AN ASSESSMENT OF THE HYDROLOGIC INFORMATION REQUIRED FOR THE U.S. BUREAU OF LAND MANAGEMENT-U.S. GEOLOGICAL SURVEY COAL-HYDROLOGY PROGRAM IN THE WEST

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Interagency Assignment with the U.S. Geological Survey

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CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSION FACTORS

Inch-poung units in this report may be expressed in the International System of Units (SI) by use of the following conversion factors:

Multiply inch-pound units	*By*	*To obtain SI units*
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
inch	25.40	millimeter
mile	1.609	kilometer
square mile	2.590	square kilometer

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By Richard A. Herbert[1]

ABSTRACT

In 1974, the U.S. Bureau of Land Management began the Energy Minerals Rehabilitation Inventory and Analysis (EMRIA) Program, now known as the Coal Hydrologic Investigations Program, to collect detailed information on water and other resources of proposed coal-lease areas. The U.S. Geological Survey has been collecting water-resource information for the U.S. Bureau of Land Management since the program was started. This report summarizes the U.S. Bureau of Land Management's hydrologic information needs in the different stages of the land-use planning and coal-leasing process and presents an evaluation of the use of the U.S. Geological Survey's precipitation-runoff model from a Bureau of Land Management perspective. Information collected by the U.S. Geological Survey for precipitation, surface water, ground water, and water quality has been used extensively in environmental assessments and site-specific analyses for coal leasing.

The U.S. Geological Survey also has been calibrating a precipitation-runoff model used to estimate the surface discharge of ungaged basins in northwestern Colorado. A test of the model shows that it will provide surface-discharge estimates for ungaged basins within the accuracy required for the U.S. Bureau of Land Management's land-use planning and coal-leasing process. However, the model is most effective when applied by an experienced user. In addition, more verification of the model is needed before it will accurately predict the impacts of coal mining on surface water.

[1]Hydrologist, U.S. Bureau of Land Management on Interagency Assignment with the U.S. Geological Survey.

INTRODUCTION

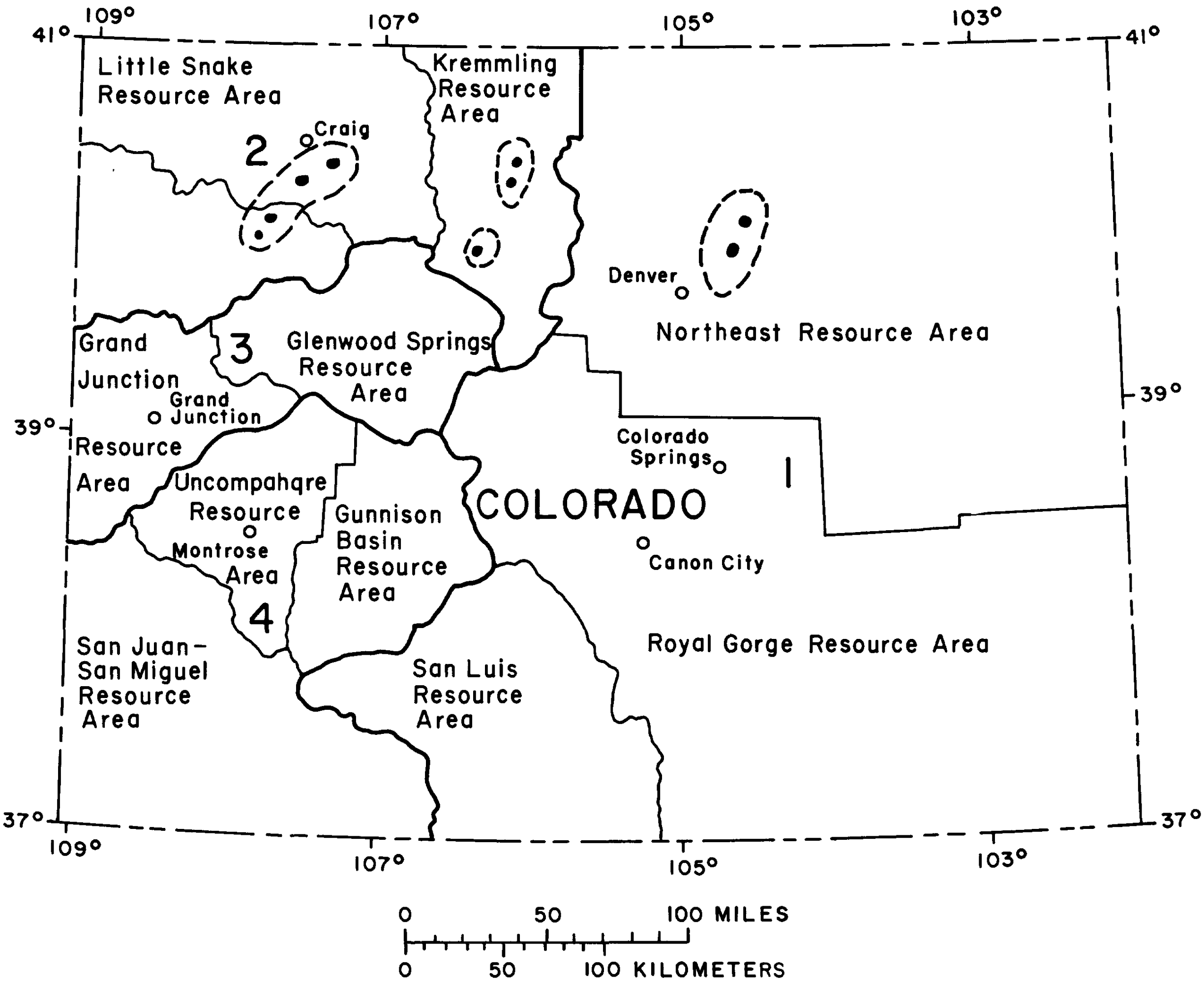
In 1974, the U.S. Bureau of Land Management began the Energy Minerals Rehabilitation Inventory and Analysis (EMRIA) Program (Van Haveren, 1980). The program was designed to collect detailed information on the hydrology, soils, overburden characteristics, and reclamation potential of proposed coal-lease areas to ensure that informed decisions were made during the Bureau's land-use planning and coal-leasing process. In July 1981, this program was terminated as an effort to inventory and analyze rehabilitation aspects of coal mining when the policy decision was made that determinations of reclaimability did not have to be made prior to issuing a lease. Although the Bureau's coal program continues to be a user of such information during its planning process, it will no longer be a generator. However, hydrologic studies designed to identify the impacts of mining Federal coal lands (both underground and surface) are continuing. This report reviews the Bureau's land-use planning and coal-leasing process and describes the efforts of the U.S. Bureau of Land Management and the U.S. Geological Survey to collect and analyze the water-resources information required throughout the process. Use of the precipitation-runoff model being developed and calibrated by the Geological Survey also is assessed from a Bureau of Land Management perspective.

U.S. BUREAU OF LAND MANAGEMENT'S LAND-USE PLANNING AND COAL-LEASING PROCESS

Description

The Bureau of Land Management leases coal mostly under three different circumstances: (1) Regional lease sales, (2) preference-right lease applications (PRLA's), and (3) leasing by application. Because PRLA's and leasing by application require fewer hydrologic analyses than regional lease sales, this discussion will concentrate on a brief description of the processes involved in regional lease sales. Regional lease sales are accomplished through the Bureau's land-use planning and coal-leasing process. The Bureau usually refers to land-use planning as "multiple-use planning" and the coal-leasing process as "coal-activity planning." In this report, the land-use planning and coal-leasing process is referred to as the "planning and coal-leasing process."

Bureau planning is conducted as needed to meet the demand for use of public land. This means that whenever there is enough demand, all coal with development potential in a Bureau of Land Management Resource Area is evaluated for possible leasing through the Bureau's planning process. As shown in figure 1, a Bureau of Land Management Resource Area is an administrative unit within a Bureau of Land Management District. Also shown in figure 1 and discussed later are hypothethical examples of areas acceptable for further consideration for coal leasing which normally contain one or more proposed lease tracts.



EXPLANATION

——— U.S. BUREAU OF LAND MANAGEMENT'S DISTRICT BOUNDARY

DISTRICT

I	Canon City
2	Craig
3	Grand Junction
4	Montrose

——— U.S. BUREAU OF LAND MANAGEMENT'S RESOURCE AREA BOUNDARY

– – – – – AREA ACCEPTABLE FOR FURTHER CONSIDERATION FOR COAL LEASING--Hypothetical example

● PROPOSED LEASE TRACT--Hypothetical example

Figure 1.--The U.S. Bureau of Land Management's Districts and Resource Areas, areas acceptable for further consideration for coal leasing, and proposed lease tracts in Colorado.

The major steps in the planning and coal-leasing process which require hydrologic data are shown in figure 2. The first step in the process is to identify major issues. In this case a major issue would be the need for additional coal leasing. If water is an issue or potential problem, it would be identified as such at this time. If there is a lack of information, a water-resources inventory is conducted after the issues have been identified. This inventory generally consists of a reconnaissance of an entire Resource Area during one field season. Inventories of other resources such as rangelands, wildlife, energy, and minerals also are conducted at the same time or as needed. Potential coal-lease areas are identified by locating coal deposits that could be mined. The information obtained in these inventories is used in the preparation of land use and activity plans. It also is used in the preparation of the environmental assessments required for the land-use plan or in the coal-activity planning process.

