Chapter 5

Baseline and Monitoring Data

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CHAPTER OVERVIEW

Overall, the quantity and quality of data collected for reclamation planning have improved dramatically since the passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA). However, data-related problems still place important limitations on both reclamation in the field and the advancement of reclamation science. First, data inadequacies still exist for some aspects of reclamation. These usually are the result of limitations in current state-of-the-art data collection methodologies, rather than operators' failure to carry out the necessary data collection.

In some cases, natural obstacles limit operators' ability to collect reliable data on some parameters. The mobility and adaptability of wildlife make it unlikely that highly reliable data suitable for quantitative species population analyses ever will be available. Similarly, infrequent and unpredictable flow events in ephemeral streams and extremely long spoil-aquifer recharge times will limit the availability of these hydrologic data in the West. **These obstacles are unlikely to be overcome soon and reclamation planning will have to continue to adjust its methods to the uncertainties in these areas.**

We can reasonably expect other data inadequacies to be overcome soon. The lack of techniques for generating chemical data about overburden is a serious limitation on the ability to delineate overburden materials that may be detrimental to revegetation or postmining water quality. Operators are developing new sampling, sample preparation, and laboratory techniques so that they can identify unsuitable materials and keep them out of reconstructed root zones and postmining water tables as much as possible.

Second, **the lack of** coordination **in data collection is a serious obstacle to *regional* data compilation and analysis. This is particularly true in hydrology, for regional cumulative hydrologic impact assessments (CHIAS).** The three CHIAS completed to date on Western mining areas uncovered serious, but not prohibitive, data inadequacies. To be valid in the quantitative models used for these mandatory assessments of regional impacts, hydrologic data must be collected at the same time and with the same methods. Initial steps are being made toward the necessary standardization, but coordination of data collection efforts remains the exception rather than the rule.

The lack of standardized methodologies for collection of some data seriously limits their usefulness. The lack of standardized surface water quality collection methods, especially for ephemeral streams, limits the usefulness of these data in determinations of the probable hydrologic consequences (PHC) of mining, as well as in CHIAs. As discussed in chapter 7, this data gap also makes it difficult to apply hydrologic performance standards.

Wildlife is another discipline for which standardized data-collection methodologies are lacking. Wildlife baseline studies now emphasize the description and delineation of habitats, rather than data collection about animal populations. But standard methodologies for the quantitative characterization of the various physical and floral features of wildlife habitat are not available. Development of such methodologies is necessary for assessing wildlife impacts and designing mitigation measures. Standardization is particularly important for wildlife data of regional concern—as large mammal, raptor, and bird data are—because such data have many potential users.

A third, and equally important, concern is that **the quantity of data being collected has created serious data management problems for both regulatory authorities and operators. Data collection often outpaces analysis** in the current reclamation permitting and monitoring process. It is not uncommon for regulatory authorities to require data to be collected and submitted, but to have insufficient time and other resources to analyze or review it. Also, **data frequently are presented in a format that contributes to data management problems.** Except for more recent permits in Wyoming and Colorado, there is no standard format for the applications. This makes it difficult for potential outside users to find information.

In part due to these data management problems, and in part due to limited regulatory authority resources, monitoring data are not used consistently or effectively. These data must be collected so that both operators and regulators will know how reclamation is progressing and what changes are needed in the mining and reclamation plan. In many areas, however, the collection of monitoring data has become perfunctory. Only in Wyoming has the regular review of monitoring data become part of the State's annual permit review process. Even there, personnel are not available to analyze all monitoring data the operators submit. In addition, monitoring data are rarely accessible by computer, or even indexed, and therefore are very difficult to review.

OTA was unable to determine whether all baseline and monitoring data collected are necessary, or whether all necessary data are being collected. We did find, however, that data collection requirements usually are not derived from any systematic examination of data uses in the reclamation planning and evaluation processes. Except for wildlife data, there is no "scoping" process (similar to the process used to support an environmental impact statement) to identify necessary data. Furthermore, in some disciplines or jurisdictions, these requirements have not been reviewed or updated since approval of the initial regulatory programs. Since that time, operators and regulators have learned a great deal about what data are actually needed and used to plan and evaluate reclamation—lessons that may not be reflected in data requirements.

OTA did not find redundancy in data collection to be a significant problem *within* the mine permitting process. Data needed for permit applications are site-specific. Thus, data collected for other mine sites rarely provide more than background information for permit applicants and regulatory authorities. **As mining in the West expands and the amount of permit data available grows, however, Federal agencies and research groups may find themselves repeating the data collection efforts of permit applicants if the data in permit applications are not made more accessible and useful.**

BASELINE AND MONITORING DATA: USES AND COLLECTION REQUIREMENTS

Data on surface and groundwater hydrology, geology, soils, overburden, vegetation, wildlife, and other mine-site features and resources form the foundation of all reclamation planning and evaluation. These data may be divided into two broad categories. Operators collect **baseline data** before mining to aid in the formulation of the mining and reclamation plan that is submitted as part of the permit application package. Baseline data enable the operator to predict the impacts of mining and to define the postmining land use. [1] Operators collect **monitoring data** during and after mining and reclamation to track the impacts of mining and judge the success of reclamation, and to refine the mining and reclamation plan if necessary. Without enough valid baseline data, the techniques used to analyze the data will produce unreliable and misleading results. Without sufficient valid monitoring data, the success of reclamation cannot be evaluated.

[1] If mining began before implementation of the Federal and State regulatory programs under SMCRA, mines had to be repermitted under those programs, and operators usually undertook baseline studies soon after SMCRA was approved to support repermitting. Many of the case studies presented in vol. 2 describe older mines where baseline studies postdate the beginning of mining. See, for example wildlife case studies D and H, soils case D. But also note hydrology cases 3.7 and 3.18, where monitoring began before SMCRA.

This chapter surveys data collected for or used in reclamation planning and evaluation, with emphasis on data management, and data gaps or the collection of unnecessary data. The chapter reviews and compares regulatory requirements for data collection, both at the Federal level and within the five States in the study area. It identifies methods used to collect the required data and discusses the relative merits of and limitations of the various methods. Special attention is paid to disciplines in which good data are not being collected, either because current collection methods are inadequate or are not standardized, or because there are natural obstacles to the development of collection methods. Because this study was prompted in part by a criticism that much of the data collected at great expense are not used, or are not used optimally, special attention is also given to more efficient use and better accessibility of data.

Data collection methods and data-related problems are radically different in each of the reclamation disciplines. Hydrology is a highly quantitative discipline in which vast amounts of numerical data are collected and managed. Large quantities of numerical overburden data also are collected, but their analysis is a very young science and not all of the necessary techniques have been fully developed. Wildlife biology is a less quantitative discipline in which the mobility and natural variability of wildlife populations limits the ability to collect valid numerical data. Therefore, relatively few quantitative wildlife data are collected and their meaning is subject to varying professional interpretations. Vegetation science and data collection techniques are, by contrast, well established. Operators (and others) use so many different techniques for collecting each type of vegetation data, however, that aggregation of data for regional analyses is almost impossible.

Data collection requirements for each discipline are almost entirely State requirements, based on the general guidelines established in SMCRA and the Federal regulations (see ch. **4).** Thus, baseline and monitoring data requirements vary with the different environments, prevalent postmining land uses, and other concerns peculiar to each State. Some State requirements for some disciplines have changed since the Federal permanent regulatory program was first promulgated in 1979, and they are still changing. At the time of this writing, Montana and Colorado are revising their regulations and guidelines (7). The Montana and Colorado requirements discussed here are those in force as of April 1985. It should also be noted that a number of these regulations, including requirements for the scope of hydrologic data for PHC determinations and CHIAS, were challenged successfully in Federal court and must be rewritten by the Office of Surface Mining (OSM) and the States (see ch. 4, box 4-C).

SOURCES OF DATA

The surface mining and reclamation permitting and evaluation processes outlined in chapters 4 and 7 are very data intensive, and permit applicants and regulatory authorities turn to a wide range of data sources to meet SMCRA'S data collection requirements. As companies first begin to prepare a mining and reclamation plan, they compile data available in the published literature or in the files of various Federal and State agencies. These data are then supplemented with site-specific field data collected to support the permit application package. Data collected by the operators during mining and reclamation monitor the progress of reclamation and serve as the basis for evaluating reclamation success.

Data Collected Outside of the Permitting Process

in fulfilling data requirements for surface mining permits, operators naturally turn first to existing sources of data. The U.S. Geological Survey (USGS), the Bureau of Land Management (B LM),[2] the U.S. Fish and Wildlife **Service (Fws),** the Soil Conservation Service (SCS), State fish and game and other agencies, university researchers, and many other groups collect data on the soils, geology, hydrology, vegetation, wildlife, and

[2] BLM's Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) reports maybe particularly helpful as general compendia of data on all resources on a particular lease tract; see ch. 9.

other resources of the Western coal regions for their own purposes. These data may also be useful in planning surface mine reclamation. in addition, the data in the permit application for one surface mine may be helpful in permitting at nearby mine sites. Making maximum use of such sources of data is in everyone's interest. It saves time and money for operators and contributes to the efficiency of the permitting process.

However, data collected outside the permitting process will not meet all of the requirements for the permit application package, and their usefulness to applicants varies. Sometimes data may be directly useful and operators may even include them in permit applications. These include USGS geologic and hydrologic data and SCS soils data, although even these usually must be augmented to meet State requirements for site-specific data. Other data, such as most of the available vegetation and wildlife data, are helpful only as the most general background information, but may provide a starting point and guide for an operator's own data collection efforts.

There are several reasons that data collected for other purposes are of limited usefulness to permit applicants. First, **the intensity and areal extent of the data rarely are compatible with permit requirements.** Most regional data are too few over too large an area to fulfill permitting requirements. They can, however, give a preliminary profile of the mine site and surrounding area, and thus may highlight potential reclamation problems or other factors that need special attention in site-specific data collection and analysis. Conversely, data from academic or independent research projects are often too intense over too small an area to be directly useful as permitting data.

Second, **quality control problems exist with many of these data.** They may have been collected improperly or with techniques not approved by the regulatory authority. Third, **the data may be inaccessible.** Some data are proprietary (e.g., exploration data on coal resources submitted to BLM and OSM). Other data are simply in unmanageable formats. Accessibility limits the usefulness of most available data to at least some degree. Few of the existing data related to surface mining are accessible by computer; most have not been published. Perhaps the best example of valuable but relatively inaccessible data are the permit applications, themselves (see box 5-A).

