15

Ground Water Flow Systems in Idaho's Western Phosphate Field

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ABSTRACT

Complex ground water flow systems and hydraulically connected surface water systems occur within the southeastern Idaho phosphate field. Factors such as the geologic, topographic, hydrogeologic, chemical, and climatic characteristics of the area largely control the occurrence, movement and quality of water in these flow systems through alteration of existing characteristics. At certain mine sites the water resource systems have the potential to interfere with mining operations through mine pit flooding and through pit and waste dump stability problems. Potential hydrogeologic impacts from mining and potential hydrologic limitations to mining are often difficult to predict because of the many variables involved.

Hydrogeologic studies in the southeastern Idaho phosphate field show that there are definite relationships between geologic, topographic, hydrogeologic, and climatic factors and existing ground water flow systems. The ore-bearing Phosphoria Formation effectively separates ground water flow in the Thaynes and Dinwoody formations from the underlying Wells Formation. Considerable ground water discharge occurs from the lower member of the Dinwoody Formation. Stream flow is commonly lost into the upper member of the Wells Formation. Analysis of existing mine sites shows that relationships exist between the water resource systems which occur at a mine site and the potential hydrologic impacts from mining. Hydrologic limitations to mining are also related to the water resource systems which occur at the mine site.

Ground water flow system theory and observed water resource systems relationships were used to develop conceptual models that identify water resource systems at mine sites and evaluate mine sites for potential hydrologic impacts and mining limitations. The conceptual models can be used to interpret flow systems at existing or proposed mine sites. Such analyses will facilitate environmental management with minimum costs to industry and also provide important inputs for mine management. The models yield highly reliable results when used as specified.

INTRODUCTION

Statement of the Problem

Southeastern Idaho encompasses a large portion of the western phosphate field. The Idaho phosphate deposits contain about 80 percent of the ore reserves of the western phosphate field, or about 35 percent of the United States reserves (U. S. Department of the Interior, U. S. Department of Agriculture, 1977). Phosphate ore is mined by open-pit methods along outcrops of the Meade Peak member of the Phosphoria Formation, where it has been exposed through folding, faulting, and erosion (Fig. 1).

Water resources within the phosphate field exist in complex ground water and surface water flow systems. These