The information collected during the inventory is used in the management-situation analysis to formulate management alternatives. At this point in the process, 20 unsuitability criteria must be applied to all potential coal-lease areas to determine their suitability, or lack of suitability, for mining. The requirement for the application of unsuitability criteria was established by Section 522a of the Surface Mining Control and Reclamation Act of 1977.

The major unsuitability criteria dealing with water resources are special flood plains (described as "100-year flood plains" in the regulations), municipal watersheds, National Resource Waters, and alluvial valley floors. When applying these criteria to potential coal-lease areas, the 100-year flood plains and alluvial valley floors are the most difficult to delineate. For example, available Statewide techniques for determining flood discharge and depth on public lands in Colorado are questionable (McCain and Jarrett, 1976). Generally, during this phase, areas are delineated which could potentially be a 100-year flood plain or an alluvial valley floor. The delineation of exact boundaries is deferred until the coal-lease tracts have been selected. Municipal watersheds and National Resource Waters are fairly easily delineated at this stage. If a 100-year flood plain, an alluvial valley floor, a municipal watershed, or National Resource Waters are within a potential coal-lease tract, that part of the tract is considered unsuitable for leasing.

During the management-situation analysis, the water resources also are evaluated throughout the entire Resource Area. Normally, a general evaluation is made to determine if there are any problems, such as excessively mineralized water or flood hazards, or if there are unique features, such as pristine streams or municipal water supplies that need special attention.

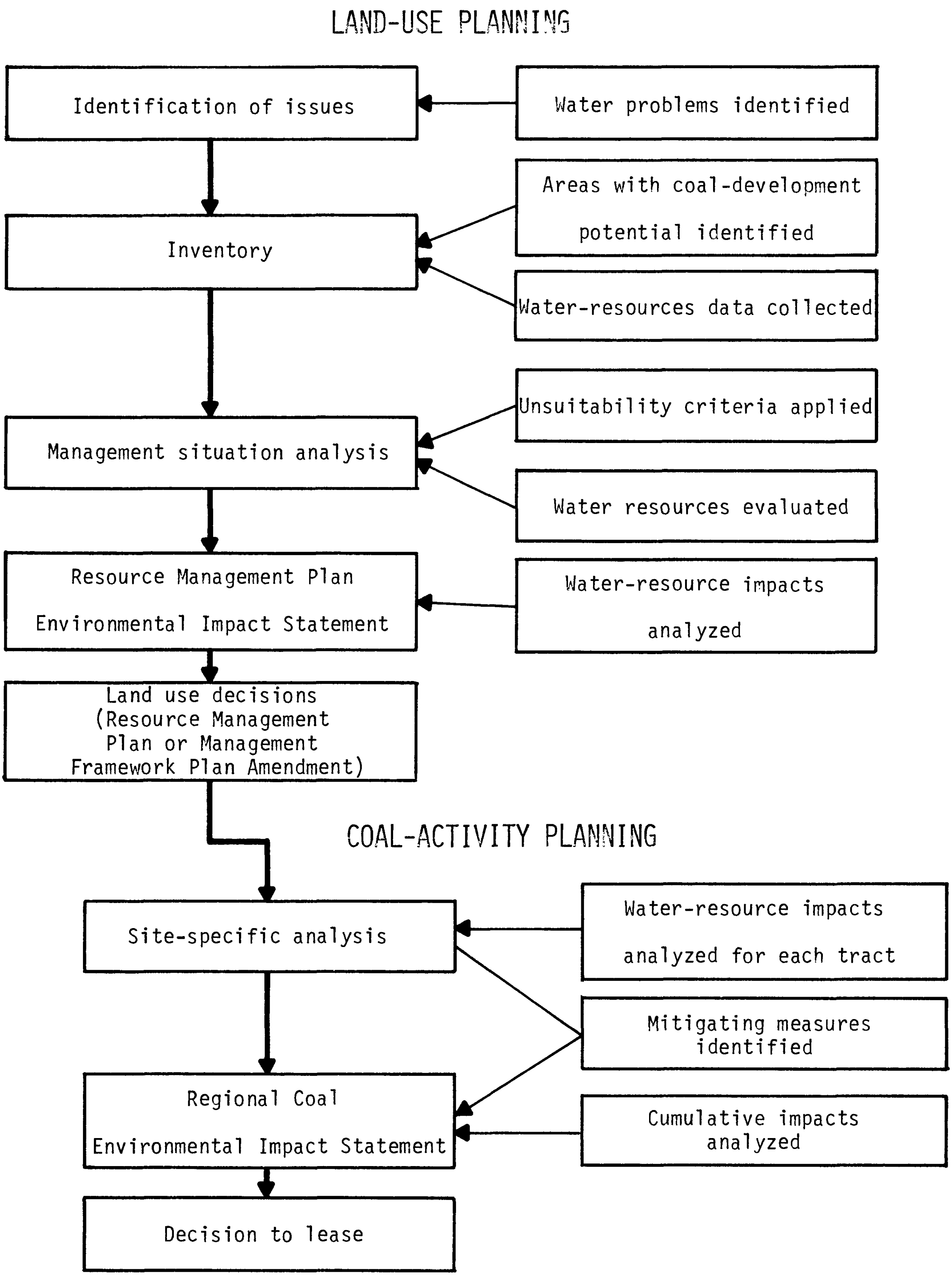


Figure 2.--Major steps in the U.S. Bureau of Land Management's planning and coal-leasing process for which water-resources data are required.

After several alternative uses have been selected for all of the land within a Resource Area, a Resource Management Plan Environmental Impact Statement (EIS) is written. Preparation of the impact statement requires quantification of existing hydrologic conditions for the entire Resource Area, as well as quantification of the impacts of the preferred action and alternatives. Once an analysis of the impacts of the preferred action and the alternatives is completed, land-use decisions are made. These decisions result in the delineation of areas acceptable for further consideration for coal leasing (fig. 1).

In many cases, a Management Framework Plan Amendment would be completed in place of a Resource Management Plan, but the process as discussed above virtually is the same for both plans. The major difference is that a Resource Management Plan is a new multiple-resource plan, whereas a Management Framework Plan Amendment is an amendment to an existing plan where there is new interest in one resource, such as coal or wilderness.

After completion of the land-use planning, there is a solicitation for expression of industry interest in leasing coal. If there is an interest, the U.S. Minerals Management Service delineates potential coal-lease tracts, and then Coal-Activity Planning is begun.

The next step in the process requiring water-resource data is the site-specific analysis (fig. 2) which is then made for these potential lease tracts. During the site-specific analysis, a complete evaluation of water-resource impacts is conducted based upon existing or additional data, if necessary, and the most probable mining methods to be used. Mitigating measures which will minimize or eliminate potential impacts are identified during this phase and in the preparation of the Regional Coal Environmental Impact Statement.

The last major step in the process before the decision to lease is the development and publication of the Regional Coal Environmental Impact Statement. The information contained in the site-specific analysis is incorporated into the Regional Coal Environmental Impact Statement, where the cumulative impacts of several leasing proposals within a coal region (fig. 3) are described. A decision to lease is then made, and the selected leases are sold through competitive sale and issued accordingly. Appropriate stipulations may be placed on a lease, based in part on the mitigating measures identified in the Environmental Impact Statement and on laws and regulations.

Analyses of water resources and water-resources impacts during the planning and coal-leasing process begin on a general scale in the Resource Management Plan Environmental Impact Statement and are nonspecific (such as a Resource Area with many land uses). The analyses narrow in scope and become extremely specific in the site-specific analysis (lease tract with coal mining the major use) and finally broaden in scope but remain fairly specific for the Regional Coal Environmental Impact Statement (an entire coal region with coal mining comprising one of the major land uses).