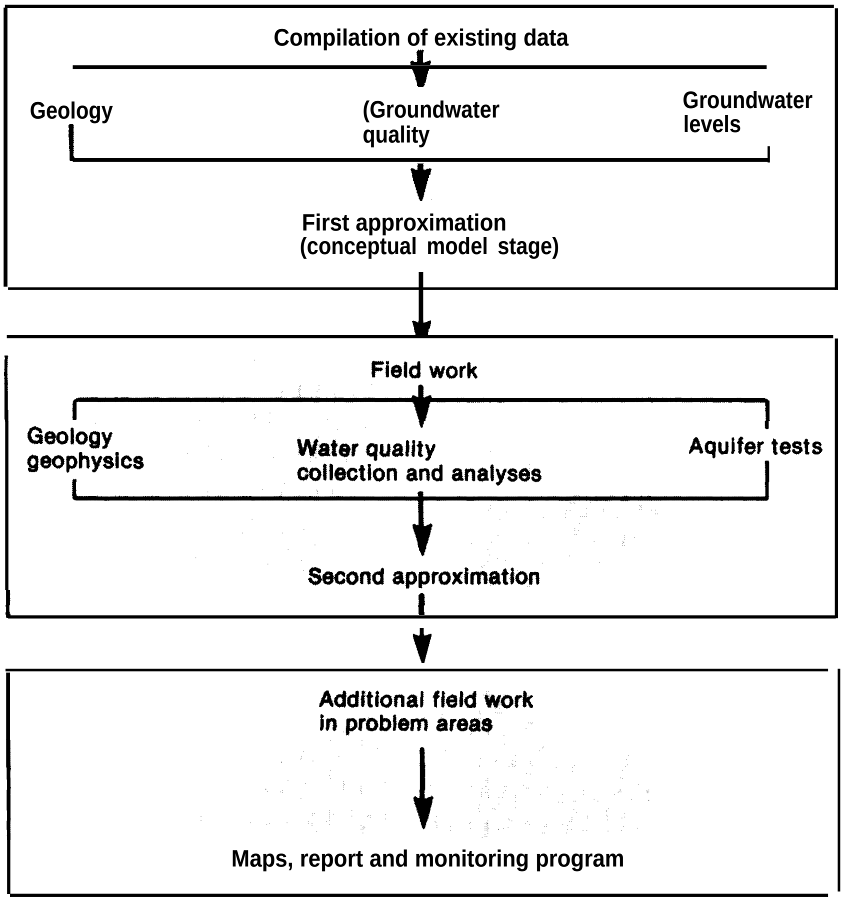
Collection of Site-Specific Data by Operators

Despite their limitations, data collected outside the permitting process often allow permit applicants to make a preliminary outline of a mining and reclamation plan. Using this first, very rough plan, an applicant can identify data needs for permitting and reclamation planning more precisely, and thus can design more intensive, site-specific,

Box 5-A.—Use of Data in Permit Application Packages

Permit application packages for other surface mines in an area have the potential to be one of the most useful sources of preexisting data for permit applicants. While data from one mine's permit cannot be substituted for the site-specific data necessary for permitting a new mine, they can be invaluable inputs into the analyses required in permit applications; for example, correlations of toxic strata in overburden, groundwater quality and quantity calculations, analyses of wildlife impacts. However, permit applicants rarely use these applications, primarily because the format of the data and of the applications themselves poses a formidable obstacle to efficient utilization. Permit applications have grown in size over the past several years so that, on average, they consist of 25 to 30 three-inch thick three-ring binders lined up on shelves in OSM and State regulatory authority offices. The data in the applications are not accessible by computer, or reduced in any way. With the exception of more recent applications from Wyoming and Colorado, there is no standard format for organization of the permit application packages or for presentation of data and analyses. The lack of specified formats is compounded by the absence of any sort of "scoping" process for data collection, which frequently leads to permit applicants' collecting more data than actually are needed to support the demonstrations required in SMCRA.

Figure 5-1 .-A Conceptual Approach to Hydrogeologic Investigations



SOURCE: National Research Council, *Coal Mining and Ground-Water Resources in the United States* (Washington, DC: National Academy Press, 1981) p. 153,

data collection programs. As these site-specific data are collected for permitting, the mining and reclamation plan is continually refined. This refinement continues after the onset of mining, as monitoring data yield additional information that is incorporated into the plan. Figure 5-1 illustrates this refinement process for hydrogeology; the process in other disciplines is similar.

A common, and sometimes unavoidable, shortcoming of baseline studies is that they provide only a snapshot of premining conditions over a narrow period of time. The narrow temporal focus of baseline data can be particularly problematic in assessing hydrology, vegetation, and wildlife, which may vary greatly over time with climatic and other conditions or natural succession processes. Mining impacts and reclamation success can only be evaluated if some idea of the range of natural variation in these disciplines has been established in the baseline surveys.

In some instances, data collection over the time required to document the full range of this natural variation is impractical. For example, for obvious statistical reasons, baseline studies are unlikely to document a 25-year, 24-hour flow event in an ephemeral stream. Similarly, baseline studies are unlikely to document either the natural vegetative succession on the site or the effects of long-term climatic cycles, Other *significant* variations over shorter periods of time, particularly seasonal variations, can and should be documented with baseline data, however. Ways of compensating for lack of actual data on long-term variations are discussed in chapter 6.

As with baseline data, monitoring data must be collected over sufficient periods of time to account for the range of natural and seasonal variations. Some amount of monitoring is mandated under the regulatory programs and/or stipulated by regulatory authorities in permit approvals. Also, operators often undertake monitoring programs on their own initiative to help them plan their operations and identify any reclamation problems early, when correction of those problems may still be relatively simple and inexpensive.

SOILS AND OVERBURDEN

Data Requirements

State and Federal data collection requirements for soils and overburden are summarized in table S-I. All five States require a soil map at about the same scale, and Montana, New Mexico, and Wyoming describe the level of detail of required mapping in their guidelines. The minimum size of soil units that must be mapped varies from 0.5 to 2 acres. Soil sampling, which is important in the characterization of soil chemistry, varies from one to six profiles required per mapped unit. Requirements for chemical and other analyses of samples differ somewhat, but all States require analyses for pH, electrical conductivity (EC), moisture content saturation (Sat percent), sodium adsorption ratio (SAR), and texture.

Four of the five States require geologic maps showing both coal croplines and dip. All five require cross-sections showing the seam(s) to be mined, any thin seams above or below the coal to be mined ("rider" seams), and the underburden (see fig. **5-7,** below). All five States also require lithologic logs of overburden drilling, but only North Dakota requires geophysical logs.

All of the States studied except North Dakota have guideline suggestions for chemical analyses of selenium, boron, and acid-base potential.[4] Each of these four States also defines, in rules or guidelines, required trace element tests. Wyoming did require quality assurance samples for overburden analytical work so that analyses could be spot-checked and verified by another lab, but recently rescinded this requirement.

All five States require the identification of potentially acid-, alkaline-, and toxic-forming zones of overburden that may adversely affect revegetation or postmining water quality, but only in Wyoming do the cross-sections have to show these zones. These cross-sections can be difficult to prepare because the zones may not occur in predictable, mappable units. Also, the scale of cross-sections is so large relative to the scope of potentially deleterious zones that the zones do not appear (see ch. 6).

Overburden drilling is the method used to characterize overburden and to determine the location and extent of deleterious strata. Required intensity for overburden drill holes ranges from one hole per 40 acres in Montana, North Dakota, and Wyoming, to one hole per 640 acres in Colorado. **The changes in lithology and geochemistry over short distances in many of the Western coal regions, particularly the Powder River basin, have spurred considerable debate about whether higher intensity drilling results in more accurate overburden characterization. Available data suggest that the accuracy of unsuitability characterization is not much better at one hole per 40 acres than at one hole per 640 acres.** One study found that an extremely high (and very expensive) intensity of 195-foot spacing between drill holes (or slightly over one hole per acre) would be required to predict the occurrence of deleterious strata in overburden with 80 to 90 percent accuracy (4). Not all mine sites are so geologically variable, however, and, at those that are,

[3]Unless otherwise indicated, the material in this section is adapted from reference 13.

[4]Mines in the Fort Union region of North Dakota may have highly sodic clays in the overburden, but the requirement for **4** feet of suitable cover over all spoils in that State is considered sufficient to protect the root zone.

Table 5-1.—Selected Requirements for Baseline Studies

Item	Federal (30 CFR 700.1 1984)	Colorado (MLRD 1981 and MLRD 1983)	Montana (DSL 1980 and DSL 1983)	New Mexico (MMD 1980 and MMD 1984)	N (ND N
Soils:					
Map, base map requirements	yes (R-770.21)[a]	yes (R-2.04.9)	yes; 1″=400′ (G-I,B.2)[b]	1″=500′ min.(G)	yes; 1′ (R-69-0
Minimum size map unit delineation	not addressed	not addressed	1 acre minimum (G-I,B.1)	½ acre minimum (G)	not add
Sampling intensity	not addressed	based on complexity (R-2.04.9)	3 representative locations (G-I,D.2)	up to 6 profiles (G)	not add
Depth of sampling	not addressed	not addressed	7 ft (G-I,D.1)	6 ft (G)	up to 5 ft
pH, EC, Sat%, texture	not addressed	yes [R-(1)(b)]	yes (R-26.4.304)	yes (G)	yes (R-69-(
SAR, ESP	not addressed	SAR (R-2.04.9)	SAR, ESP (G-I,E)	SAR (G)	SAR, ESP (R-60.05.2-(
Se, B	not addressed	not addressed	Se, B (G-I,E)	Se, B (G)	not addres
Trace metals	not addressed	not addressed	not addressed	Mo, Cu (G)	not addres
Other	not addressed	other chemical analysis as required (R-2.04.9)	% OM (G-I,E)	$CaCO_3$ (G)	free lime % %OM (R-69 -08-10)
Overburden:					
Geologic map coal crop lines, strike-dip	yes (R-779.25)	yes (R-2.04.6)	not specified	yes (R-8-25)	yes (R-69-05
Overburden isopach map	not specified	not specified	not specified	not specified	yes (R-69-05
Cross-sections; mined seams, rider seams, underburden	yes (R-779.25)	yes (R-2.04.6)	not specified	yes (R-8-25)	yes (R-69-05
Drill hole intensity	not specified	1 hole/640 acres, 3 holes minimum (G-table 3. B.1.)	1 hole/40 acres, more for suspect areas (G-III, D.2)	1 hole/150 acres, minimum of 3 holes; (G)	1 hole/40 a (R-69-05.2-0
Sample interval	not specified	4 to 10 ft (G-table 3.B)	not specified	2-10 ft (G)	5 ft (R-69-0
Quality assurance split sampling	not addressed	not addressed	not addressed	not addressed	not addres

II,B) (recently omitted)

Table 5-1.—Selected Requirements for Baseline Studies From Regulations and Guidelines—Contin

Item	*Federal* (*30* CFR 700.1 1984)	*Colorado* (MLRD 1981 and MLRD 1983)	*Montana* (DSL 1980 and DSL 1983)	*New Mexico* (MMD 1980 and MMD 7984)	*North Dakota* (NDPSC 1983 and NDPSC 1984)	*Wyoming* (WDEQ 1980 and WDEQ 1984)
Lithologic logs	yes (R-780.22)	yes (R-2.04.6)	yes (G-I II, C.31)	yes (R-8-14)	yes (R-69-05.2-08-05)	yes (G-11)
Geophysical logs	not specified	not specified	not specified	not specified	yes (R-69-05.2-08-05)	1 geophysical log/1,000 ft (G-II,B)
Identify acid and toxic forming strata	yes (R-780.22)	yes (R-2.04.6)	yes (R-26.4.304)	yes (R-8-14)	ǀ.304) yes (R-8-14)	yes (R-69-0!
ESP, SAR	not addressed	SAR (G-table 3.A)	ESP, SAR	SAR (G)	SAR (R-69-05.2-08-05)	SAR (G-appendix 1)
Se, B	not addressed	Se, B (G-table 3.A)	Se, B (G-111 D.5)	Se, B (G)	not addressed	Se, B (G-appendix 1)
ABP, sulfur forms	not addressed	pyritic, sulfate, organic, total (G-table 3. A.)	ABP may be requested (G-111, D.5)	ABP (for some sampies) G SO, (R-8-14)	not addressed	ABP (G-appendix 1) organic carbon
Trace elements	not addressed	Mo, Pb, As, Cd, Fe, Mn, Cu, Hg, Zn (G-table 3.A.)	Mo (G-111, D.5)	Al, As, Ba, Cd, Cr, Co, Cu, Cn, Fe, Pb, Hg, No, Ni, Ag, So-4, U, V, Zn, Ra-226, Ra-228 (R-8-14) Mo, Cu, (G)	not addressed	As, Mo (G-appendix 1)

[a]R—denote~ topic addressed in regulations and the numbers following designate where it is discussed.
[b]G—denotes topic addressed in guidelines and the numbers following designate where it is discussed. The Montana Guideline has recently been rescinded.