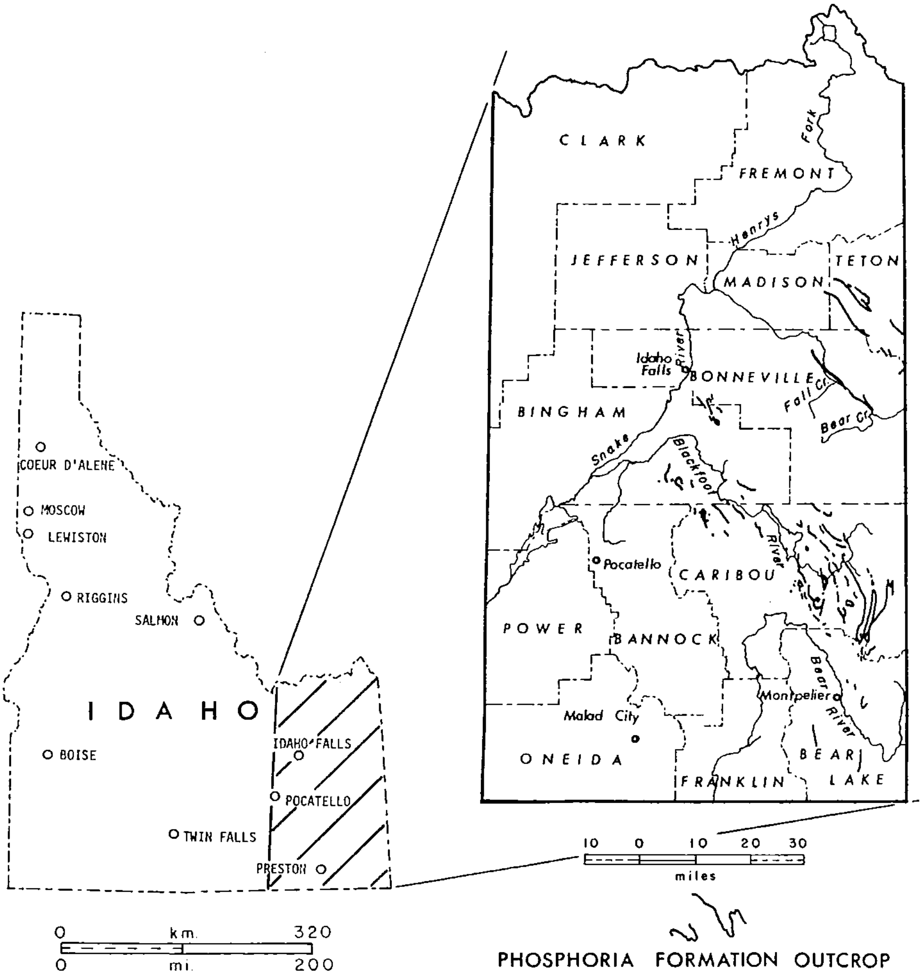


Figure 1. Location of Phosphoria Formation outcrops in the southeastern Idaho phosphate field (after Ralston, et al., 1977).

complex water resource systems have developed over geologic time, through the interaction of many environmental factors. Factors such as the geologic, topographic, hydrogeologic, chemical, and climatic characteristics of the area influence the occurrence, movement, and quality of the water resource systems.

Mining activities within the phosphate field alter the existing environmental characteristics and therefore will, or have the potential to, impact the water resource systems. The water resource systems also have the potential to hamper mining operations in certain areas through pit flooding and through pit and waste dump stability problems.

An expected future increase in mining activities increases the potential for impacts of the water resource systems. It is evident that a thorough understanding of the many interrelated factors which control the water resource systems is necessary before potential mining impacts can be predicted and assessed. A definite need exists for a systematic method of identifying water resource systems at mine sites and evaluating mine sites for potential hydrologic impacts. Accurate identification of water resource systems allows more efficient environmental management with less cost to industry. It also provides important inputs for mine management.

Purpose

The purpose of this paper is to present conceptual models of water resource systems of the southeastern Idaho phosphate field that can be used to systematically identify water resource systems at mine sites and evaluate mine sites for potential hydrologic impacts. The conceptual models are to be based on ground water flow theory and on observations of existing flow systems and mining impacts. The models can be used to evaluate present and potential mining impacts on the water resource systems and also to predict potential limitations to mining imposed by the water resource systems. The evaluation method should be of benefit to both mining interests and resource administration.

Description of the Phosphate Mining Region

Several important major valleys and ridges occupy the central portion of the western phosphate field in Idaho. These ridge and valley systems trend predominantly northwest-southeast. The ridges in the study area are from 5 to nearly

40 miles long and from 1 to 10 miles wide. Elevations of ridge tops range from 7,000 feet to nearly 10,000 feet. The valleys as a rule are narrower and shorter than the ridges and range in altitude from about 5,800 to 7,500 feet.

Average annual precipitation in the study area ranges from about 15 inches or less at the lower elevations, to more than 35 inches on the higher ridge tops. In the southern and eastern portions of the study area, an average of 54 percent of the annual precipitation falls between November 1 and April 30, mainly as snow (U.S.D.A. Forest Service, 1978, p. 57). Snow accumulations on the lee (northeast) side of ridges may create drifts up to 30 feet or more in depth.

Geologic Setting

Rocks exposed in the study area range in age from Precambrian to recent; however, the marine sedimentary rocks of Carboniferous, Permian and Triassic age are of primary importance to the phosphate mining industry. Phosphate ore is mined from the Meade Peak member of the Phosphoria Formation, which is of Permian age. Hydrogeologic descriptions of pertinent formations in the study area are presented in table 1.

The geology of the study area is extremely complex. The general northwest-southeast linear trend of the mountains and valleys can be attributed to major thrusting and deformation during the Laramide Orogeny of Cretaceous age. Structure of the study area is dominated by major northwest-southeast trending synclines, anticlines, and associated faults. Subsequent erosion formed many valleys along the anticlinal fold axes. Normal faulting of the region during late Tertiary and throughout the Quarternary further complicates the structure. Quarternary basalts blanket a portion of the study area and form the Blackfoot lava field in the vicinity of the Blackfoot Reservoir. Most valleys of the study area contain Quarternary deposits of colluvium and alluvium.

WATER RESOURCE SYSTEMS OF THE PHOSPHATE AREA

Introduction

Hydrogeologic investigations conducted at three separate mine sites reveal relationships between specific geologic

Table 1. Hydrostratigraphic columnar section in the investigated areas in southeastern Idaho (after Ralston et al., 1977).