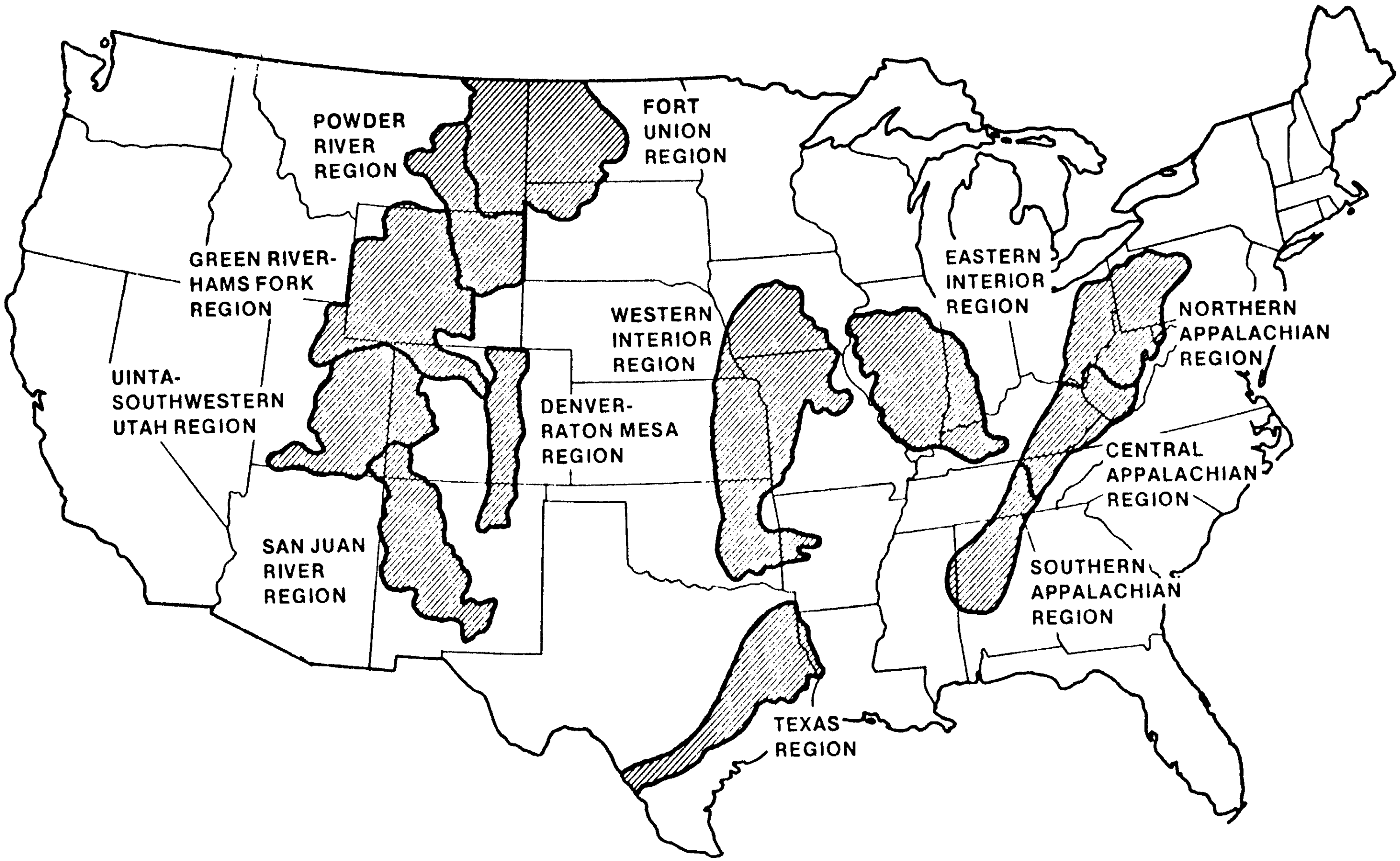


Figure 3.--Major coal regions in the conterminous United States.

Water-Resources Information Required

The hydrologic data required for the Bureau of Land Management's planning and coal-leasing process varies depending upon the phase of the process and the locations being considered. Because the process starts by considering large land areas and then narrows to specific sites, the data required normally are general at first and become more detailed as the scope narrows. Because a detailed evaluation of water resources and water-resource impacts must be completed for the site-specific analysis of each proposed lease tract, the coal-hydrology program traditionally has been oriented towards providing the detailed data required for those analyses. Interpretations of the data must be made on each tract for several components of the hydrologic cycle, including ground water, surface water, water quality, and water use. Some examples of the types of interpretations required are: (1) Estimates of total salt load being produced by the proposed lease area and expected changes in load once mining begins; (2) present and projected consumptive use of water in the lease area; (3) areal extent of any aquifers that may be affected by mining and the impacts mining will have on local wells or water supplies; and (4) an analysis of existing water-quality conditions and predicted impacts of mining.

One purpose of the environmental assessments is to assist land managers in making environmentally sound land-use decisions. When making these land-use decisions, the managers need to be presented with a general perspective on the quality and quantity of surface and ground water as well as existing water rights for every management unit within the Resource Area. In addition, the managers need to know the impacts of each alternative management proposal and how good or bad the impacts will be when compared to existing conditions or known standards.

The interpretation of the data is the most important aspect of the program. Uninterpreted hydrologic data usually mean nothing to a Bureau of Land Management manager. For example, a dissolved-solids concentration determined for a certain stream may or may not be useful. Before this information becomes meaningful, several questions must be answered, such as: Does the dissolved-solids concentration exceed any standards? If it does exceed a standard, what is the source? Is the source natural or a result of man's activities? Will a change in the land use affect the concentration? Obviously, Bureau hydrologists have to make some of these evaluations, but Survey hydrologists generally collect and interpret hydrologic data and can provide the information in their reports with little additional effort.

The general types of water-resources information usually required during the Bureau's planning and coal-leasing process are listed in table 1. The relative importance of the information, as well as the degree of accuracy required for each phase in the process, also is presented. However, each area and each specific tract has different State requirements, local flow conditions, local geochemical conditions, and other information, so actual needs will vary from site to site. In an ideal situation, the entire list of data would be available for each coal-lease tract. Obviously, the better the data and interpretations, the better the decisions and mitigating measures will be for an area. However, the importance of the water-resource impacts relative to other impacts and conditions will determine the actual hydrologic data-collection effort required.

Table 1.--*Hydrologic information required for the U.S. Bureau of Land Management's planning and coal-leasing process*

[Relative importance: 1, necessary; 2, desirable; 3, optional. Approximate degree of accuracy: 1, high (about 50 percent or less error); 2, medium (about 50-100 percent error); 3, low (about 100-300 percent error); N, not needed]

Type	Relative importance	Approximate degree of accuracy: Resource management plan E.I.S.	Site-specific analysis	Regional coal E.I.S.	Remarks
Springs:					
location	1	1	1	1	
mean monthly flow	1	2	1	2	Necessary only for selected sources.
water quality[1]	1	2	1	1	Must have only for selected sources.
geologic source	1	2	1	N	
Wells:					
location	1	1	1	1	
well yield	2	3	1	N	
depth to water	1	2	1	2	
seasonal fluctuations	3	3	2	N	
Areal extent of important aquifers.	1	3	1	3	Necessary only for selected areas.
Potentiometric surface	1	3	1	3	Necessary for selected areas.
Storage coefficients	3	N	2	N	More important where ground water is a critical element.
Transmissivities	3	N	2	N	
Recharge and discharge areas	1	3	1	3	
Quality of ground water[1]	1	2	1	2	Necessary only for selected wells.
Streams:					
location of gages	1	1	1	1	
flow-duration curves	2	3	2	3	
mean monthly flows	1	2	1	2	Necessary for selected sites.
low-flow frequency	2	3	2	3	
flood frequency	1	3	2	3	Necessary for selected areas.
Flood-plain maps (100-year recurrence)	1	3	2	2	Necessary for selected areas.
Quality of surface water[1]	1	2	1	2	
Monthly pan evaporation	2	3	2	3	If streamflow data is not available, these become more important for use in the rainfall-runoff model.
Precipitation duration, distribution	2	3	2	2	
Soil types	2	3	2	3	
Vegetation types and density	2	2	2	3	
Existing water rights	2	2	1	2	Necessary in some areas.
Water uses (volume, season, type)	1	2	1	2	
Surface-water storage	2	2	1	3	
Diversions (locations)	1	2	1	2	Necessary only in selected areas.
Location of municipal watersheds	1	1	1	1	
Location of other water supplies (water savers)	2	2	1	N	

[1]See table 2.--Water-quality data required for the U.S. Bureau of Land Management's planning and coal-leasing process.

The data shown in table 1 were compiled by polling Bureau hydrologists in Colorado, Montana, New Mexico, and Utah to determine the importance and accuracy needed for each type of water-resources information for an average or normal situation. The results were variable, so the trend for each type was selected for use in the table. As indicated in the remarks, in areas where ground water is a critical factor the information related to ground water would be more important.

Some information would be classified in the "necessary" category for selected sites, whereas the same data for other sites could be eliminated from consideration. For example, mean monthly flow is necessary for springs that might be affected by mining operations, whereas springs outside the affected area need not be considered further.

The three degrees of environmental assessment listed in table 1 require quantification of existing hydrologic conditions, as well as quantification of the impacts resulting from the proposed actions. The required accuracy of the different types of information varies with the phase of the process and the relative impact. Quantification of existing hydrologic conditions and impacts in the Resource Management Plan Environmental Impact Statement can be within one or two orders of magnitude. However, the assumptions and methods need to be clearly defined. The important thing is to ensure that the predicted direction of change is accurate. In other words, the method selected to predict impacts should not predict a decrease in dissolved solids if an increase will actually occur. The hydrologic information used in the site-specific analysis requires the greatest accuracy, which is why the coal-hydrology program has concentrated on this phase of the leasing process.

The Regional Coal Environmental Impact Statement assesses the cumulative impacts of the specific tracts on the regional environment. Since the site-specific impacts already have been determined at this point, the majority of the work already has been completed. The analysis required for the Regional Coal Environmental Impact Statement consists of combining the impacts of all sites and determining the cumulative downstream impacts. The accuracy required is similar to that required for the Resource Management Plan Environmental Impact Statement.