SOURCE: James P. Walsh & Associates, "Soil and Overburden Management in Western Surface Coal Mine Reclamation," contractor report to OTA, August 1985.

economically realistic drilling intensities can at least identify parameters of concern and indicate areas where more intensive drilling might be appropriate.

The sampling densities needed for adequate postmining spoils monitoring also are in dispute. The Wyoming Department of Environmental Quality has recently begun to investigate the statistical basis for required sampling densities (both vertical and horizontal) on regraded spoils to ensure the adequate delineation of unsuitable material (18). An analysis of regraded spoil data from one mine concluded that, to distinguish adequately between 6-acre parcels with 95 percent confidence, approximately three to five samples were needed for an adequate description of their differences in pH, salinity, and Sat percent (two samples at 80 percent confidence). Six-acre parcels could not be distinguished from one another when analyzing for acid-base potential. Similar analyses may be required for the parameters of concern at every mine to determine adequate sample densities for regraded spoils.

Sources of Previously Collected Data

Soil Conservation Service Soil Survey Reports are available for most of the coal fields and are used almost universally as the starting point for more intensive soil inventories on the mine site. The SCS data are collected according to a uniform National Cooperative Soil Surveys methodology. The reports include soil maps, descriptions of map units, soil series descriptions, typical pedon descriptions, s soil classifications, and limited chemical and physical data and interpretations. SCS soil surveys can be of five different orders, with first order surveys being the most detailed. Table 5-2 shows the criteria used for the different orders of surveys. Surveys available for potential mining sites are usually order two for cropland and order three for rangeland.

The U.S. Geological Survey is probably the most common source of background geologic data on regional geology, stratigraphy, and lithology, Data are readily available for virtually all coal regions. The quality of the published information is very high but the compilation and publication process is extremely slow. Open-file reports are available for projects in progress.

[5] A pedon is a three-dimensional body of soil with lateral dimensions large enough to permit the study of soil horizon shapes and relations; its area ranges from 1 to 10 square meters.

Data Collection by Operators

Because soils and overburden do not vary with seasonal and climatic changes, the data are not time-dependent and could be collected all at once. As a practical matter, however, both sets of data are collected in stages to optimize information gathering at reasonable cost. After examining the available SCS and USGS data, operators formulate a baseline data-collection program in consultation with the regulatory authority, and then collect the data according to methods described below. Using the baseline data, operators identify potentially unsuitable areas on their site. These areas receive special attention in subsequent sampling and sample analysis.

Unsuitability is more of a concern with overburden than with soil because the disturbance and consequent exposure of overburden to the surface environment causes physical changes as well as chemical reactions from oxidation and leaching. Yet data on the potential for such reactions are difficult to collect because the overburden is buried and because unsuitable materials may only occur in very isolated pockets. Soils, on the other hand, usually are more nearly in chemical equilibrium with the surface environment. While disturbance of soils prompts new chemical reactions, soil material has already been oxidized and leached. Therefore, such reactions in soils are unlikely to pose as much of a potential threat to the success of reclamation as, for example, oxidation of pyrites in overburden. Moreover, soils are easily observable and accessible, so unsuitable materials are relatively easy to delineate.

Soil baseline studies begin with a site-specific soil inventory, usually more detailed than the available SCS soil surveys. The intensity of inventories varies among States and mines, but most are detailed order two or general order one (see table 5-2). Scales for soil maps range from 1 inch equals 400 feet (1:4800) to 1 inch equals 800 feet (1:9600), as per State guidelines. The inventories typically include soil maps (fig. 5-2), map unit

Table 5-2.—Key for Identifying Kinds of Soil Surveys

Level of data needed	Field procedures	Minimum size delineation hectares[a]	Typical components of map units	Kinds of map units[b]	Appropriate scales for field mapping and publication	Kind of soil survey
Very intensive (i.e., experimental plots, individual building sites)	The soils in each delineation are identified by transecting or traversing. Soil boundaries are observed throughout their length. Remotely sensed data is used **as an** aid in boundary delineation.	1 or less	Phases of soil series, miscellaneous areas	Mostly consociations, some complexes	1:15,640 or larger	1st order
Intensive (i.e., general agriculture, urban planning)	The soils in each delineation are identified by transecting or traversing. Soil boundaries are plotted by observation and interpretation of remotely sensed data. Boundaries are verified at closely spaced intervals.	0.6 to 4	Phases of soil series; miscellaneous areas; few named at a level above the series	Consociations and complexes; some undifferentiated and associated	1:12,000 to 1:31,660	2nd order
Extensive (i.e., rangeland, forestland, community planning)	The soils are identified by transecting representative areas with some additional observations. Boundaries are plotted mostly by interpretation of remotely sensed data and verified with some observations.	1.6 to 256	Phases of soil series and levels above the series; miscellaneous areas	Mostly associations or complexes; some consociations and undifferentiated groups	1:20,000 to 1:250,000	3rd order
Extensive (i.e., regional planning)	The soils are identified by transecting representative areas to determine soil patterns and composition of map units. Boundaries are plotted by interpretation of remotely sensed data.	40 to 4,000	Phases of levels above the series; miscellaneous areas; phases	Mostly associations; some consociations, complexes, and undifferentiated groups	1:100,000 to 1:1,000,000	4th order
Very extensive (i.e., selections of **areas** for more intensive study)	The soil patterns and composition of map units are determined by mapping representative areas and applying the information to like areas by interpretation of remotely sensed ‘data. Soils are verified by occasional onsite investigation or by traversing.	1,000 to 4,000	Phases of levels above the series; miscellaneous areas	Associations; some consociations and undifferentiated groups	1:500,000 to 1:1,000,000 or smaller	5th order

[a] **This is about the smallest delineation allowable for readable soil maps. In practice, the minimum size delineations are generally larger than the minimum Size shown.**

[b] **Where applicable, all kinds of map units (consociations, complex, association, undifferentiated) can be used in any order of soil survey, end they are not identified as a particular order of map unit.**

SOURCE: Soil Conservation Service.

Figure 5-2.–Soil Map Legend and Portion of Soil Map

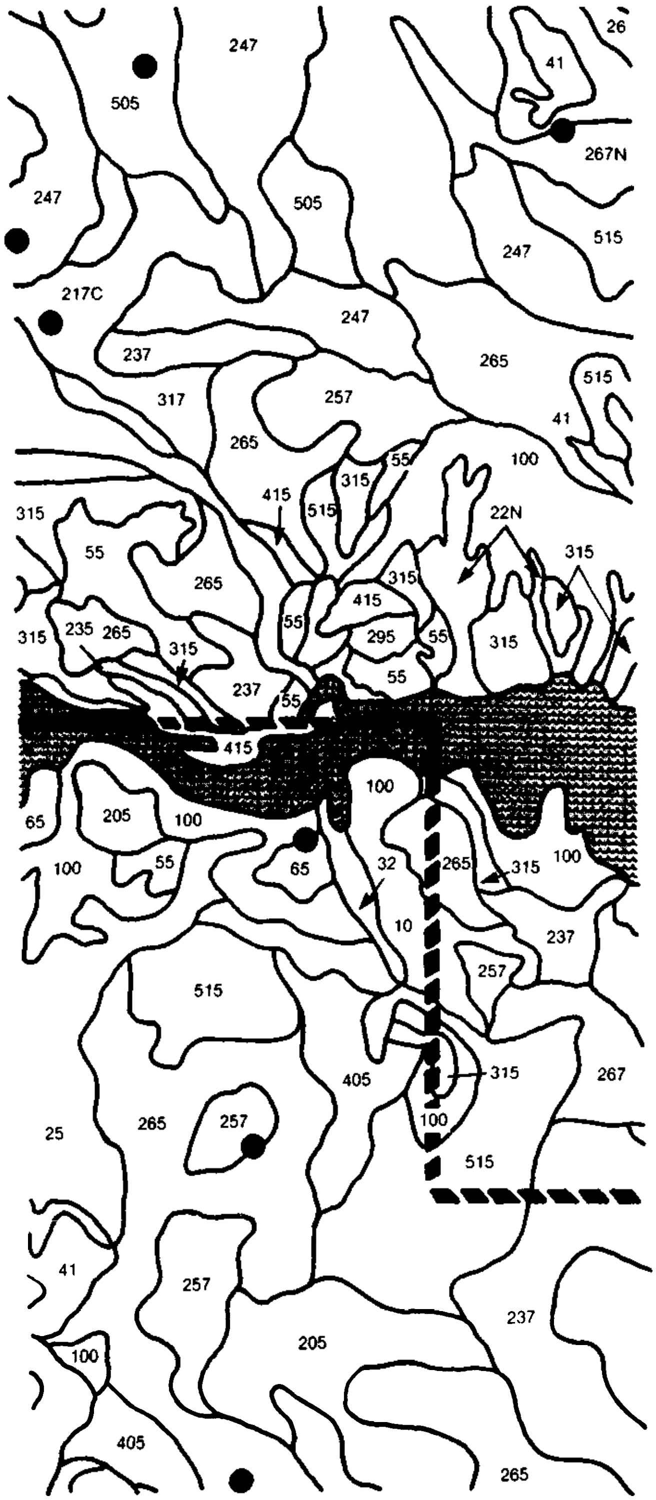
Soil classification legend

22	Kim clay loam
22s	Kimsal clay loam
22N	Nonkim clay loam
32	Limon clay loam
41	Samsil-Louviers complex
55	Single-shake complex
65	Thedalund loam
75	Wibaux channery loam
82	Reno clay loam
107	Tassle fine sandy loam
107N	Lessat fine sandy loam
117N	Embry fine sandy loam
121	Nomil clay
146	Dillingson very fine sandy loam
205	Cushman loam
217	Donkey fine sandy loam
217C	Donkman fine sandy loam
225	Fort Collins loam
237	Maysdorf fine sandy loam
247	Olney fine sandy loam
247N	Yenlo fine sandy loam
257	Pugsley fine sandy loam
257C	Pugman fine sandy loam
265	Renohill loam
267	Renohill fine sandy loam
267N	Rencalson fine sandy loam
295	Ulm loam
297	Ulm fine sandy loam
307N	Vonson fine sandy loam
315	Thunder loam
315C	Worfka loam
317	Thunder fine sandy loam
325	Worf loam
405	Abstinate loam
405P	Abstinate loam, ponded phase
407	Abstinate fine sandy loam
415	Absted loam
415N	Abman loam
417	Absted fine sandy loam
505	Bidman loam
505P	Bidman loam, ponded phase
515	Briggsdale loam
100	Shallow entisols
200	Porcelinite outcrops and very shallow soils
SL	Rockland, sedimentary rock
CUT	Structural cuts and fills

● Sampling locations
soil profile description locations

Reservoir

Scale 1“ = 1000’



SOURCE: ELM District Office, Casper, WY, personal communication descriptions (fig. 5-3), series descriptions, pedon descriptions (fig. 5-4), and a map legend.