	Formation	Member	Thickness feet	Lithology	Hydrogeologic Characteristics (Permeability)	Hydrogeologic Classification
Triassic	Thaynes	Upper	900-1200	Limestone and sandstone with some shale siltstone layers	moderate to high	Aquifer
		Middle	2000	Limestone facies interbedded with greater portion of siltstone and shale	low to moderate	
		Lower	2000	Limestone facies interbedded with greater portion of siltstone and shale	low to moderate	
	Dinwoody	Upper	900	Interbedded limestone and siltstone with discontinuous shaly zones	moderate for limestone and siltstone, low for shale and silt	Aquifer
		Lower		Calcareous shale and siltstone with few thin limestone beds.		
Permian	Phosphoria	Rex Chert Unit	120- 150	Chert and cherty limestone, thick bedded	permeable when fractured	Aquifer or Aquitard
		Meade Peak Unit	150- 200	Phosphatic shale, mudstone and phosphatic rock. Some limestone and siltstone	low to semi-permeable	Aquiclude
Carboniferous	Wells	Upper	50	Siliceous limestone	Moderate	Aquifer
		Middle	1500	Sandy limestone, sandstone	high	
		Lower		Limestone, mostly sandy and cherty	moderate to high	
	Brazer	Upper	200	Black and white laminated	very low	Aquifer
		Middle	1000	Thick bedded limestone	high	
		Lower	600-1000	Thin bedded limestone	high	

units and ground water flow systems. In each area the Thaynes and Dinwoody formations were found to support significant ground water flow systems. It was also determined that the Phosphoria Formation does not support any major ground water flow systems; however, the underlying Wells Formation does support flow systems (Ralston and others, 1977). Winter (1979) demonstrated that the "phosphate sequence" of sedimentary rock units (Dinwoody, Phosphoria and Wells formations) exhibit similar hydrogeologic properties over a large area. Winter's study included measuring stream gain or loss over the "phosphate sequence" and locating springs with respect to geologic controls.

The hydrogeologic characteristics of the specific units combine with structural, topographic and climatic factors to control the flow systems in the area. It is important to understand how these factors interrelate to form the complex water resource systems found at mine sites.

Hydrogeology

The sedimentary sequence of the Dinwoody, Phosphoria, and Wells formations forms the basic stratigraphy at all mine sites within the study area. Colluvium and alluvium are also important at some sites.

The Dinwoody Formation of Triassic age consists of an upper member and a lower member. Winter (1979) identified 25 springs discharging from the Dinwoody Formation in eastern Caribou County. Of these 25 springs, 20 were discharging from the lower member. Stream gain-loss studies indicated that flow increased at most sites across exposures of the Dinwoody Formation because of ground water discharge into the stream. Hydrogeologic investigations suggest that both members of the Dinwoody Formation will support ground water flow systems throughout the study area, provided that recharge is available to the formation. The cross section of the Little Long Valley Mine presented in figure 2 shows that the stream in the valley receives most of its baseflow from a ground water flow system in the Dinwoody Formation on Rasmussen Ridge. Similar springs issue from the Dinwoody Formation at most mine sites.

The Phosphoria Formation of Permian age consists of the Rex Chert Member (the Cherty Shale Member is included as part of the Rex Chert Member) and the Meade Peak Phosphatic Shale Member. The Rex Chert Member generally has very low