Water-quality data requirements for surface water, ground water, and spring water are listed in detail in table 2. The types of water-quality constituents that must be collected to the degree of accuracy indicated in table 1 depend upon the type of use proposed for the water. On public land, the water normally will be used for wildlife and livestock. If these two uses are combined with the factors that are required to be tested by regulation, then almost all water-quality constituents must be tested. However, common sense dictates that there is no need to determine loads for an element which does not exist or is not critical to a downstream use. The logic to be followed when determining the degree of sampling necessary for a potential coal-lease tract is outlined in figures 4 and 5.

Table 2.--*Water-quality data required for the U.S. Bureau of Land Management's planning and coal-leasing process*

[mg/L, milligram per liter; counts/100 mL, number of bacteria per 100 milliliters of sample; pCi/L, picocuries per liter; µmho, micromho per centimeter at 25° Celsius; T/mi^2, ton per square mile; °C, degree Celsius]

Water-quality constituent or property (dissolved, unless noted)	Units	Proposed water use[1]					
		Municipal water supply	Wildlife and aquatic life	Recreation	Irrigation	Livestock	Required by regulation for coal leasing[2]
Acidity	mg/L as $CaCO_3$	-	X	-	-	-	X
Alkalinity	mg/L as $CaCO_3$	X	X	-	-	-	X
Ammonia	mg/L	X	X	-	X	-	-
Arsenic	mg/L	X	X	-	X	X	-
Bacteria	counts/100 mL	X	X	X	X	X	-
Barium	mg/L	X	-	-	-	-	-
Bicarbonate	mg/L	-	-	-	-	-	X
Boron	mg/L	X	-	-	X	X	-
Cadmium	mg/L	X	X	-	X	X	-
Calcium	mg/L	-	-	-	-	-	X
Chloride	mg/L	X	-	-	-	-	X
Chromium	mg/L	X	X	-	X	X	-
Copper	mg/L	X	X	-	X	X	-
Cyanide	mg/L	X	X	-	X	X	-
Dissolved oxygen	mg/L	X	X	X	-	-	X
Fluoride	mg/L	X	-	-	-	-	-
Hardness	mg/L as Ca	X	-	-	-	-	-
Iron (total and dissolved)	mg/L	X	X	-	-	-	X
Lead	mg/L	X	X	-	X	X	-
Magnesium	mg/L	-	-	-	-	-	X
Manganese (total and dissolved)	mg/L	X	X	-	-	-	X
Mercury	mg/L	X	X	-	-	X	-
Nitrate-nitrite	mg/L	X	-	-	X	X	X
Pesticides	mg/L	X	-	-	-	-	-
pH	standard units	X	X	X	X	-	X
Physical appearance	([3])	X	X	X	-	-	X
Phosphate	mg/L	X	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	X
Radiochemicals	pCi/L	X	-	-	-	-	-
Selenium	mg/L	X	X	-	X	X	-
Sodium	mg/L	X	-	-	-	-	X
Specific conductance	µmho	X	-	-	-	-	X
Sulfate	mg/L	-	-	-	-	-	X
Sediment transport	T/mc^2	-	-	-	-	-	X
Temperature	°C	X	X	-	-	-	X
Dissolved solids	mg/L	X	-	-	-	X	X
Other heavy metals	mg/L	X	X	-	X	X	-

[1]Combination of several State's requirements.
[2]From Office of Surface Mining, 1980.
[3]Color, odor.

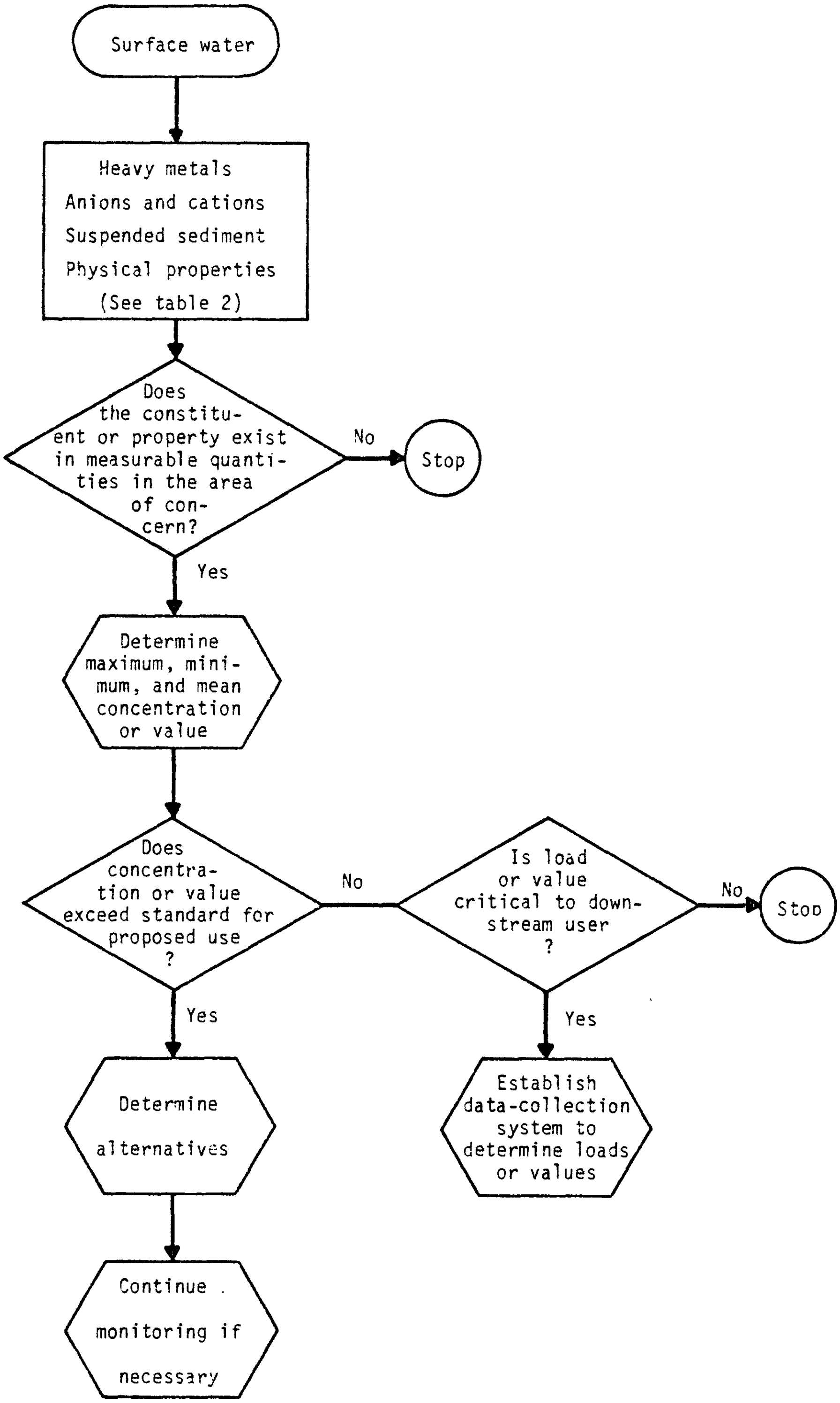


Figure 4.--Logic to be followed when determining the degree of surface-water quality sampling necessary for a potential coal-lease tract.

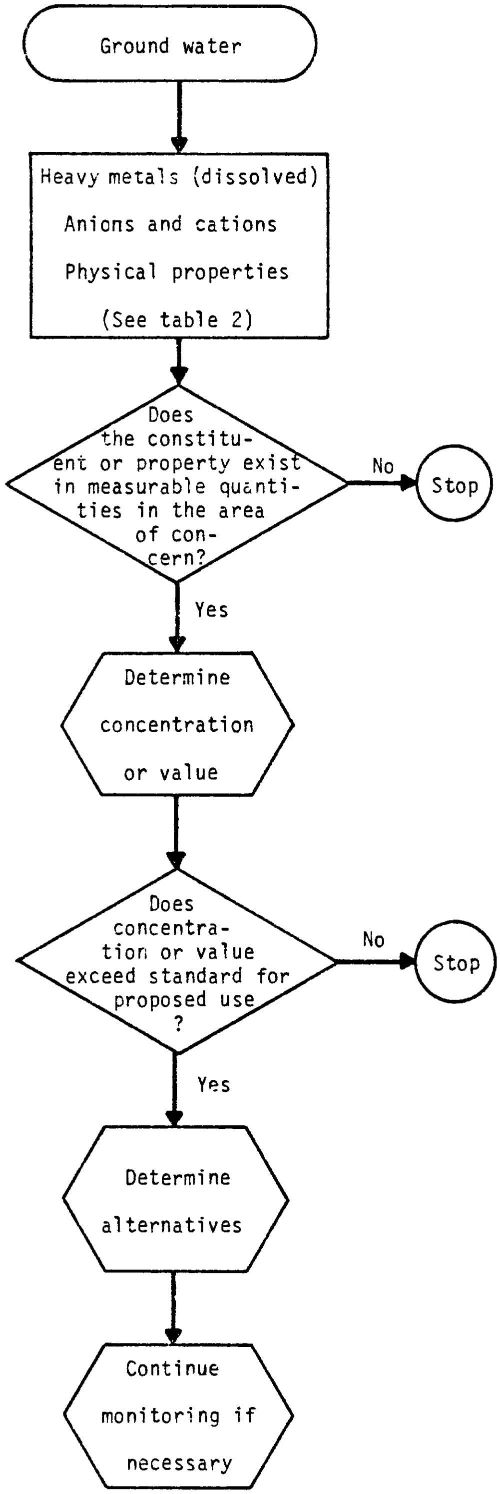


Figure 5.--Logic to be followed when determining the degree of ground-water quality sampling necessary for a potential coal-lease tract.