One minor shortcoming was common in the soil surveys included in the permit applications OTA reviewed. Typically up to three soil phases made up most of each map unit with one or two other phases being minor inclusions. However, rarely did the application include an estimate of the percentage of the unit constituted by each major component and each inclusion. This omission would affect the accuracy of any volume calculation made from the soil survey because the various inclusions have different stripping depths.

Following the survey, soils are sampled for laboratory analysis of their chemical composition. Sampling intensity varies and in several States is specified by guidelines or regulations. Most often between one and three vertical profiles of the soil are taken in each type of mapped unit. The profiles are then sampled by horizon, usually with more detailed sampling in the upper horizons. Samples are tested for a fairly standard set of agronomic properties that typically includes pH; EC; SAR; Sat percent; percent organic matter (OM); and percent sand, silt, and clay. Tests for trace elements, boron (B) and selenium (Se), are often run on salty soils. Tests for nutrient elements such as nitrogen, phosphorus, and potassium (N, **P,** and K) also may be run during baseline studies, although they are more useful if run prior to reseeding. Standard procedures for all of these tests have been published by the U.S. Department of Agriculture (USDA) (1 1). Even using standard techniques, however, variations in the results of the same test on the same sample run by different labs can be significant for some chemical parameters. b

Figure 5-3.—Example of a Soil Map Unit Description

125—Armolls channery sandy loam, 20 to 35 percent slopes

These are deep, welldrained soils on ridges and sideslopes throughout the permit area at elevations of 3,200 to 3,450 feet. They developed in residuum weathered from fractured Fort Union sandstone. Average annual precipitation ranges from 13 to 19 inches, and the frost-free season is typically 110 to 125 days. Mean annual soil temperature ranges from 42 to 46° F. Slopes are moderately steep to steep.

Typically the surface layer is brown or reddish brown calcareous channery sandy loam about 4 inches thick. The upper part of the substratum is brown or reddish brown calcareous very channery sandy loam about 8 inches thick. The lower part of the substratum is reddish yellow calcareous very channery sandy loam to depths of 60 inches or more. In some profiles the surface layer is leached of calcium carbonates. Coarse fragments comprise 35 to 75 percent of the soil, by volume. The unit is typical of the series.

Permeability is moderately rapid. The available water holding capacity is low. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is slight from wind and water. The unit is in pine woodland with an understory of native range.

Land Capability Classification: VIls

Topsoil Suitability

This unit is unsuited to use as a source of topsoil because of its high content of coarse fragments.

Prime Farmland Considerations

The Armolls soil falls outside the scope of prime farmland criteria on the basis of its steep slopes, arid moisture regime, and stoniness.

Post-Mining Erosion Hazards

Depending on the size and amount of coarse fragments, this soil may be spread over a wide area, which would essentially eliminate the hazard of erosion from this material. More probably, the material should be buried during grading.

SOURCE: James P. Walsh & Associates, "Soil and Overburden Management in Western Surface Coal Mine Reclamation, " contractor report to OTA, August 1985,

Figure 5-4.—Example of a Soil Pedon Description

NELAR SERIES

Classification: Entic Haplustoll-coarse-loamy, mixed, mesic family.

Location: Sec. 11 T9S R40E 400 feet north and 150 feet east of W1/4 corner in road cut.

Profile Description: Nelar loam.

A_1 Reddish brown (5yr4/4 when dry) light loam; dark reddish brown (5yr3/4 when moist); moderate fine and very fine granular structure; soft when dry; very friable when moist; nonsticky and nonplastic when wet; few flat fragments.

C_1 ca 8-36" Light reddish brown (5yr6/3 when dry) light loam; reddish brown (5yr4/3 when moist); weak coarse prismatic structure; slightly hard when dry; very friable when moist; nonsticky and nonplastic when wet; very strong effervescence with a few threads of lime; few lime coated angular fragments.

C_2 36-80" Reddish brown (5yr5/4 when dry) light loam and fine sandy loam; reddish brown (5yr4/4 when moist); massive; soft when dry; very friable when moist; nonsticky and nonplastic when wet; strong effervescence; few lime coated angular fragments.

Range in Characteristics: The texture of control section is loam or sandy loam with less than 12 percent clay and less than 15 percent by volume of angular fragments. Bedrock is typically deeper than 5 feet but can occur above this depth in some profiles. The sandy loam substratum can occur at any depth below 30 inches. In places a very weakly expressed B2 horizon is present.

Colors are in hues redder than 7.5yr.

SOURCE: James P. Walsh & Associates, '(Soil and Overburden Management in Western Surface Coal Mine Reclamation," contractor report to OTA, August 1985.

[6]See reference 13, table 4.2-1 which summarizes some results of round-robin soils tests conducted by the Montana DSL; see also reference 2. The USGS has conducted similar tests recently with similar results (10).

Additional soils data are collected to plan soil handling in order to optimize stripping depths and maximize soil recovery. In rare instances, such additional data are superfluous (e.g., in parts of New Mexico there is no suitable topsoil). However, in much of the West, 100 percent topsoil recovery is a major concern. In these areas, following baseline studies but before the onset of mining, transects (narrow belts) are used to refine soil classifications and stripping depths. The soil is then staked at close spacings (every 200 feet is common) with markings on each stake indicating the stripping depth at that particular spot. At larger operations, a soil scientist may assist the scraper operator to ensure maximum topsoil recovery. Many mines (particularly in Wyoming) are required to maintain "budgets" of their total soil volume. In Wyoming and North Dakota, operators commonly demonstrate full topsoil recovery to the regulatory authority by leaving pillars of topsoil at specified intervals.

Overburden baseline studies center around the overburden drilling and sampling requirements in the five States. Required spacing of drillholes ranges from one hole per 40 acres to one hole per 640 acres. Holes generally must be sampled at 5- to 10-foot intervals through the overburden. Samples may be collected either from the cuttings from rotary drill holes or from continuous core samples. Rotary drilling is a somewhat crude method of collecting samples as there is some mixing of cuttings as they rise in the hole. The alternative, coring, is much more expensive. Therefore, it is rarely used for overburden characterization beyond the initial baseline study, for which some core samples may be required (e.g., in Wyoming). Overburden samples collected at later stages, during developmental and blasthole drilling, are all from rotary drill holes,

For overburden, these additional samples are first collected during developmental drilling, which usually precedes the path of mining by about 5 years. Developmental drill holes are more closely spaced than baseline holes; operators use them to refine coal seam maps. If an initial baseline drillhole indicates the potential for unsuitable material, developmental drill holes may be sampled around the baseline hole. if the extent of the material is still not clear or if further information is needed, additional overburden samples may be taken during the drilling of closely spaced blastholes (used to loosen the overburden immediately before mining). Even this progressively more intensive data collection may only satisfactorily delineate deleterious material that occurs in contiguous, mappable strata, usually of carbonaceous shales or pyritic sandstones. The occurrence of isolated pods of undesirable material, usually containing high levels of trace metals such as arsenic or boron, cannot be mapped with any economically reasonable density of drill holes (see ch. **6).**

Sample contamination from pipe grease and drilling fluids has been a problem in both coring and rotary drilling. Depending on the nature of the contamination, it may be easy to spot (as in fig. 5-s, where high lead concentrations were reported at regular 20-foot intervals over the length of the drill stem). In other cases, contamination is more difficult to detect (see box 5-B). Oxidation of overburden samples also can affect the lab test results, but is usually only a problem when samples have been stored for long periods, for example when samples taken before 1977 are tested for the parameters now required under SMCRA regulations.

A geologist compiles a lithologic log for each drill hole either from the core, from cuttings collected onsite, or from the driller's logs. Figure 5-6 is an example of a page from a typical lithologic log. Western lithologic descriptions are not standardized, and in some of the permit applications reviewed by OTA, lithologic descriptions were sketchy, with one word descriptions of rock types such as "shale" or "sandstone." The developers of a standardized rocktype key for the Eastern United States (6) recently published a similar lithologic key for Western coal overburden (5). This key standardizes lithologic descriptions and reduces each standard type to a numerical code. This facilitates compilation of overburden databases and use of the growing variety of overburden software programs.