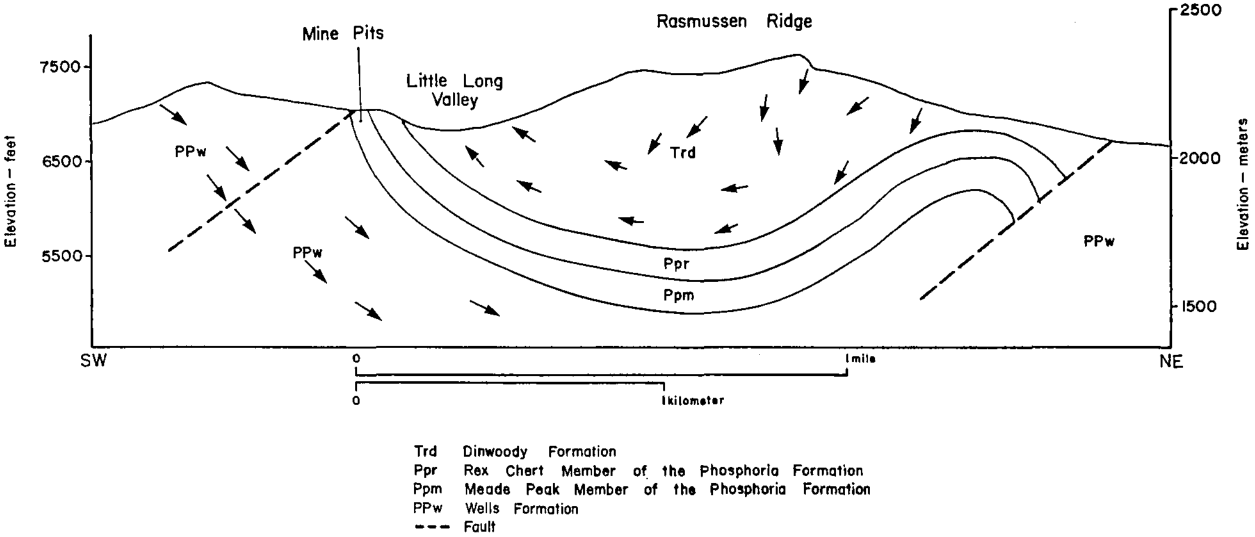


Figure 2. Generalized geologic section of the Wooley Valley Mine area (after Mohammad, 1977).

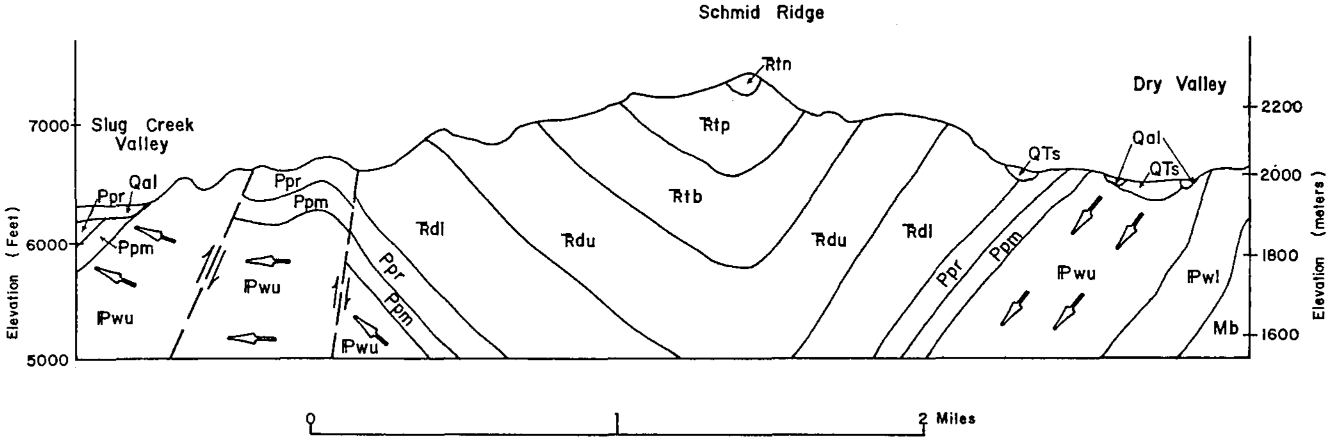
hydraulic conductivity except where it has been significantly altered by fracturing and jointing. Aquifer tests conducted at the Lower Dry Valley Mine site by Vandell (1978) demonstrated that highly fractured zones within the Rex Chert can yield significant quantities of water; however, these zones are discontinuous features that are not widespread. Winter (1979) concluded that the Rex Chert and Meade Peak members of the Phosphoria Formation do not support any major ground water flow systems in the study area. His conclusion was based on the limited number and size of springs that discharge from the Phosphoria Formation. Streams generally do not gain or lose across exposures of the Phosphoria Formation due to the low hydraulic conductivity of the formation. Studies at specific mine sites support the hypothesis that the Phosphoria Formation does not support any major ground water flow systems in the study area. Figure 2 shows that the Phosphoria Formation separates the flow system in the Dinwoody Formation from a deeper flow system in the Wells Formation in Little Long Valley.

The Wells Formation of Pennsylvanian age is divided into an upper member and a lower member. Both members of the Wells Formation support major ground water flow systems in the study area. Sections of the Wells Formation exhibit high hydraulic conductivity and readily accept recharge. Stream gain-loss measurements made by Winter (1979) showed that stream flow is always lost to some degree, if not entirely, across exposures of the upper member of the Wells Formation. Several large springs in the study area issue from the Wells Formation or from the underlying Brazer Limestone. These springs have relatively constant discharge, suggesting a regional ground water flow. A ground water flow system in the Wells Formation accounts for the lack of streamflow in Dry Valley near a mine site in that area (Fig. 3). Large springs occur in Slug Creek Valley at the end of this flow system.