For surface-water quality (fig. 4) both the suspended (heavy metals) and dissolved (anions and cations) constituents listed in table 2 would be sampled to determine if they exist in measurable quantities. If certain constituents are not present, then further testing for those constituents obviously is not needed. Continued sampling during high and low flows is necessary to determine the maximum, minimum, and mean concentrations of the constituents that do exist in measurable quantities. If the concentrations exceed standards for the proposed use of the water, then mitigating measures or alternatives to the proposed action must be determined. If the loads for a certain parameter (such as salinity in the Colorado River) are critical to a downstream user, then a data-collection system to determine loads may be necessary. Sampling for ground-water quality (fig. 5) would follow similar logic.

The data shown in tables 1 and 2 and in figures 4 and 5 could be used as a checklist and initial point of discussion whenever the Bureau requests that the Survey collect hydrologic data in a given area.

U.S. GEOLOGICAL SURVEY'S PRECIPITATION-RUNOFF MODELING SYSTEM

Present Capabilities

Early in the coal-hydrology program it was recognized that every potential coal-lease area could not be surveyed and analyzed. Because of shifting priorities, areas that were chosen for analysis would not necessarily be leased. Therefore, the Bureau and the Survey decided a mathematical model was needed that would provide managers and specialists with hydrologic information for ungaged areas. The model would aid in preparing environmental assessments and in making land-use decisions. However, the intent and use of the model have sometimes been misunderstood. At one time the Bureau expected to enter a minimal quantity of data into the model and be able to get answers to all questions concerning surface water, ground water, water quality, water use, and the impacts of mining and reclamation on each of these categories.

Presently a model is being developed (Van Haveren and Leavesley, 1979), which will, "When applied to watersheds having little or no hydrologic data, . . . define estimates of the hydrologic characteristics of the basin including the water balance of individual HRU's (hydrologic response units), stream hydrographs, flood peaks and volumes, sediment yields, water-quality characteristics, soil-water relationships, and ground-water recharge." They go on to say, "If a hypothetical mine plan is superimposed on the watershed, the model can be run to predict impacts of mining. These outputs can then be used by the hydrologist, who must then interpret the results for the land manager." The model described above has not been developed completely yet but can be used in its present form to answer some of the Bureau's questions concerning surface-water discharge.

An unpublished User's manual for the model has been compiled by G. H. Leavesley, R. W. Lichty, B. M. Troutman, and L. G. Saindon (U.S. Geological Survey, written commun., 1982). The model presently is being calibrated in several States and is now or soon will be available to transfer runoff data to ungaged watersheds within the geographic areas for which it is calibrated. The transferability of hydrologic data is fairly reliable within the areas that have been calibrated (R. S. Parker, U.S. Geological Survey, oral commun., May 1981). Applicability of the model for predicting the impacts of proposed mining in the West has not been tested or verified.

Puente and others (1980) developed several regressions that were adapted later to the precipitation-runoff model to predict changes in water quality in Alabama. R. S. Parker (oral commun., 1981) presently is developing similar water-quality relationships that will be useful in predicting some water-quality constituents such as sodium, bicarbonate, sulfate, and chloride for ungaged streams in northwestern Colorado.

The precipitation-runoff model has a subroutine capable of predicting sediment yields; however, a great deal of data collection is necessary before the subroutine can be tested and verified. The data and assumptions for the sediment subroutine will require extensive sensitivity analyses before they can be estimated with any reliability (G. H. Leavesley, U.S. Geological Survey, oral commun., 1981).

The volume of interpretive ground-water information that can be provided for any given site depends on the volume of data that are available. The Survey has Statewide ground-water monitoring networks and also collects site-specific, ground-water data through the coal-hydrology program. Ground-water data and interpretations for Environmental Impact Statements and site-specific analyses can be provided on a site-by-site basis by Survey project personnel. However, calibrated ground-water models generally are not available, and the ground-water component of the precipitation-runoff model is only a highly generalized system of ground-water storage reservoirs.

The model was used to determine runoff in an ungaged watershed in northwestern Colorado. At the same time, an evaluation was made of the suitability of the model for Bureau purposes. Results of the modeling effort are included in the next section.

Evaluation of the Use of the Precipitation-Runoff Model for U.S. Bureau of Land Management's Purposes

Because the Bureau of Land Management plans to use the Survey's precipitation-runoff model in making hydrologic analyses required for coal leasing, the model was tested to evaluate the feasibility of a Bureau hydrologist with little or no modeling experience applying the model to an ungaged basin. Morgan Gulch in northwestern Colorado was selected as the test watershed. The objectives of the project were to:

1. Determine how long it would take to learn how to apply the model.

2. Model the Morgan Gulch watershed for use in an EMRIA site report.

3. Evaluate three methods of deriving model parameters.

4. Identify problems encountered when applying the model.

Morgan Gulch is south of the Yampa River and about 18 miles north of Meeker, Colo. (fig. 6). The 26.5-square-mile watershed drains the Danforth Hills coal region in a northeasterly direction. The watershed ranges in elevation from about 6,400 to 8,400 feet, and the predominant vegetation types are sagebrush at the lower elevations, oakbrush at the midelevations, and aspen on north-facing slopes and at higher elevations. Average annual precipitation is about 15 inches, most of which is snow. The sources of perennial streamflow are mainly spring discharge and snowmelt. Runoff from snowmelt generally peaks in April and May, and infrequent runoff from rain occurs in late summer and early fall. Streamflow has been monitored since the installation of a gage (fig. 6) in September 1980.

The first step in the modeling effort was to become familiar with the model. After brief discussions with current users of the model, about 8 hours were spent reviewing the unpublished User's manual by G. H. Leavesley, R. W. Lichty, B. M. Troutman, and L. G. Saindon (U.S. Geological Survey, written commun., 1982), and Leavesley's (1973) Ph. D dissertation. These two documents provided a basic understanding of the model, but they left unanswered numerous questions about how to use the model.

A few days were spent collecting maps, aerial photographs, and vegetation and soils data. Then the watershed was divided into hydrologic-response units (HRU's) based mainly on vegetation, slope, aspect, and elevation. Values were assigned to each input parameter for each HRU using available data, literature, judgment, and the help of current users. Temperature data for water years 1979, 1980, and the first 8 months of 1981 were obtained from the National Weather Service's climatic station at Meeker. Precipitation data for the same period were obtained from a climatic station located between Morgan Gulch and Wilson Creek (fig. 6). The data were then coded and punched on cards. The total process of becoming familiar with the model, establishing a data deck, and producing the first results took almost 2 weeks.

The initial model run was completed with no knowledge of existing runoff conditions in the area. After completion of the initial model run, about 7 months of actual runoff data for Morgan Gulch near Axial (station 09250700) was compared to the predicted hydrograph. Because the period of record consisted of very low flows, total annual discharge from Wilson Creek near Axial (station 09250600) during water years 1979 and 1980 also was used for comparison and later for calibration. The discharge at Wilson Creek near Axial (station 09250600) cannot be compared directly with Morgan Gulch near Axial (station 09250700) because the periods of record do not overlap, as shown in