After a hole has been drilled, a variety of probes are lowered down into it to develop a *geophysical log.* These probes measure parameters such as electrical conductivity and resistivity, natural

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Figure 5-6.—Example of a Geologic Log

MINE NAME: ____________ **BED:** ________ **HOLE NO:** ________

COUNTY: ____________ **STATE:** ________ **SEC.** ________ **TWP.** ________ **RG.** ________

DRILLER: ____________ **DATE:** ________ **EL.** ________

Page ______ of ______

Total Ft.	& I0ths		Thickness Ft.	& I0ths	Sub-sample	Composite sample
0		Siltstone, light gray, sandy	10	0		
10	0	Sandstone, very fine grained, yellow, silty, < IO°\o carbonaceous	5	6		
15	6	Shale, light gray-yellow, sandy, limonite stained, < 10°/0 carbonaceous	7	1		
22	7	Sandstone, very fine-fine grained, buff, slightly calcareous	2	9		
25	6	Shale, buff-gray, limonite stained, gypsum, c 10°/0 carbonaceous	3	9		
29	5	Sandstone, very fine-fine grained tan		2		
29	7	Shale, gray, < 10% carbonaceous, limonite stained	4	9		
34	6	Sandstone, very fine grained, tan, slightly calcareous, shaley	5	6		
40	2	Limestone, light gray, < 10% carbonaceous	1	2		
41	4	Sandstone, very fine grained, tan, calcareous, < IO% carbonaceous, shaley	4	4		
45	8	Shale, gray, sandy, > IO% carbonaceous	2	7		
48	5	Carbonaceous shale, w/coal, pyritic		2		
48	7	Shale, gray, sandy, < 10°/0 carbonaceous	11	3		
60	0	Sandstone, very fine grained, gray, slightly calcareous, shaley, c 10°/0 carbonaceous	21	8		
81	8	Shale, gray, > 10°/0 carbonaceous	1	8		
83	6	Sandstone, very fine grained, light gray, shaley, calcareous, < IO% carbonaceous	13	3		
96	9	Shale, gray, sandy, < 10°/0 carbonaceous	29	6		
126	5	Sandstone, very fine-fine grained, light gray, < 10°/0 carbonaceous, w/shale stringers	4	0		
130	5	Shale, gray, sandy	2	0		
132	5	Sandstone, very fine-fine grained, salt & pepper, shaley, < 10% carbonaceous	1	0		
133	5	Shale, gray, sandy, < IO% carbonaceous	14	2		
147	7	Sandstone, very fine-reed. grained, salt & pepper, < IO% carbonaceous, shaley	5	4		
153	1	Shale, gray, < 10% carbonaceous	1	6		
154	7	Coal, pyritic	1	9		
156	6	Coal	4	0		
160	6	Bone coal		3		
160	9	Coal, pyritic	2	1		
163	0	Carbonaceous shale, w/coal strands		2		
163	2	Coal	1	1		
164	3	Carbonaceous shale		2		
164	5	Coal, pyritic	1	1		
165	6	Carbonaceous shale		1		
165	7	Coal, pyritic	13	7		
179	4	Carbonaceous shale, w/coal, pyritic		2		
179	6	Coal		9		
180	5	Carbonaceous shale		8		

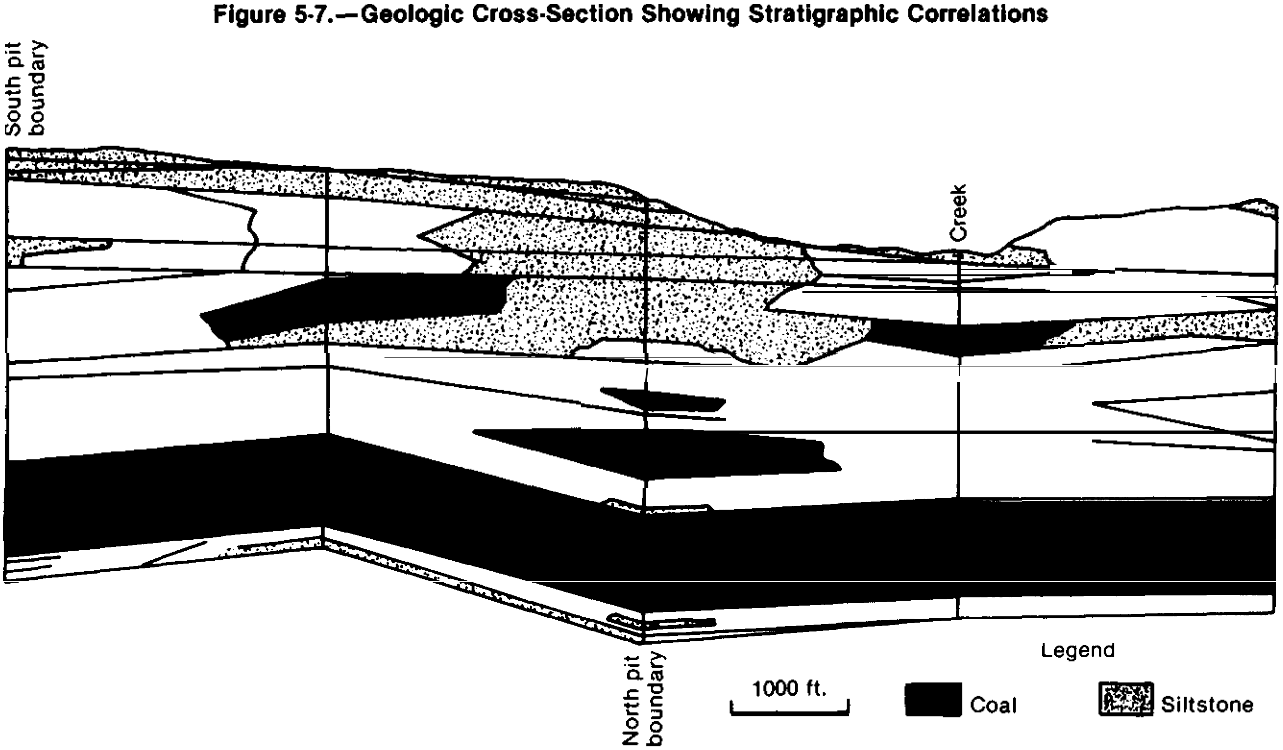
SOURCE: James P. Walsh & Associates, "Soil and Overburden Management in Western Surface Coal Mine Reclamation," contractor report to OTA, August 1985.

gamma radiation, and density as determined from induced neutron radiation. A geologist then attempts to correlate data from the lithologic and geophysical logs across the distance between drillholes and so draw the geologic maps and cross-sections required by most States. The level of detail in these maps is highly variable. Geologic cross-sections usually show topography, coal seam(s) to be mined, easily recognizable overlying strata (e.g., coaly or carbonaceous zones and large sand bodies), and the underlying stratum. Figure 5-7 shows one of the better geologic cross-sections from the permit applications reviewed by OTA.

Samples taken from drillholes are also tested for a variety of geochemical parameters that may adversely effect revegetation and postmining water quality. Typically these include pH, salinity, SAR and/or exchangeable sodium percent, texture, Sat percent, and concentrations of a variety of trace elements such as selenium and boron. Where acid formation in overburden is considered a potential problem, these samples also might be tested for acid-base potential (see ch. **8).** Many of the lab tests currently used for these purposes were borrowed directly from soil science, and experience in recent years is calling into question the validity of these tests when applied to overburden. Unlike soils, overburden typically is not oxidized (except in near-surface strata) and so is not in chemical equilibrium with the surface environment. Furthermore, soils are soft and friable and extracts for analysis can be taken readily. Overburden, however, generally is in the form of rock that must be ground before testing, and the amount of grinding affects the test results. Tests designed to extract trace metals from oxidized soil material often do not perform **in the same manner** when applied **to unoxidized overburden.** Tests used for nitrates and selenium are particularly suspect as of this writing (see box 5-C). Methods used to test for acid-base potential in overburden are also controversial (see ch. **8).**

Soil and overburden monitoring on regraded surfaces is done indirectly, through monitoring

Figure 5-7.—Geologic Cross-Section Showing Stratigraphic Correlations



SOURCE: James P. Walsh & Associates, "Soil and Overburden Management in Western Surface Coal Mine Reclamation," contractor report to OTA, August 1985.

Box S-C.--Detecting Selenium in Overburden Samples

The current procedure used to detect selenium in overburden samples is a hot-water extraction developed for agricultural soils. in surficial materials, such as soils, selenium is in an oxidized state, readily soluble, and thus easily extracted by this method. Baseline overburden samples, of km obtained at considerable depths, are in a reduced condition and the unoxidized selenium compounds are not readily soluble. Therefore, hot-water extraction does not work, The Wyoming Department of Environmental Quality has noted the limitations of this procedure. In one instance, a sample from the Shirley basin known to contain a total selenium value of 410 ppm yielded only 1 ppm in the standard extraction procedure. This appears to explain why selenium has rarely been detected above trace-level concentrations in baseline overburden analyses. While hot-water extraction may not be a valid test for baseline studies, it may still be useful for testing regraded spoils, During the mining and reclamation process, most overburden materials are exposed to the air long enough to become oxidized, particularly its dragline operations where spoils may be unburied for up to a year. Once oxidized, the selenium becomes more soluble, and the hot-water method will work (l).

of water quality and vegetation. None of the five States routinely requires long-term monitoring of normal backfilled spoils or redressed soils, but the regulatory authorities often impose monitoring programs in cases where soil or overburden conditions have been identified as a problem (see the case studies in vol. **2).** Types of programs commonly required include: one-time sampling of regraded spoils for unsuitable material in the root zone; one-time or periodic sampling of soils, most often for sodium migration; and monitoring for erosion.

Most monitoring programs require sampling of the surficial spoils (those immediately beneath the soil) only once, immediately prior to topsoiling. If there is little or no change in spoil character over time, one-time sampling may be adequate. However, the extent to which chemical reactions will occur in overburden and the time required for their completion are not well understood. Similarly, the speed and ultimate extent of sodium migration through spoils is difficult to predict. Where sodium has been identified as a potential problem, periodic spoil sampling programs are being carried out. **Without more research on spoil chemistry, the adequacy of current monitoring programs is difficult to assess.**

Moreover, as noted previously, the horizontal and vertical sampling densities for collecting spoils monitoring data are not standardized. At mines reviewed by OTA, data on recontoured spoils were most often based on a grid with samples collected at horizontal intervals varying from **400** to 660 feet (4 to 11 acres/sample).[7] Depth of sampling varied: at two mines, spoil was sampled to 8 feet; at two others, spoil was sampled to 4 feet but at 2-foot intervals. One Wyoming operator proposes to sample on a 625-foot grid (9 acres/sample); if unsuitable material is found in any sample, the surrounding area would be sampled on a 200 foot grid (1 acre/sample). The regulatory authority has not yet acted on this proposal. Another mine is sampling on a 500-foot grid (6 acres/sample). An innovative sampling program is described in box 5-D.

Soil sampling and erosion monitoring programs also vary because they are designed for each individual mine (see box 5-E). At one North Dakota mine, sodium migration and salinity of soils were monitored on a limited basis using research plots.[8] At another mine in Montana, sodium in redressed topsoil over sodic and clayey overburden is being monitored from 20 different sampling locations on the mine-site.[9]

Sampling of spoil in reconstructed aquifers is extremely difficult and so is much less common than sampling of surficial spoil. If there is reason to suspect that deleterious material may be present in the water table, operators may be required to produce samples, but such sampling

[7] See reference 13, case studies C, E, F, G, H and 1.
[8] See reference 13, case study B.
[9] See reference 13, case study D.

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HYDROLOGY[10]

Data Requirements

Requirements for hydrologic data collection are summarized in table 5-3. Wyoming has the most specific guidelines and regulations, followed in order by Montana, Colorado, North Dakota, and New Mexico. The latter two States have not published guidelines, relying on regulations and personal contacts between operators and regulatory personnel to develop hydrologic data collection programs on a mine-specific basis.

Under the Federal and State programs, **surface water baseline studies** must include:

- detailed location of all surface water features;
- streamflow quantity data, including seasonal and annual variations, floods, and low flows;
- streamflow quality data, including both physical and chemical characteristics and the relationship between discharge and quality; relationship between discharge and quality;
- quantification of physical watershed parameters, including topographic features, surficial geology, hydrologic soil types, vegetative cover, and channel and flood plain geometry;
- a description of climatic characteristics that affect surface water hydrology, such as mean annual precipitation, precipitation frequency versus duration relationships, and seasonal and annual variations in precipitation; and
- a description of surface water uses.