Quarternary deposits of colluvium and alluvium support ground water flow systems in the study area. Major valleys contain aquifers within alluvium which play important roles in ground water-surface water relationships.

Structure

The geologic structure of the study area is dominated by folds and faults. Structural features have greatly influenced the devlopment of ground water and surface water flow



Mb	Brazer Limestone	Ꞧdu	Upper Dinwoody Formation
IPwl	Lower Wells Formation	Ꞧtb	Lower Thaynes Formation
IPwu	Upper Wells Formation	Ꞧtp	Middle Thaynes Formation
Ppm	Meade Peak Member of the Phosphoria Formation	Ꞧtn	Nodular Siltstone Member of the Thaynes Formation
Ppr	Rex Chert Member of the Phosphoria Formation	QTs	Sedimentary Deposits
Ꞧdl	Lower Dinwoody Formation	Qal	Alluvium
		⟵	Postulated Flow Path

Figure 3. **Postulated Dry Valley-Slug Creek Valley ground-water flow system**

systems. Major surface drainages are generally parallel to fold axes or follow fault structures. Stream valleys generally occur within the eroded cores of anticlines and ridges generally follow synclinal axes.

Structural features control to a large extent the location of ground water recharge and discharge areas. Ground water entering a geologic formation tends to follow bedding planes because hydraulic conductivity is higher parallel to bedding than across bedding planes. Valleys in the study area often lie on anticlinal axes, which provides a structural avenue for ground water to flow from one valley to another under ridges. Recharge to permeable rock outcrops on ridges may also follow fold structures and discharge in distant valleys. Fault structures affect the location of many springs. Figures 2 and 3 show how structure controls ground water flow in Little Long Valley and Dry Valley.

Topography and Climate

Topography and climate greatly influence flow system development in the study area. Basically, the topography is dominated by ridge and valley systems which trend northwest-southeast. Wind patterns cause snow to accumulate on the eastern and northern slopes of these ridge systems. Snow drifts on ridges may accumulate to more than 30 feet in depth and be as long as six miles (U.S.D.A. Forest Service, 1978). Eastern and northern ridge slopes and other lee slopes accumulate a large snowpack; therefore these areas are major recharge areas for ground water and surface water flow systems.

Summary of Water Resource Systems

Definite patterns of surface water and ground water flow are evident in the southeastern Idaho phosphate field. These ground water and surface water flow patterns are largely controlled by geology, hydrogeology, topography, and availability of recharge.

Precipitation on lee slopes supports flow in small surface channels and recharges ground water flow systems in the Thaynes, Dinwoody and Wells formations and in colluvial deposits. Ground water within saturated colluvium moves down slope forming local flow systems. These local flow systems discharge as small springs or seeps. Many of these local ground water flow systems dry up during summer months.

Recharge which enters the Thaynes and Dinwoody formations forms local and intermediate ground water flow systems. Recharge comes mostly from direct precipitation and from discharge by small local ground water flow systems. Ground water within these formations moves down gradient following bedding planes and fault structures. Discharge from the flow systems is to springs and streams where bedding planes and faults intercept land surface. Some of the ground water within these flow systems moves across bedding planes into the lower member of the Dinwoody Formation. Further cross bedding flow is virtually prevented by the relatively low hydraulic conductivity of the Phosphoria Formation. Ground water commonly discharges along the Dinwoody-Phosphoria contact in the form of springs and increased stream flow (Winter, 1979).

The Meade Peak member of the Phosphoria Formation supports no significant ground water flow systems. The Rex Chert member may support localized flow systems where it is highly fractured. The Phosphoria Formation forms an effective hydrologic barrier between flow systems within the Thaynes and Dinwoody formations from those within the Wells Formation and Brazer Limestone. A possible exception to this is where considerable displacement has occurred due to faulting.

The Wells Formation supports major ground water flow systems within the study area. Evidence suggests that these flow systems are regional in extent. Recharge to regional ground water flow systems in the Wells Formation occurs from precipitation, streamflow loss, and downward percolation from alluvial valley aquifers. The high mountains and valleys, which receive the greatest precipitation, are the principal recharge areas for regional flow systems. Discharge from regional flow systems is controlled largely by topography and structure. The Snake River Valley and the Bear River Valley are probably primary discharge areas for regional ground water flow systems.

Alluvial material in valleys contain large quantities of ground water. Surface water and ground water flow systems within alluvial materials readily interact. Some stream reaches within valleys lose to underlying alluvium while other reaches gain water from the alluvium.