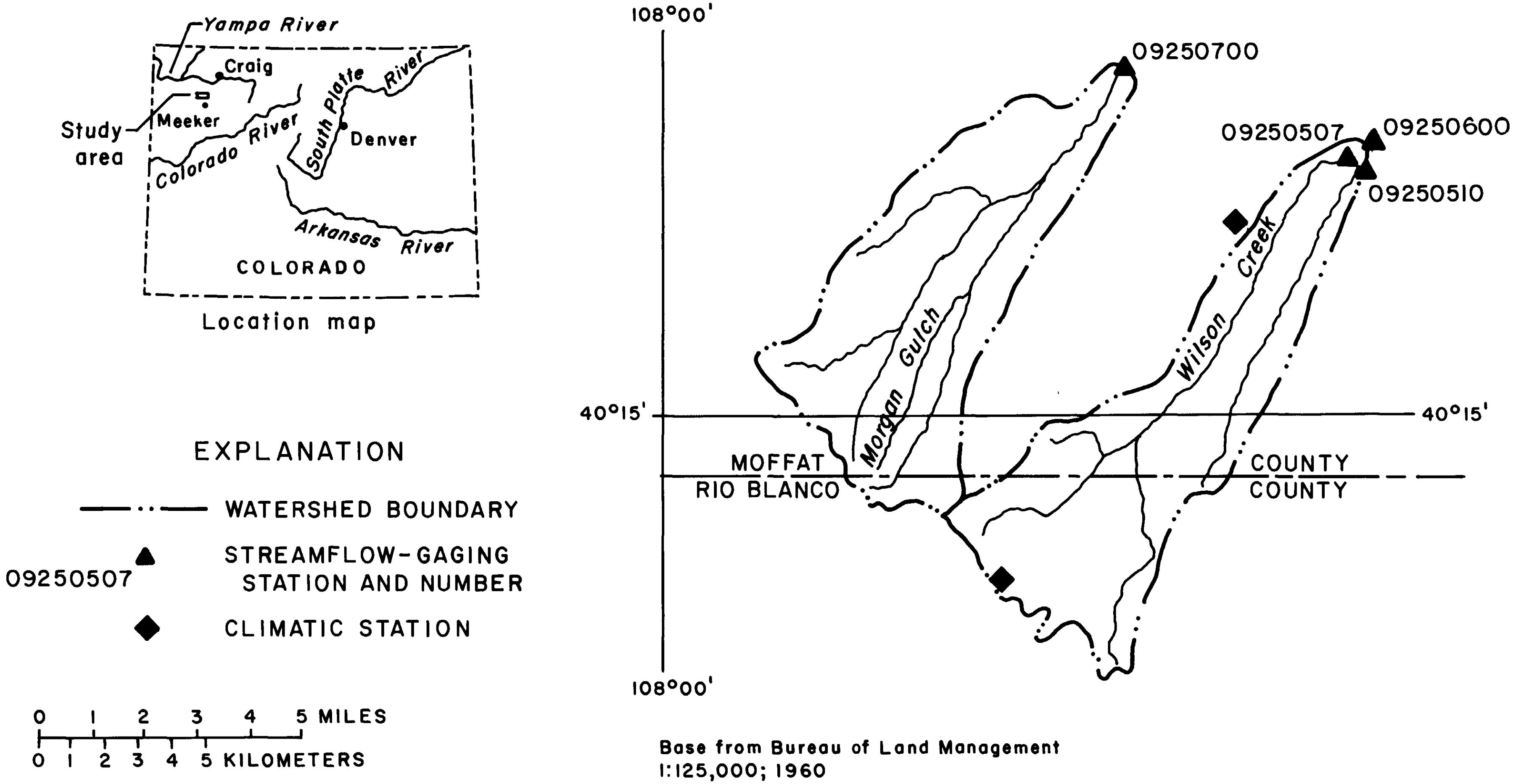


Figure 6.--Morgan Gulch and Wilson Creek watersheds.

table 3. However, the gage on Wilson Creek was moved to Wilson Creek above Taylor Creek, near Axial (station 09250507) in September 1980. By adding the discharge from Taylor Creek at mouth, near Axial (station 09250510) to Wilson Creek above Taylor Creek, an approximate comparison can be made of the discharge from the Wilson Creek watershed with that of the Morgan Gulch watershed. Thus, the total discharge for the Wilson Creek watershed was 12 percent less than Morgan Gulch for the 7 months of concurrent record (277 cubic feet per second-days for Morgan Gulch and 243 cubic feet per second-days for Wilson Creek), which lends support to the above assumption.

A comparison of actual discharge and the initial simulation of discharge for Morgan Gulch is shown in figure 7. With the exception of the high peaks in March and April, the initial simulation discharge was about two to three times greater than the actual discharge. The total predicted flow for the period of record, November through May, was about 350 percent greater than the actual discharge (table 4). This large error does not meet the Bureau's degree of accuracy for any water-resources information requirement shown in table 1. However, the period of record was for a dry period and discharge was very small which makes comparison on a percentage basis misleading. The actual difference between the actual and simulated discharge was 1.36 inches of runoff from the watershed. In addition, the predicted flow of Morgan Gulch for water years 1979 and 1980 was only about 40 to 80 percent greater than the actual discharge in Wilson Creek (table 3). In this instance, the model could have been used to predict flow conditions without the benefit of discharge data. The results meet the degree of accuracy needed by the Bureau to write the Resource Management Plan Environmental Impact Statement and the Regional Coal Environmental Impact Statement but fail to meet the requirements for the site-specific analysis (table 1).

After the initial simulation, several weeks were spent calibrating the model to more closely represent actual runoff conditions in Morgan Gulch. Because there were so few discharge data available for Morgan Gulch, the total annual discharge of Wilson Creek was assumed to be similar to that of Morgan Gulch for water years 1979 and 1980. Calibration of the model on such sparse data is questionable, but no other data were available.

A comparison of actual discharge for Morgan Gulch and the calibrated discharge for Morgan Gulch is presented in figure 8. The total predicted discharge for November through May was 24 percent greater than the actual discharge (table 3). The predicted discharge calibrated for Morgan Gulch was 7 percent less for water year 1979 and 69 percent more for water year 1980 than the actual discharge in Wilson Creek (table 3). These predictions fit within the high and medium categories of accuracy in table 1. Predictions of surface-water discharge in Morgan Gulch using the calibrated simulation discussed above meet all of the environmental-assessment requirements of the Bureau's planning and coal-leasing process.

Table 3.--*Comparison of Wilson Creek and Morgan Gulch watersheds*

	Wilson Creek	Morgan Gulch
U.S. Geological Survey station No.----	09250600----------------------	09250700.
U.S. Geological Survey station name---	Wilson Creek near Axial-------	Morgan Gulch near Axial.
Period of record----------------------	October 1974 to September 1980	November 1980 to May 1981.
Drainage area-------------------------	26.9 square miles-------------	26.5 square miles.
Maximum elevation---------------------	8,600 feet--------------------	8,400 feet.
Drainage direction--------------------	northeast---------------------	northeast.
Major vegetation types----------------	Aspen, oakbrush, sagebrush----	Aspen, oakbrush, sagebrush.
Average annual precipitation----------	15 inches---------------------	15 inches.

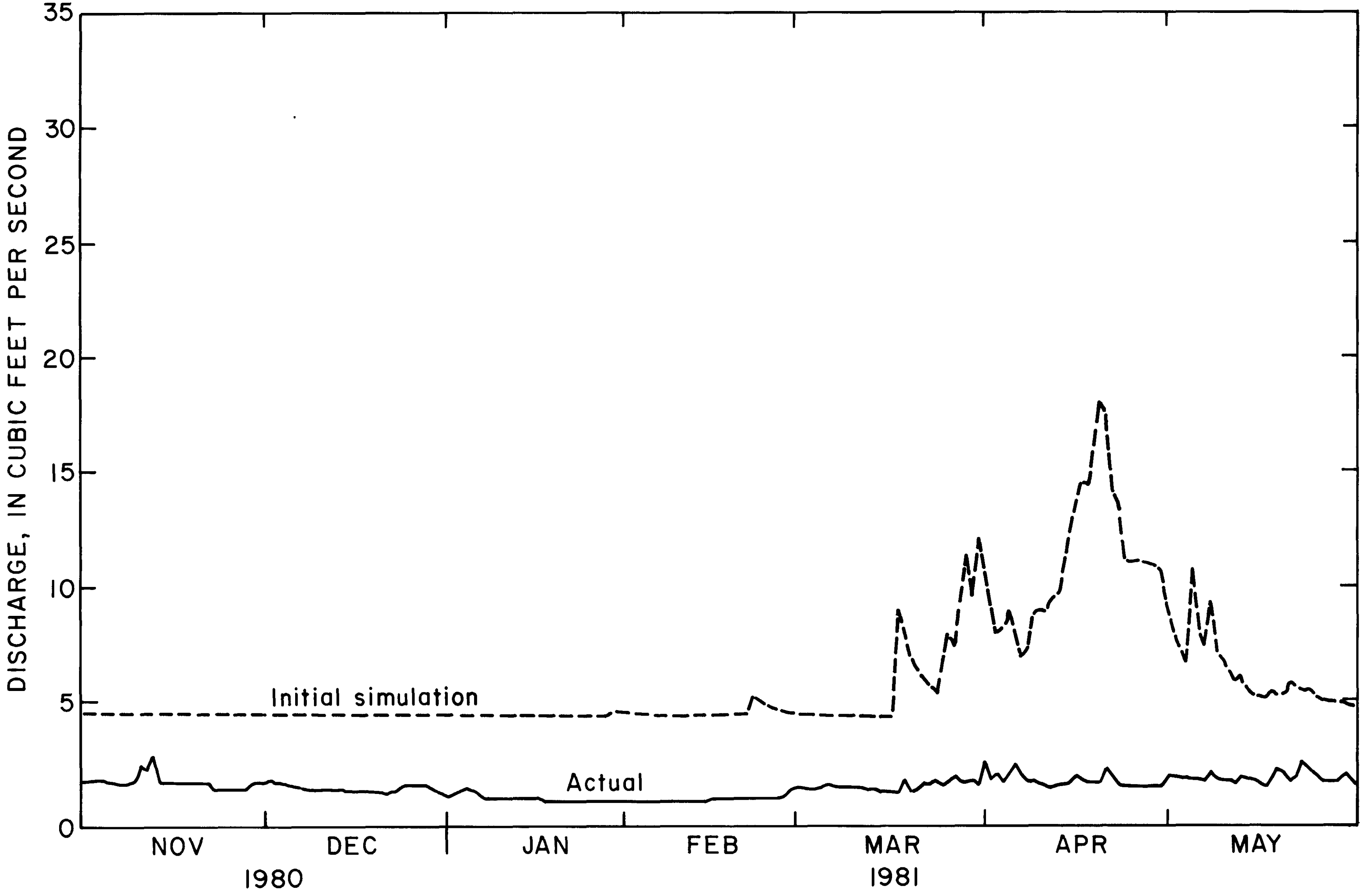


Figure 7.--Comparison of the actual discharge of Morgan Gulch with the initial-simulation discharge.