Some of this information is in or can be compiled from existing sources of data. For example, information on climatic characteristics may be obtained from the National Weather Service.

Groundwater baseline studies must include:

- location of all groundwater features in the area, including existing wells and springs which may be affected by mining;
- geologic data, such as surficial geologic maps and geologic cross-sections that show: depth and extent of aquifers, confining layers, and hydrologic barriers and boundaries, including any faults or folds;
- static water level data, including seasonal and annual variations, for all affected aquifers sufficient for the construction of potentiometric surface maps to determine flow directions and locate recharge and discharge areas;
- water quality data for all affected aquifers sufficient to determine seasonal and annual variations and suitability of the water for domestic, irrigation, or livestock uses;
- geochemical data for the overburden materials for use in predicting postmining chemical quality of the spoils aquifers;
- results of pump tests to determine: permeability, transmissivity, and storage coefficients for all affected aquifers; effects of hydrologic barriers and boundaries; interaction between aquifers; and interactions between the groundwater and surface water systems.

Alluvial valley floor (AVF) baseline studies must determine whether there are AVFS in or near the proposed permit area, whether an AVF cannot be mined because it is significant to farming, the potential impacts of mining on the AVF, and the prospects for restoring the essential hydrologic functions (EHFs) of the AVF (see chs. 3 and 4).

Federal regulations require that surface and groundwater monitoring data be submitted to the regulatory authority every 3 months (19,20). **While quarterly monitoring might be a valuable safeguard of hydrologic resources in the East, it is inappropriate and unnecessary in the West.** In the East, there are many small operators mining in close proximity to one another and the hydrology is highly variable. There, hydrologic impacts may occur rapidly and unpredictably. In a large Western operation, however, a pit may be 4,000 feet long and may only move at a rate of 1,000 ft/yr. Thus, water levels and quality in

[10]Unless otherwise noted, the material in this section is adapted from reference 15; see also reference 9.

Table 5-3.—Summary of Hydrologic Baseline Data Collection Requirements by State

Type of data	Colorado (guidelines and regulations)	Montana (guidelines and regulations)	New Mexico (regulations)	North Dakota (regulations)	Wyoming (guidelines and regulations)
Surface water quantity data:					
Perennial	Continuous recording gages. Report max, rein, and mean flow.	Continuous recording gages.	Min, max, and avg discharge conditions identifying low flow and peak discharge rates.	Max, rein, and avg discharge conditions which identify low flow and peak rates.	Continuous recording gages.
Intermittent	Sample frequency will be dealt with on an individual basis. Determine duration of flow season and peak flow.	Continuous recording gages.	Min, max, and avg discharge conditions identifying low flow and peak discharge rates.	Max, rein, and avg discharge conditions which identify low flow and peak rates.	Continuous recording gages.
Ephemeral	Install crest stage recorders. Flow measurement frequency will be dealt with on an individual basis.	Crest stage gages.	Min, max, and avg discharge conditions identifying low flow and peak discharge rates.	Max, rein, and avg discharge conditions which identify low flow and peak rates.	Monthly reading of crest gages.
Duration	Not stated.	Not stated.	Not stated.	Not stated. Submit quarterly reports.	Min. of one year of data (see above).
Surface* water *quality data:					
Parameters	Field: pH, EC, temp, DO Lab: TDS, TSS, Oil and Grease, SAR, HC03, Ca, Cl, Mg, N03, N02, P04, Na, S04, Al, As, Cd, Cu, Pb, Mn, Hg, Mo, Se, Zn.	EC, pH, Alk, SAR, TDS, Al, As, Ba, HC03, B, Cd, Ca, C03, Cl, Cr, F, Fe, Pb, Mg, Ni, N03, P04, K, Se, Ag, Na, S04, V, Zn.	TDS, TSS, cidity, pH, total and dissolved Fe, total Mn, others as required by the regulatory authority.	TDS, TSS, EC, pH, total Fe, others as required.	Field: pH, temp, EC, chloride, Aik, discharge, turbidity, DO Lab: NH3, N03, N02, Al, As, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Zn, HC03, C03, Ca, Cl, B, F, Mg, K, Na, S04, TDS.
Perennial	Field: measure water quality parameters monthly. Complete chemical analysis quarterly.	Quarterly.	Discuss with regulatory authority. Submit quarterly reports.	Discuss with regulatory authority.	Sufficient to characterize quality—discuss with regulato~ authority.
Intermittent	Sample frequency will be dealt with on an individual basis.	Quarterly.	Discuss with regulatory authority. Submit quarterly reports.	Discuss with regulatory authority.	Sufficient to characterize quality—discuss with regulatory authority.
Ephemeral	Sample water for complete chemical analysis twice a year, once during snowmelt, and once during a storm event.	When possible.	Discuss with regulatory authority. Submit quarterly reports.	Discuss with regulatory authority.	Sufficient to characterize quality—discuss with regulatory authority.

Table 5-3.—Summary of Hydrologic Baseline Data-Collection Requirements by State—Continued

Type of data	Colorado (guidelines and regulations)	Montana (guidelines and regulations)	New Mexico (regulations)	North Dakota (regulations)	Wyoming (guidelines and regulations)
Springs and seeps	Measure field water quality parameters monthly. Sample water for complete chemical analysis quarterly.	Not stated.	Discuss with regulatory authority. Submit quarterly reports.	Discuss with regulatory authority.	Sufficient to characterize quality—discuss with regulatory authority.
Groundwater quantity data:					
Well Density	None specified.	None specified.	None specified.	Min. 1 data point per aquifer per 4 sq. mi.	Min. 3 data points per affected aquifer per sq. mi.
Pump Tests	Not stated.	Within each affected aquifer.	Not stated.	Not stated.	Within each affected aquifer (2-3 may be adequate).
Methodology Specified? YIN	No.	No.	No.	No.	No, but some recommendations are made.
Static Water Level Frequency	See water quality sampling frequency.	Monthly for at least one year, one well in each aquifer continuously monitored.	Discuss with the regulatory authority.	Discuss with regulatory authority.	Quarterly.
Potentiometric	Not stated.	For each affected aquifer and next aquifer beneath coal if deemed necessary.	Not stated.	For each affected aquifer and next aquifer beneath coal.	For each affected aquifer.
Groundwater quality data:					
Parameters	Field: pH, EC, Temp Lab: TDS, HC03, Ca, C03, Cl, Mg, NH3, N03, N02, P04, Na, S04, As, Cd, Fe, Mn, Hg, Se, Zn.	EC, pH, Alk, SAR, TDS, Al, As, Ba, HC03, B, Cd, Ca, C03, Cl, Cr, F, Fe, Pb, Mg, Ni, N03, P04, K, Se, Ag, Na, S04, V, Zn.	Discuss with the regulatory authority.	TDS, HC03, Na, Fe, hardness, N03, S04, Cl, pH, SAR, Ca, Mg, EC, others as requested.	Field: pH, temp, EC, chlorine, Alk, turbidity Lab: NH3, N03, N02, Al, As, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Az, HC03, C03, Ca, Cl, B, F, Mg, K, Na, S04, TDS.
Frequency	Bedrock Aquifers: Field parameters monthly. Complete chemical analysis semiannually. Alluvial Aquifers: Field water quality parameters monhtly. Complete chemical analysis quacterly.	Min. of quarterly.	Discuss with the regulatory authority.	Discuss with regulatory authority.	Sufficient to characterize quality in potentially affected aquifers.

Table 5-3.—Summary of Hydrologic Baseline Data-Collection Requirements by State—Continued

Type of data	Colorado (guidelines and regulations)	Montana (guidelines and regulations)	New Mexico (regulations)	North Dakota (regulations)	Wyoming (guidelines and regulations)
AVF surface water quantity:	Contact the regulatory authority.	Not stated.	Adequate frequencies to indicate long-term trends. Discuss with regulatory authority.	See above.	See above.
AVF surface water quality:	Contact the regulatory authority.	Describe seasonal variations over one full year at a minimum.	Adequate frequencies to indicate long-term trends. Discuss with regulatory authority.	See above.	See above.
AVF groundwater quantity:	Contact the regulatory authority.	Monitoring should be performed at frequencies sufficient to indicate long-term trends. 2 years minimum.	Adequate frequencies to indicate long-term trends. Discuss with regulatory authority.	See above.	See above.
AVF groundwater quality:	Contact the regulatory authority.	Monitoring should be performed at frequencies sufficient to indicate long-term trends. 2 years minimum.	Adequate frequencies to indicate long-term trends. Discuss with regulatory authority.	See above.	See above.

SOURCES: Western Water Consultants, "Hydrologic Technologies for Western Surface Coal Mining," contractor report to OTA, Aug. 1, 1985. Colorado Mined Land Reclamation Division 1982 Guidelines for the collection of baseline water quality and overburden geochemistry data, permit manual, and 1982 Regulations. Montana Department of State Lands 1983 Water Resources Guidelines and Guidelines for the Identification of Alluvial Valley Floors and April 1980 Rules and Regulations. New Mexico Mining and Minerals Division, 1984 Regulations. North Dakota Public Service Commission, Rules Governing the Reclamation of Surface-Mined Land, June 1983. Wyoming Department of Environmental Quality—Land Quality Division Guidelines and October 1984 Rules and Regulations.

monitoring wells offsite are not likely to change rapidly. In addition, as is noted elsewhere in this report, Western regulatory authorities already receive more data than they can review on a regular basis. Instead, they review hydrologic monitoring data when they have to make a decision based on those data (e.g., permit renewal, bond release, or, in Wyoming, annual bond adjustment) or when there is reason to believe some problem exists at a site. As a result, monitoring programs in the West often require semi-annual rather than quarterly monitoring, and operators generally submit these data to the regulatory authorities annually.