MINING AND WATER RESOURCE SYSTEMS

Environmental Factors Which Control Water Resource Systems

The flow systems indigenous to the phosphate field of southeastern Idaho are the result of the interaction of the many physical factors actively at work within the environment. These include geologic, topographic, hydrogeologic, climatic and chemical factors. Identification of these environmental factors and determination of their influence on flow system processes is important to the development of flow system models of the phosphate mining areas. Impacts of mining on water resource systems can only be predicted if the relationships between environmental factors and flow system development are understood. For example, potential impacts of mining on a ground water flow system can be predicted only if it is known how changes in geologic, topographic, and hydrogeologic factors affect a ground water flow system, because mining alters these factors.

Geologic factors greatly influence the location and development of ground water and surface water flow systems. Some of the geologic factors which affect the development of flow systems are: 1) areal extent and thickness of rock units, 2) dip of rock units, 3) orientation of rock units relative to topography, 4) folding of rock units, 5) fracturing and faulting, and 6) outcrop patterns.

Topographic factors influence the geometry of a basin and the development of local, intermediate, or regional flow systems. Some of the topographic factors which affect the development of flow systems are: 1) regional slope of valley flanks within a basin, 2) amount of local relief, 3) relative size of basins, and 4) orientation of valleys and ridges.

Hydrogeologic factors within a basin directly affect ground water flow rates, flow capacities of rock units, and location of major flow systems. Hydrogeologic factors include: 1) hydraulic conductivities of rock units, 2) relative hydraulic conductivities parallel and perpendicular to bedding planes, 3) specific yield or storage of rock units, and 4) fluid potential within rock units.

Climatic factors include: 1) precipitation, 2) wind velocity and direction, and 3) evaporation and evapotranspiration potential.

Chemical factors of primary importance to water quality include: 1) available nutrients, radioactive elements, and heavy metals in the rock, soil, and water, 2) chemical stability of earth materials, and 3) pH balance between ground water and earth materials.

Mining Factors Which Affect Water Resource Systems

Mining activities alter or have the potential to alter the existing geology, topography, hydrogeology, biology, and chemical equilibrium within a basin. Changes to these factors will, in turn, affect the water resource system. Potential impacts to water resource systems include changes in the occurrence, movement, and quality of ground water and surface water flow systems. The development of pits and waste dumps are the mining factors which have the greatest potential to affect water resource systems because they create the largest changes in geology, topography, and hydrogeology.

Excavation of mine pits necessarily alters the geology and topography. Factors of pit construction include: 1) areal extent, 2) depth, 3) wall slopes, 4) location relative to geologic structure and 5) location relative to topography (Mohammad, 1977).

Construction of waste piles involve several factors that may affect the occurrence, movement, and quality of flow systems. These include: 1) areal extent, 2) thickness, 3) slopes of waste dump surfaces, 4) hydraulic conductivity of waste rock, 5) location relative to topography, 6) location relative to geologic structure, and 7) chemical stability of waste rock to leaching (Mohammad, 1977).

CONCEPTUAL MODELS OF WATER RESOURCE SYSTEMS

Introduction

The conceptual, qualitative models presented in this section are based on ground water flow systems theory and on the regional, intermediate, and local flow system relationships outlined previously. The factors found to exert the greatest influence on flow systems within the study area are variations in topography, geology, climate, and hydraulic conductivity of geologic formations. Combinations of these factors are used to determine the ground water flow systems which are most likely to occur at any given mine site. The models are valid only for areas which contain the "phosphate sequence" of sedimentary rock units in well defined ridge and valley systems such as those found in the southern and eastern portions of the study area. The models cannot be used to reliably predict ground water flow systems in areas which are dominantly fault controlled and show no definite ridge and valley systems.

Assumptions

Several assumptions are necessary for application of these models to ground water flow systems. It is assumed that the relative hydraulic conductivities of the geologic units are consistent over the study area; the Thaynes and Dinwoody formations exhibit moderate hydraulic conductivity, the Phosphoria Formation exhibits low hydraulic conductivity, and the Wells and Brazer Limestone formations exhibit high hydraulic conductivity. The hydrogeologic study on ground water flow systems in the phosphate sequence conducted by Winter (1979) indicates that this is a valid assumption.

It is assumed that relationships between the environmental factors of geology, topography, hydrogeology and climate, and ground water flow system development are the same wherever the same combination of factors exists. Analysis of six existing mine sites in the area indicates that areas which have similar environmental characteristics have similar ground water flow systems. Ground water flow system theory also supports this assumption.