Table 4.--*Comparison of actual annual discharge with three simulated discharges of Morgan Gulch*

[$ft^3/s \cdot d$,=cubic foot per second-days]

Water year	Total annual discharge						
	Actual discharge ($ft^3/s \cdot d$)	Original input parameter		Calibrated parameter		Regionalized parameter	
		($ft^3/s \cdot d$)	Percent difference	($ft^3/s \cdot d$)	Percent difference	($ft^3/s \cdot d$)	Percent difference
1979	[1]1,400	1,980	41	1,300	-7	475	-66
1980	[1]1,555	2,775	78	2,630	69	980	-37
November 1980 to May 1981	277	1,240	347	345	24	390	41

[1]Actual discharge of Wilson Creek. Discharges of Morgan Gulch and Wilson Creek are assumed to be similar.

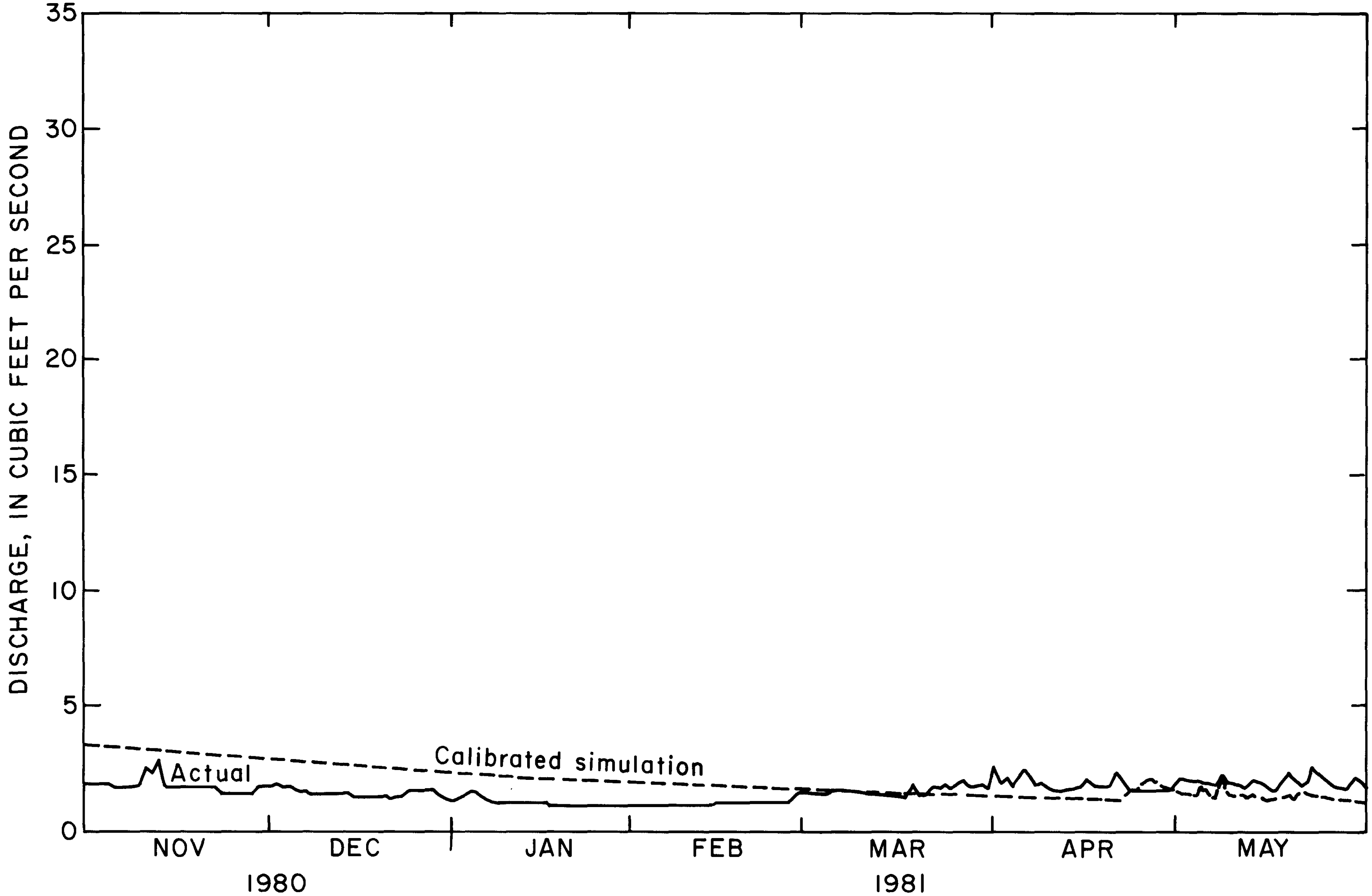


Figure 8.--Comparison of the actual discharge of Morgan Gulch with the calibrated-simulation discharge.

For several years, the Survey has been developing regionalized input parameters (primarily SMAX--maximum available water-holding capacity of the soil profile) for use in the model for predicting runoff from ungaged basins. As an additional check of the model for Bureau purposes, regionalized input parameters were obtained for the region surrounding Morgan Gulch (R.S. Parker and J. M. Norris, U.S. Geological Survey, oral commun., 1981). A comparison of the actual discharge of Morgan Gulch and the discharge predicted using regionalized parameters is presented in figure 9. The total predicted discharge was 41 percent greater than the actual discharge in Morgan Gulch. The predicted discharge was 66 percent less than the actual discharge of Wilson Creek for water year 1979 and 37 percent less for water year 1980 (table 3). The error of these predicted values fits within the medium category of accuracy described in table 1 and would meet most of the Bureau's planning and coal-leasing requirements. However, in this instance, the degree of accuracy is only marginally adequate for a site-specific analysis.

The three methods of deriving model parameters discussed above are adequate for most of the Bureau's planning and coal-leasing requirements. Deriving model parameters from data in the literature with no knowledge of discharge from a basin produces results that can be used by the Bureau, but the results are not as accurate as desired. As expected, calibration of the model parameters to fit actual surface discharge produced the most accurate results. Although the results of the calibration seem reasonable, using 7 months of actual data in Morgan Gulch and 2 years of actual data in an adjacent watershed (Wilson Creek) for calibration does not produce the best product. With only 7 months of actual data, there is no way to determine how accurately the model was calibrated for years with greater or lesser discharges. It would have been better to calibrate the model using more actual data from Morgan Gulch.

Regionalized model parameters are more than adequate for describing existing surface discharge in ungaged basins required by the Resource Management Plan Environmental Impact Statement and the Regional Coal Environmental Impact Statement. However, using regionalized parameters to produce information for the site-specific analysis is only marginally adequate in this instance.

During the process of learning how to apply the Survey's precipitation-runoff model, several problems were identified:

1. Although the unpublished User's manual describes how to delineate HRU's and set up a data deck, without previous experience, proper delineation of HRU's and choosing of reasonable input variables would be difficult at best. The User's manual seems to be directed toward an experienced user rather than a novice. For example, the manual does not contain a complete list of acronyms or definitions of terms. Also the units used in the output tables are not defined. Without these types of information, a novice must depend on the aid of an experienced user to run the model.