Important Sources of Previously Collected Data

The USGS, Environmental Protection Agency (EPA), and the State water offices compile the most commonly used sources of existing hydrologic data available to permit applicants and regulatory authorities in the West (see table 5-4). The USGS's Water Resources Division maintains several excellent data collection networks, including the National Water-Data Exchange (NAWDEX), the National Water-Data Storage and Retrieval System (WATSTORE), and the Index to Water-Data Activities in the Coal Provinces of the United States. NAWDEX indexes data from a nationwide confederation of water-oriented organizations and assists users in identifying and locating water data. WATSTORE digitizes a variety of types of surface and groundwater data collected by USGS at their monitoring stations, including daily values of sediment concentration, stream flow, and reservoir levels; water quality; peak flows; chemical analyses; and geologic data for groundwater stations. The Index to Water-Data Activities indexes available data sources by data type (e.g., streamflow, surface water quality, groundwater quality) for five geographic regions. All of these

Table 5-4.—Primary Sources of Existing Hydrologic Data

Agency	Program	Summary description
Us. Geological Survey	Annual Water-Data Reports	Records of stage, discharge and quality of streams, stage and contents of lakes and reservoirs, and water levels and quality of groundwater, Published annually by State. Reports available for purchase from NTIS.
Us. Bureau of Reclamation	Water and Power Management	Reservoir water levels and discharge of streams, rivers and canals. Reports available on request from respective regional office.
U.S. Bureau of Land Management	Energy Mineral Rehabilitation Inventory and Analysis (EMRIA), discontinued	Intended to be a coordinated approach to field data collection, analyses, and interpretation of overburden, water, vegetation and energy resource data in the Western coal field. Data compiled in various EMRIA reports available from U.S. Dept. of the Interior.
Us. Dept. of Agriculture	Various Programs of the Agricultural Research Service, Forest Service, and Soil Conservation Service	Each agency conducts limited monitoring for specific program needs. Data are available from the respective agency on request,
Us. Environmental Protection Agency	STORET	Computerized database system for storage and retrieval of data relating to water quality, water quality standards, point sources of pollution, pollution-caused fish-kills, waste-abatement needs, implementation schedules, and other water-quality related information. Any government agency can become a STORET user. The system is accessed by the EPA or by a government agency or university that uses STORET.
National Water Well Association (as part of National Center for Ground Water Research established by EPA through Oklahoma, Oklahoma State and Rice Universities)	National Ground Water information Center (NGWIC)	Computer retrieval system that searches hydrogeology and water well technology database that resides on a computer at Battelle Columbus Laboratories, Database available to any individual or group upon request or through time-sharing account. Costs assessed for computer time, Geographical coverage is worldwide.

SOURCE: Western Water Consultants, "Hydrologic Technologies for Western Surface Coal Mining," contractor report to OTA, Aug. 1, 1985.

Table 5-5.—Summary of Major USGS Water-Data Management and Acquisition Programs

Program	Description	Accessibility y	Geographical coverage
National Water-Data Exchange (NAWDEX)	National confederation of water-oriented organizations aimed at making their data more accessible, Services include assistance in identifying and locating needed water data and referring the requester to the organization that retains the data. Master Water-Data Index (MWDI) identifies sites for which water data are available, type of data available, and information necessary to obtain the data. Water Data Sources Directory (WDSD) identifies organizations that are sources of water data and locations within these organizations from which data may be obtained.	Services available to anyone through USGS National Center and Assistance Centers in 45 states and Puerto Rico. Charges for computer and personnel time and duplicating services.	Nationwide
WATSTORE	Computerized system for processing water data and managing data-releasing activities. includes the following files: Station-Header File (WRD.STAHDR)-an index of sites for which data are stored in DVFILE, PKFIL, QWFILE, and WRD.UNIT (see below). Daily Value File (DVFILE)—daily values for streamflow, reservoir levels, water-quality parameters, and groundwater levels. Peak Flow File (PKFIL)—annual maximum discharge and gage height values at surface water sites. Water Quality Data File (QWFILE)—results of surface water and groundwater quality analyses. Unit Values File (WRD.UNIT)-water parameters measured more frequently than daily. National Water Use Data System (NWUDS)—a national Federal-State cooperative system designed to collect, store, and disseminate water-use data.	Information available to anyone through any of USGS Water Resources Division's 46 district offices.	Nationwide
Office of Water Data Coordination (OWDC)	Index to Water-Data Activities in Coal Provinces of the United States. Five-volume index to availability of streamflow, surface water and groundwater quality data and hydrologic investigations in the five major coal provinces. Index was derived from the Catalog of Information on Water Data, a computerized information file about water-data activities in the United States.	Individual volumes available for purchase from USGS. Additional information available from NAWDEX Assistance Centers.	Five major coal provinces of the United States

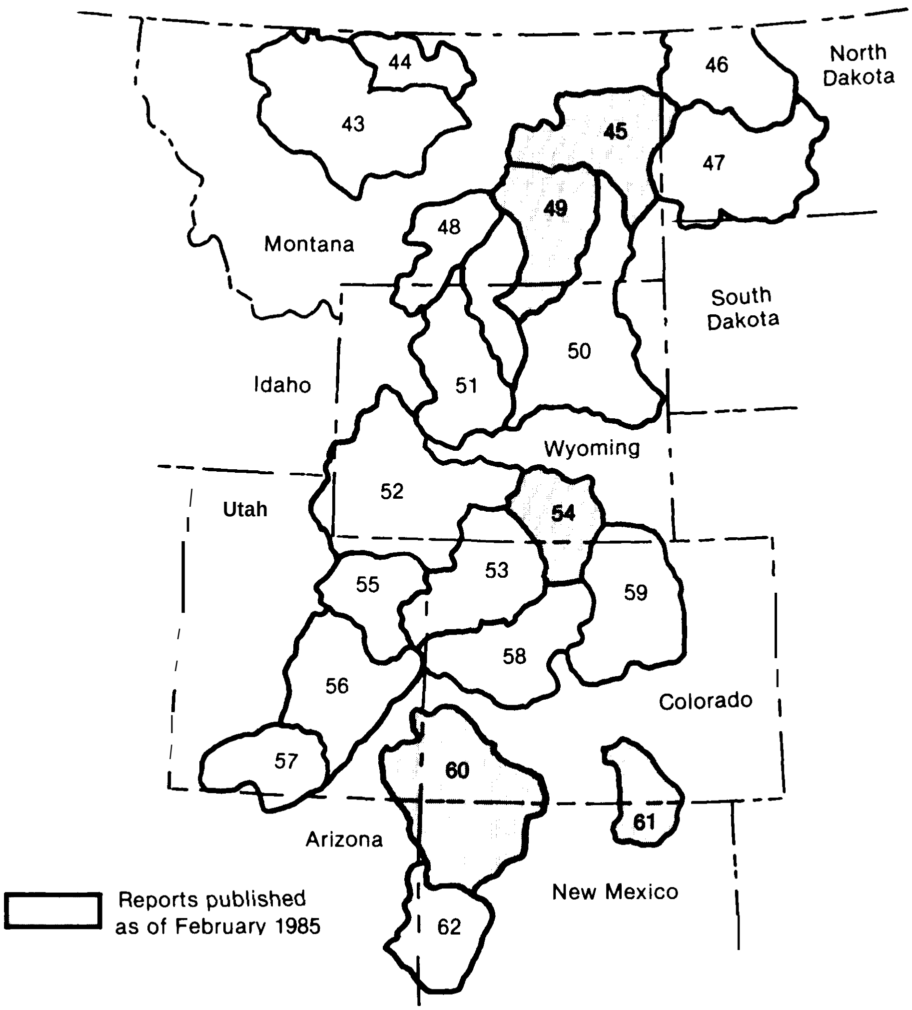
SOURCE: Western Water Consultants, "Hydrologic Technologies for Western Surface Coal Mining," contractor report to OTA, Aug. 1, 1985.

data are available to any individual or organization through the USGS district or national office. Table 5-5 contains additional information on these USGS data management programs.

In addition, the USGS has been compiling a series of reports that describe existing hydrologic conditions and identify sources of hydrologic data in the Nation's coal provinces. These reports are intended to fulfill SMCRA'S requirement that an "appropriate Federal or State agency" make "hydrologic information on the general mine area prior to mining" available to permit applicants. The reports also help regulatory authorities judge whether a proposed mining plan adequately "minimizes the disturbances to the prevailing hydrologic balance." Figure 5-8 shows the areas covered by these reports as of February 1985,

EPA maintains a database called STORET that includes water quality data, water quality standards, and point sources of pollution. All govern-

Figure 5.8.—Location Map of Hydrologic Areas for Which USGS Is Preparing Regional Hydrologic Reports



SOURCE: Western Water Consultants, "Hydrologic Technologies for Western Surface Coal Mining," contractor report to OTA, Aug. 1, 1985.

ment agencies can become STORET users. EPA also funds and oversees the National Ground Water Information Center (NGWIC), a computerized database of groundwater references operated by the National Well Water Association. Geographical coverage of the database is worldwide. Any individual or group may use the database. Charges are assessed on the basis of computer time used.

Each State in the study region has an office (usually in the State Engineer's office or the State natural resources department) responsible for water appropriation. These offices maintain a centralized system of information on locations of diversion points, names of appropriators, and types of water use. The Montana and New Mexico Bureaus of Mines also have some water quality information. In addition, under the Clean Water Act, each State must maintain a system for classifying streams on the basis of water quality and quantity and suitability for various uses (see ch. 4).

The Wyoming Water Research Center *(WWRC)* maintains a computerized database of all regularly reported streamflow, groundwater quality, climatological, water well level, and snow course data. The data may be accessed by any individual or organization who contacts the WWRC office in Laramie. Charges for computer and personnel time are assessed.

The Gillette Area Groundwater Monitoring **organization** (GAGMO) is an organization of mine operators in the Powder River basin around Gillette, Wyoming, who measure static water levels in their monitor wells around October 1 of each year and publish the data in annual reports.

Data Collection by Operators

Hydrologic data collection methods and data formats are more standardized than in other disciplines because the methods of hydrologic analysis are more quantitative and increasingly are computerized (see ch. 6). Although this means that the hydrologic data available from outside sources are more extensive and of better quality than is the case in other disciplines, more and better data still are necessary to perform the sophisticated analyses required for permitting. Thus, as in other disciplines, existing data sources may be helpful for initial planning but the vast majority of data still must be collected onsite by the operator.

Moreover, hydrology changes constantly at any given mine site. The mobility of water through the ecosystem makes it impossible to consider hydrology and hydrologic data in the static, site-specific fashion in which soils and overburden data are considered. Consequently, hydrologic data collection that begins as part of baseline analyses usually continues through the life of a mine and becomes part of the hydrologic monitoring of the mine (see fig. 5-1, above). This is true, not just for surface mine reclamation, but for all types of hydrologic work. As a result, hydrologists traditionally have maintained and exchanged data more than in other disciplines. It is worth noting that hydrology is the one area where operators routinely consult previously filed permit applications and occasionally even coordinate and pool monitoring data (e.g., GAGMO).

The bulk of the **surface water baseline data collection effort goes** into streamflow quantity and quality data. Because streamflow characteristics change constantly, data should be collected over sufficient time to delineate the range of natural flows, although additional research may be needed to determine what period of data collection is adequate. Without such long-term streamflow data from several locations along the stream channel, the sophisticated analytical tools described in chapter 6 may not be usable or may yield invalid results.

Compiling flow data for perennial streams is not difficult. Because perennial streams are relatively uncommon in the West, they already are monitored closely, often by the USGS. Depending on the positions of these monitoring stations relative to the mine site, these data may be useful to permit applicants. If no preexisting data are available on a perennial stream at a particular site, gaging technology to collect flow data is well developed and standardized. Operators usually install water level recorders at selected points along perennial streams; these provide continuous data on both water levels and flow rates. Water sampling for water quality analyses, particularly of sediment levels, also can be done at any time.