It is assumed that relationships between water resource systems, mining factors, and hydrologic impacts are similar, wherever the same combination of factors exists. Analysis of six existing mine sites in the area indicates that a given hydrologic impact is caused by a given combination of mining factors and water resource system factors. For example, a mine pit may reduce the flow of a spring issuing from the Dinwoody Formation if the mine pit intercepts the ground water flow to that spring.

Mine Type Designation

The following steps are outlined to select the mine model that best fits a given situation.

Step 1. Is the mine site located within a definite ridge and valley system? Answer: Yes or No. If the answer is no the models do not directly apply. If the answer is yes, continue.

Step 2. From figure 4 select the topographic location of the mine site on the major ridge system. Choices are 1) ridge top, 2) ridge flank, or 3) ridge bottom. Selection should be made based on the location of the mine pits. If the bottom of the mine pit will be no more than about 300 feet below the top of the major ridge, it is classified as "ridge top". Do not classify a mine as ridge top unless it is at the crest of a major ridge or unless it occupies a secondary ridge and the bottom of the mine pits will be substantially above adjacent valley floors. Mines are classified as "ridge bottom" if mine pits will extend below the elevation of the adjacent valley floor. All mine sites located between ridge top or ridge bottom are classified as "ridge flank".

Step 3. From figure 4 select the local topographic condition of the major ridge slopes. Choices are: A) broken ridge slopes and B) smooth ridge slopes. Broken ridge slopes are characterized by numerous valleys, small ridges, and knolls which interrupt the major slope of the ridge. These topographic irregularities are in the order of 100 to 300 feet in relief.

Step 4. From figure 4 select the geologic configuration of the rock units at the mine site. Choices are: A) dip with slope and B) dip contrary to slope. Geologic configuration should be chosen with respect to the location of the mine pits on the ridge. If geologic formations are slightly overturned and the Wells Formation or Brazer Limestone is located at the top of the ridge, choose dip with slope (A). If the geologic units are horizontal and the Dinwoody Formation is located upslope from the mine pits, choose dip contrary to slope (B).

Step 5. Slect the slope aspect of the mine site. This should be the slope aspect of the major ridge slope. Choices are: A) north and/or east facing, and B) south and/or west facing.

Step 6. The mine site should now have a one digit, three letter code which designates a specific mine type. An example is 2ABB. This particular designation means that the mine pits will be located on a ridge flank with broken local topography, the formations dip contrary to the topographic slope, and the slope faces either south or west or both. Cannon (1979) presents a detailed description of each mine site classification.

