress above the areas where coal is extracted. Ninety percent of the surface subsidence caused by longwall mining occurs within 4 to 6 weeks of coal extraction.

The hydrologic impacts to surface water during longwall mining may include loss of surface water because of leakage through fractures created by subsidence that intersect the stream channels and changes in drainage patterns due to ground settlement. These changes may be of short or long duration. In other areas, water pumped from the underground mine workings during mining can increase surface-water flow. Fractures resulting from subsidence may also allow ground water from overlying aquifers or surface water to leak into the mine workings.

The hydrologic impacts to ground water may include dewatering of local aquifers caused by pumping from the mine and a resulting cone of depression. Longwall mining may also suppress water tables by disrupting confining layers beneath aquifer zones or by increasing the transmissive properties of water-bearing units from new fractures and enlarged preexisting fractures caused by subsidence.

As in room and pillar mining, the magnitude of the hydrologic impacts depends on extraction ratio, depth of cover, overburden characteristics and areal extent of mining. Because of the higher extraction ratio and removal of large continuous panels, longwall mining can result in extensive subsurface fracturing of rock strata which can alter and/or hydraulically connect aquifers.

C. Special Categories of Mining/Mining-Related Activities

Special categories of mining and some mining-related activities can have hydrologic impacts that need to be evaluated and addressed as part of the permitting process. Appropriate planning and continued maintenance are necessary in order to minimize the impacts from these activities.

Steep slope mining is surface coal mining operations on pre-mining slopes greater than 20 degrees. Under specific circumstances the regulatory authority may issue a permit for steep slope mining which includes a variance from the requirement to restore disturbed lands to their approximate original contour (See permanent program regulations at 785.15 and 785.16). The hydrologic impacts of steep slope surface coal mines are similar to those of mountaintop removal and multiple-seam contour mining.

Augering is considered to be a special category of surface mining and is used when the overburden gets too thick to be removed economically. Large-diameter, evenly-spaced holes are horizontally drilled from the highwall up to 400 feet into the coal bed by an auger. The auger head breaks up the coal and brings it to the outcrop face. The major hydrologic impact from augering can result from improperly sealed auger holes discharging water containing acid-or toxic-forming material. Also, improperly sealed auger holes can act as zones of rapid ground-water movement and thus dewater the surrounding area or adjacent flooded underground mines.

Highwall mining is a variation of auger mining that allows for the complete removal of the coal seam along the face. As a result, impacts are greater and more widespread than augering.

In situ processing activities are activities conducted in connection with in-place distillation, retorting, leaching or other physical or chemical processing of coal and includes such operations as in situ gasification, slurry mining and borehole mining. In situ processing uses some type of borehole or well. Hydrologic impacts can result from: discharge of process recovery fluids from the open-hole portion of the borehole or annular space between the wall of the borehole and the casing into geologic zones or intervals. Process recovery fluid must be prevented from moving vertically into overlying and underlying aquifers and horizontally beyond the area identified in the permit.

Remining means conducting surface coal mining and reclamation operations which affect previously mined lands (i.e., lands affected prior to August 3, 1977, and not reclaimed to SMCRA standards). With modern mining technologies, many previously mined areas can yield additional coal through remining or, in some cases, during reclamation of abandoned mine sites. Sites that lend themselves to remining include: coal refuse piles, abandoned underground mining operations, abandoned highwalls and subsidence areas. Many remining sites contain environmental problems such as AMD discharges or excessive sediment discharge to streams. While most mining activities create some hydrologic impacts, remining has a high potential to improve ambient environmental conditions.

Roads are key to both surface mining and underground mining operations. They are classified according to use as either primary or ancillary. The design and construction, location, maintenance and reclamation of roads can have hydrologic impacts that need to be evaluated and addressed. Poorly designed or maintained access and haul roads can affect surface water as the result of increased erosion and sediment load to streams. Improperly located roads can increase the possibility of downstream flooding. Haulroads across mine spoil can cause linear areas of highly compacted and less transmissive material. This in turn can impact ground-water flow patterns and the final water table adjacent to the roads.

Support facilities, such as tipples, refuse piles and processing plants can have unique effects on the ground and surface water. Coal and coal-waste products may have significant quantities of acid or toxic material that can create water quality problems. Erosion of coal and refuse piles is a concern also. Appropriate planning and continued maintenance are necessary in order to minimize impacts.

D. Coal Exploration

Coal exploration involves field gathering of coal and overburden quality and quantity data or environmental data in order to establish conditions prior to mining. Exploration operations that substantially disturb the surface can result in a range of hydrologic impacts similar to those identified for surface mines. However, most exploration operations are typically smaller in size, of shorter duration and can be more readily designed and modified to avoid or minimize impacts. As a consequence, coal exploration operations would have lower overall impacts on hydrologic systems than those expected from surface mines.