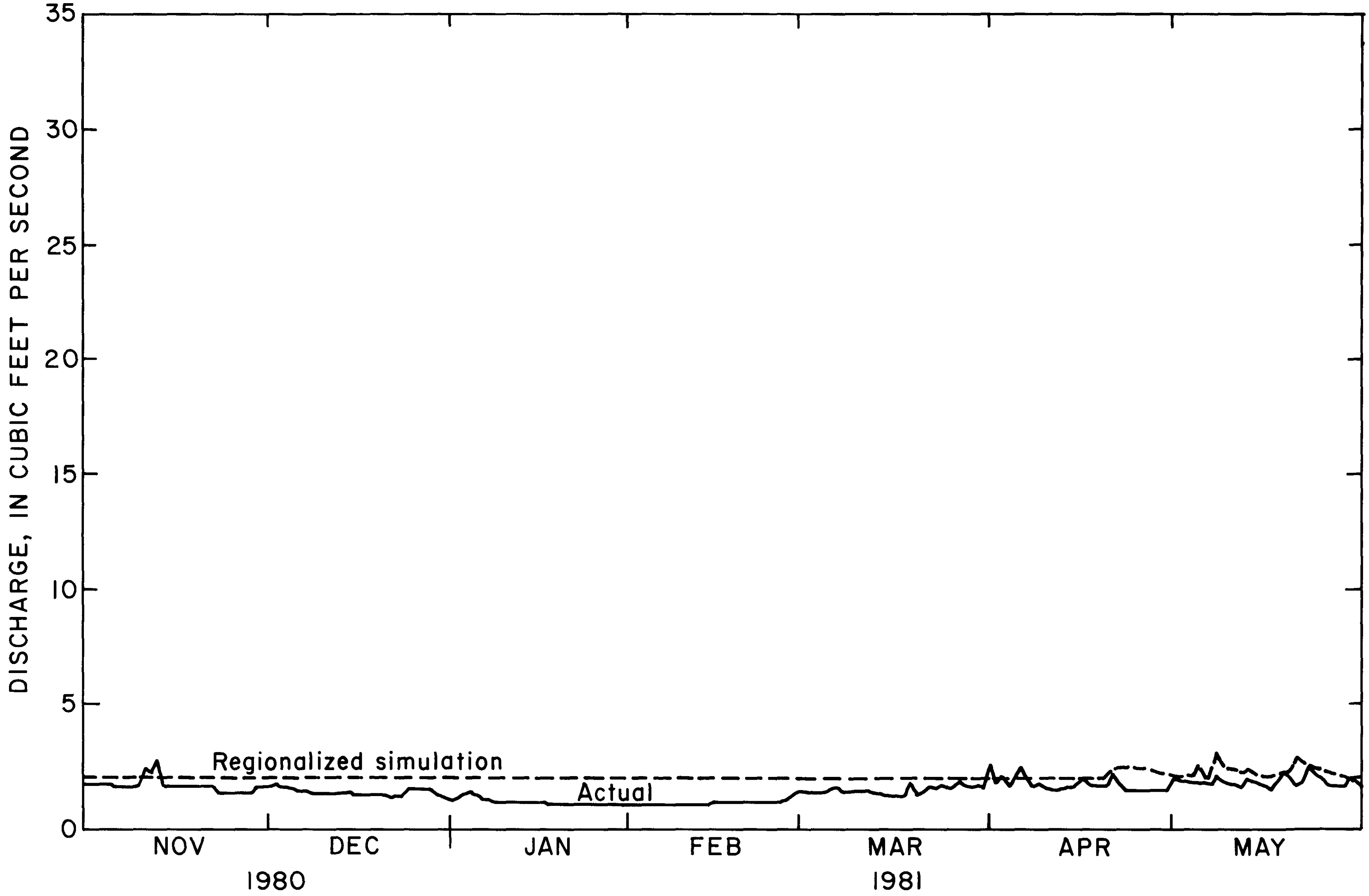


Figure 9.--Comparison of the actual discharge of Morgan Gulch with the regionalized-simulation discharge.

2. Considering the time allowed for Bureau hydrologists to meet environmental-assessment schedules and deadlines, it would not be practical for them to individually learn how to apply the model and use it in making the required analyses. Learning how to set up the model and how to communicate with a particular computer would probably consume most, if not all, of the allotted time. Also, application of the model, without direct access to an experienced user, would take much more time than described earlier in this section.

3. It would be desirable for a novice to calibrate the model on a gaged basin before trying to model an ungaged basin. By doing so, he would have a better understanding of the sensitivity of the model and would be better equipped to estimate the input variables for an ungaged basin. Unfortunately, this would add to the time described above and probably is not feasible.

4. Finally, one of the Bureau's major applications of the model would be to determine impacts of mining on a small watershed. Because there are no data available for premining and postmining conditions, application of the model for this purpose could not be verified. One of the major problems in trying to simulate postmining conditions is that the magnitude and direction of change of the more sensitive input parameters (maximum soil-moisture holding capacity and the subsurface and ground-water components) are unknown. However, by varying these sensitive parameters from best to worst case for increasing degrees of disturbance, the model user could gain some insight into what might be an acceptable degree of mining activity in a basin. Preliminary lysimeter data presently (1982) are being used to estimate some of the unknowns in the model to predict impacts of mining on stream discharge (R. S. Parker and R. S. Williams, Jr., U.S. Geological Survey, oral commun., May 1982). More intensive investigations could help to better define these unknown relationships.

FUTURE NEEDS

With increased emphasis on the development of domestic energy supplies, the demand for leasing public coal supplies may increase rapidly. As a result, the Bureau of Land Management already is faced with the task of evaluating the water resources of a large number of potential coal-lease tracts. Evaluations will, in all probability, have to be made more quickly than in the past.

Therefore, it is essential that all methods being developed or tools which potentially could be used for transferring surface-water and water-quality data to ungaged basins be perfected as rapidly as possible. In addition, tools which can predict impacts of mining activities on proposed lease tracts need to be perfected immediately. The tools, usually computer models or simple regressions, need to be as straightforward as possible and also need to be able to be used very quickly with minimum data requirements. More useful and more reliable methods for flood-plain mapping are needed to meet the requirements of the unsuitability criteria.

Development of some of the necessary predictive capabilities will require that research be conducted. There is a lack of knowledge about how mining changes components of the hydrologic cycle (such as soil moisture, shallow ground-water movement and storage, and surface-water quality).

Ground-water data collection and interpretation need to continue. However, the Survey needs to be given as much advance notice as possible about potential lease sites. For the most part, ground-water models cannot be developed and calibrated for specific sites with the data and within the time the Bureau normally has available. However, continued research is necessary to determine potential impacts of coal mining on water quality and ground water-surface water relationships. Information regarding these impacts usually is lacking during preparation of Environmental Impact Statements.

In the past, Bureau priorities for tract leasing have changed frequently. If leasing priorities do not become more stable in the future, it will continue to be difficult to coordinate coal-hydrology data-collection activities. However, if the Bureau keeps the Survey apprised of changes as they occur, the Survey can be more responsive to the Bureau's future needs.

There occasionally have been misunderstandings about the Bureau's data needs. The information given in tables 1 and 2 and shown in figures 4 and 5 could be used as guidelines and as a basis for discussions by the Bureau and the Survey whenever data-collection requirements are being determined for potential lease sites. The rainfall-runoff model requires a considerable volume of data that generally is difficult to estimate without some experience in the use of the model. For the model to be most effective, the Bureau needs to assign one individual in a central location the responsibility of becoming completely familiar with the use of the precipitation-runoff model for the regions for which it has been calibrated. That individual would be responsible for responding to modeling needs of Bureau hydrologists involved in the planning and coal-leasing process.

Survey project personnel need to become familiar with the preparation of coal Environmental Impact Statements and the hydrologic analyses required for the leasing of coal. By doing so, they could include in their reports more interpretive information that would aid Bureau hydrologists and managers in completing the numerous tasks required during the leasing process.

Finally, a technical-evaluation committee consisting of Bureau and Survey hydrologists needs to be established to review progress, to evaluate needs on a continuing basis, and to provide guidance for the overall direction of the program.

CONCLUSIONS

This report briefly summarizes the U.S. Bureau of Land Management's planning and coal-leasing process and the water-resources data required during the process. Water-resources data requirements vary, depending upon the phase of the process and the particular area being considered. Collection of water-resources data by the U.S. Geological Survey for the Bureau's coal-hydrology program has been essential for Environmental Impact Statement preparation and decisionmaking. However, because of the variability of data requirements from site to site and within the planning and coal-leasing process, it occasionally has been difficult to obtain the right data in the right detail at the right time for a given site.

Ideally, Bureau hydrologists and managers would know everything there is to know about surface water, ground water, water quality, and water uses before they prepare Environmental Impact Statements or make decisions. Realistically, they can do almost as good a job with more limited information. The Bureau's water-resources information needs are listed in table 1. The relative importance of each type of information listed in the table may be necessary, desirable, or optional, and the degree of accuracy needed for each major phase of the planning and coal-leasing process ranges from low to high. Water-quality data requirements depend upon the proposed use of the water, as shown in table 2, but the design of a water-quality data-collection network needs to vary from site to site (figs. 4 and 5).

There are three major components of the planning and coal-leasing process that require analysis and interpretation of hydrologic data: (1) Resource Management Plan Environmental Impact Statements; (2) site-specific analyses, and (3) Regional Coal Environmental Impact Statements. Because land-use decisions are based in part upon information presented in these documents, the information needs to be presented in terms that are meaningful to the managers. In general, existing conditions are compared against known standards and impacts are compared against existing conditions or known standards so that managers will know what the effects of a proposed action might be.

In areas where there are no data, interpretations commonly are based on information transferred from similar areas. The precipitation-runoff model being developed by the Geological Survey presently (1982) is capable of using data transferred from gaged watersheds to estimate stream discharge in an ungaged watershed with an accuracy sufficient for preparation of Environmental Impact Statements. However, for site-specific analyses, more data are necessary to predict runoff within the accuracies desired by the Bureau. The model generally is not suited for use by individual Bureau field hydrologists within the short time limits with which they have to work.

Runoff is only one part of the water-resources information required for analysis by Bureau hydrologists. They not only need to be able to transfer surface-water, ground-water, and water-quality data to ungaged watersheds, but they urgently need tools that will predict water-resources impacts of land uses such as coal mining. Continued refinement of the precipitation-runoff model will help provide answers to some of the Bureau's questions, but more work needs to be done in connection with impacts of mining on water quality and relationships between ground water and surface water.

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