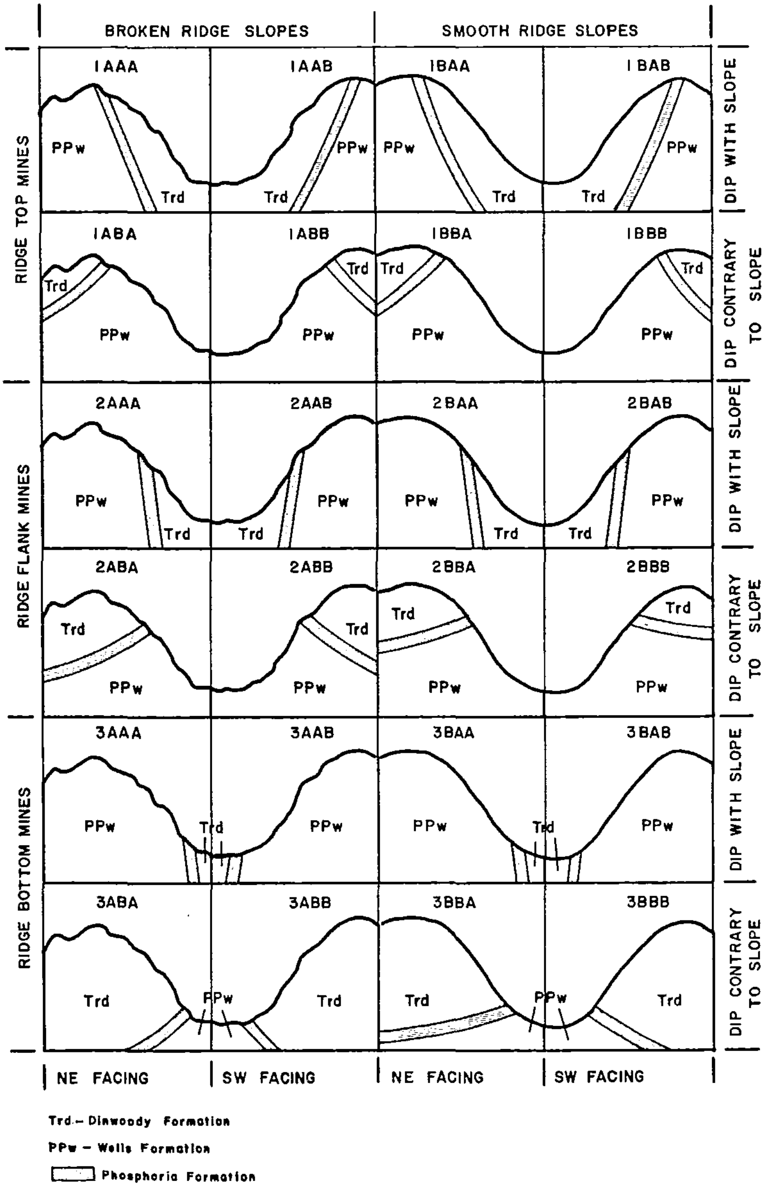


Figure 4. Diagrammatic section for each mine type.

Discussion of Model Predictions

A general ranking of each mine site is given in table 2 for: a) potential for discharge of various types of flow systems into the pit and the associated limitations on mining, b) potential mining impacts on springs which supply baseflow for perennial streams and c) potential for waste dump erosion and instability from water movement through the dump (assuming the waste dump has not been vegetated and is located downstream from the pits). Table 2 shows that mines located at ridge bottoms have the greatest potential for intersecting large flows of ground water. Ridge top mines have the greatest potential for waste dump erosion and instability.

In general, the models should predict ground water flow systems at proposed mine sites with a high level of reliability. However, all models are simplifications of real systems. Local folds or faults may cause variations in flow from that predicted.

CONCLUSIONS

1. Definite relationships between environmental factors and development of water resource systems have been observed in the study area. Past hydrogeologic studies have shown that relationships exist between geologic formation type and ground water flow systems. This study demonstrates that additional relationships exist between topographic, geologic, and climatic factors and flow system development.

2. Relationships between existing water resource systems, mining activities, and water resource impacts have been observed. The degree of hydrologic impacts from mining is related to the size (local, intermediate, or regional) and types (ground water or surface water) of flow systems encountered at the mine site. Hydrologic limitations to mining are dependent primarily on the size and types of flow systems intercepted by mine pits.

3. Conceptual models have been developed which can be used to identify water resource systems at existing and proposed mine sites in the southeastern Idaho phosphate field. The models delineate ground water flow systems based on the geologic structure, topographic configuration, topographic location, and climatic conditions of the mine area. These

Table 2. Rank of Mine Types for Various Parameters

RANK	PARAMETER					
	Potential for discharge of ground water flow systems into pits				Potential for impacts to springs which supply base flow to perennial streams	Potential for waste dump erosion and instability from water movement through dump
	Local	Intermediate	Regional	Limitations to mining		
HIGH	3ABA	3ABA	3ABA	3ABA	3ABA	1BAA
	2ABA	3BBA	3BBA	3BBA	3BBA	1AAA
	3BBA	3ABB	3ABB	3ABB	3ABB	1BBA
	2BBA	3BBB	3BBB	3BBB	3BBB	1ABA
	3ABB	2ABA	3AAA	3AAA	2ABA	2BAA
	2ABB	2BBA	3BAA	3BAA	2BBA	2AAA
	3BBB	2ABB	3AAB	3AAB	2AAB	2BBA
	2BBB	2BBB	3BAB	3BAB	2BBB	2ABA
	2AAA			2ABA		1BAB
	2AAB			2BBA		1AAB
	2BAA			2ABB		1BBB
				2BBB		1ABB
MEDIUM	2BAB			2AAA		2BAB
	3AAA			2BAA		2AAB
	3BAA			2AAB		2BBB
	3AAB			2BAB		2ABB
	3BAB					
LOW	1ABA			1AAA		3AAA
	1BBA			1ABA		3BAA
	1AAA			1BAA		3AAB
	1BAA	All Others	All Others	1BBA	All Others	3BAB
	1ABB			1AAB		3ABA
	1BBB			1ABB		3BBA
	1AAB			1BAB		3ABB
	1BAB			1BBB		3BBB

models may be utilized both for environmental management and mine planning.

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