However, most streams in the West are ephemeral or intermittent and flow only occasionally—after precipitation or spring snowmek events and, in the case of intermittent streams, when the water table is high. Opportunities for collecting data and samples may be few and far between for these streams, and they are less likely to be the objects of previous data collection efforts. Moreover, compiling reliable flow data for ephemeral and intermittent streams in the West is difficult because the crest-stage gages usually used to measure flows in these channels only record the highest water surface elevations reached since the last gage reading; they do not indicate flow rate or how fast water levels rose or receded when the flow event occurred. Flume gages equipped with water level recorders are more sophisticated methods of collecting flow data. They record how fast water rises in the channel and how fast it recedes using automatic recording devices activated by water flow. They are also about 100 times as expensive as crest-stage gages and are likely to be washed out or damaged during major runoff events.

Obtaining water quality samples from ephemeral and intermittent streams also is difficult. First, having personnel at each channel at the time of peak flow during each flow event is impracticable and sometimes dangerous. Second, and also a problem at perennial streams, the methodology to be used for taking samples has not been standardized, and different sampling methods can add significant variability to water quality data. Even the USGS has not formulated a standard procedure for how and where in the flow water quality samples should be taken. Third, water quality data are meaningful only if accompanied by data on flow rate and volume at the time of sampling. As noted above, simple crest-stage gages do not provide these data.

Obstacles to collecting reliable surface water data for ephemeral and intermittent streams often leave Western operators with insufficient data for detailed reclamation planning. At one Wyoming mine, only 33 data points were available on which to base the reclamation plan. At another, only three samples from seven sampling sites were collected. A third Wyoming mine installed five crest-gages in 1978, but oniy one fiow event has been recorded at three of the gages; none at the other two. A Colorado operator had no data available on flow or quality of ephemeral streams despite two gages on the site. No New Mexico mine reviewed was able to collect enough data on ephemeral streams to plan reclamation adequately. To compensate for this lack of surface water data, operators have turned to other methods of calculating peak and low flows based on the topography, soils, vegetation, precipitation and land use of the drainage (see ch. 6).

Necessary geologic and geochemical data for **groundwater baseline studies** usually are obtained from the overburden baseline studies described above. Permit applications from adjacent mines also may be a good source of geologic information for a permit applicant. All other data are collected with a series of observation wells drilled by the operator for this purpose. These wells are drilled with an imperfect knowledge of the subsurface hydrogeology and therefore rarely yield complete data for hydrologic modeling and construction of potentiometric surface maps. Wells must be drilled carefully so that only pertinent aquifers are open to them and all other water sources sealed off. **Since 1980, both well drilling and sampling techniques have improved and the quality of groundwater data has improved correspondingly.** Efforts **to coordinate data collection, such as the** GAGMO **agreement, could add to the utility of groundwater data.**

A variety of data are taken from these wells. Water levels are monitored regularly and are used to prepare potentiometric surface maps showing the static water level of an aquifer at a given point in time. Data on the storage and transmission properties of pertinent aquifers also are collected, usually with a pump test. By pumping water from the aquifer at a constant rate or in a series of stepped rates and measuring the change in water level, data on transmissivity and storativity of an aquifer can be calculated.[11] The calculation requires assumptions, however, about both the homogeneity, the extent, and the thickness of the aquifer, and it is accurate only to the extent that the assumptions are valid.

Water quality data also are collected from samples taken from observation wells. Standard or recommended practices exist for taking most of these types of samples, as well as for the handling and preservation of water quality samples. Some parameters such as acidity/alkalinity, specific conductivity, and pH change rapidly and should be measured in the field; other measures can be taken from laboratory samples. EPA and others have published guidelines for preservation and laboratory analysis of samples for suspended and dissolved solids, minerals, and other tests that may be prescribed in the regulatory programs.

Temporal and areal distribution is an important consideration in groundwater data collection. Ideally, baseline data are collected from enough wells and over a sufficient time period to allow determination of the natural spatial variations in aquifer permeability (saturated hydraulic conductivity), and of the spatial and temporal variations in static water levels and water quality. Spatial distribution of data is usually not a problem for Western operators, but some problems have arisen regarding temporal distributional* For ex-

[11] "Transmissivity" is the rate at which **water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.** "Storativity" **is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change** in head.

[12] Note, however, that State requirements for **spatial distribution** of groundwater **data vary considerably; see table 5-2.**

ample, data for a potentiometric surface map must be taken as close to simultaneously as possible. This is particularly important in active mining areas where water levels may change substantially over time, and in shallow, unconfined aquifers where water levels change significantly with season and with precipitation and runoff events.

identification of an AVF requires an integration of geologic, hydrologic, and agricultural land use data. Identification usually begins with a preliminary surficial geologic map, if available from the USGS, from which a rough estimate of the areal extent of stream laid deposits—the geologic sign of an AVF—can be made. This estimate is then refined using surficiai geologic maps prepared by the operator from topographic maps, stereo-paired aerial photos, and site inspection. After the areal extent of the AVF is delineated, land use is determined from county land offices and land owners to see if the prohibition against mining AVFS significant to agriculture would apply.

If the area can be mined, detailed studies are conducted to identify the essential hydrologic functions of the AVF and provide a plan for their restoration. Many of these studies are similar to those described previously for surface water and groundwater baseline studies. Data collected include:

- site geomorphology and watershed characteristics, including drainage basin parameters, streamflow characteristics and channel and flood plain geometry;
- hydrogeological characteristics of the AVF, including thickness, lithology and areal extent of the alluvial deposits; aquifer hydraulic characteristics including saturated thickness, transmissivity, storativity, flow rates, and directions of flow in the alluvial aquifer and in hydraulically connected bedrock aquifers;
- water quality characteristics of the surface water and alluvial and bedrock aquifers; and
- presence and extent of subirrigation, including installation of water level recorders on alluvial wells to determine diurnal water level fluctuations (this information, together with information on porosity and areal extent of the alluvial aquifer, can be used to quantify the amount of groundwater transpired by plants during daylight hours).

Hydrologic monitoring data are collected as a continuation of baseline studies with the same methods and equipment. The many dynamic features of a mine site's hydrologic regime mean that operators must collect data continually throughout the life of the mine. Therefore, a vast quantity of hydrologic data, particularly groundwater data, is being amassed. Regulatory authorities receive so much hydrologic monitoring data that often their personnel cannot review and analyze all, or even most, of it. None of the regulatory authorities has the time or the resources to evaluate hydrologic data from a regional perspective to test for anomalies or inconsistencies, and erroneous data could remain undetected for years. At one mine reviewed by OTA, improperly reduced crest-stage data were submitted to the regulatory authority for 2 years before the errors were detected.[13]

Ideally, operators analyze and use hydrologic monitoring data during reclamation and in evaluating reclamation success. In at least one case reviewed by OTA, an operator has organized and uses a very large amount of hydrologic data (see box 5-F). Often, however, hydrologic monitoring is perfunctory. Operators collect large amounts of data at considerable expense and submit them to the regulatory authority to satisfy monitoring requirements, and the data are not used again unless questions or problems arise. One obstacle is format. There are no uniform procedures for filing monitoring data, and most such data reside in boxes in regulatory authority offices, They rarely are published, or even indexed, and accessing them is extremely difficult and time-consuming. From the standpoint of hydrologic data, and particularly groundwater data, the ability to access and manage the vast amount of data available is much more of an issue than any gap in the data.

Steps are being taken in some areas to improve the accessibility and reporting of hydrologic mon-

[13] See reference 1.5, case study 3.13.

Box 5-F.—Managing a large Hydrologic Databasel

All Western mines are collecting a great deal of hydrologic data. For large operations that have been monitoring for many years, however, the size of the accumulated hydrologic database can be very large. At one such mine in the Powder River basin, the operator has created a hydrologic resource library to manage all of the hydrologic baseline and monitoring data, In addition, the library incorporates data collected by the various agencies that have investigated hydrologic facets of the mine operation over the years. In the library, hydrologic data are sorted into volumes on: streamffow quality and quantity; ground-

aquifer test results for monitoring wells; lithologic logs of observation wells; and well development data. Hydrologic resource reports compile annualand interim reports of monitoring data submitted to the State regulatory authority, and correspondence relating to hydrologic issues. The hydrologic resource reports also include copies of published and unpublished hydrologic studies pertinent to the mine operation, usually conducted outside routine monitoring and analysis. These studies cover such topics as AVF characteristics, selective placement of overburden, waters impounded on mine spoils, and postmining spoil water quality. The library is updated periodically and updated copies are maintained in the State regulatory authority's office.

The operator's purpose in developing this library was to facilitate both in-house and regulatory use and review of a very large database. Inhouse, the library is valuable to the operator's in preparing permit applications for mine expansion; it reduces duplication of data in those applications by referencing data previously submitted to the regulatory authority. This referencing, however, means that the permit application cannot stand on its own, but must be reviewed in conjunction with the hydrologic library. Mine company personnel report that the regulatory authority has on occasion expressed confusion about these references. However, as the regulatory authority becomes more familiar with the use and periodic revision of the library, it is likely that much of this confusion will cease.

[1]See case study mine G in reference 15.

itoring data. One excellent example is GAGMO. in addition, the Montana Bureau of Mines and Geology has submitted a proposal to the State to collect all the available hydrologic data submitted by mining companies, evaluate it, and prepare a computerized database to make the data manageable and readily available to interested persons **(8).** It is not known when and if this project will be funded. The State of Wyoming recently announced plans to place all the groundwater data from the DEQ files into the State's computerized information search and retrieval system (1 **6).** This project is expected to take 2 years or more due to the vast amount of data on file (1 **7).**

REVEGETATION[14]

Data Requirements

Requirements for collection of baseline vegetation data vary with land use. Most State regulations and guidelines focus on data collection on rangeland (by far the most extensive land use in the study area), but include alternate data collection requirements for other land uses such as wildlife habitat or pastureland. Table 5-6 summarizes requirements and accepted procedures for baseline data collection in each of the five States.

All five States require vegetation maps for all land uses. Scales for vegetation maps range *from* 1 inch equals **400** feet in Montana and North Dakota, to 1 inch equals 2,000 feet in Colorado. Most permit applications reviewed for this assess-

[14]Unless otherwise noted, the material in this section is adapted from reference 14.

Table 5-6.–Selected Current Requirements for Vegetation Baseline Data by State

	Colorado	Montana	New Mexico	North Dakota	Wyoming
Vegetation mapping	Required in all States				
Range sites		R	Z	R[f]	
Vegetation types	R	R	R	R[g]	R
Scale	R,I “=2000‘ X,I “=500’	R,I “=400‘ for veg type map	X,I “=500 ‘	R,I ‘=400‘ for both maps	X,I “=400 ‘-700‘
Cover data	Required in all States for native rangeland and wildlife habitat and in ND for tame pastureland				
Absolute cover	R	R	R	R	R
Relative cover	Z	X		Z	X
Quadrat estimation	Z	X	X	Z[g]	X
cover classes	Z	Z	Z		Z
by percent	Z	X	Z		Z
Line intercept	Z[a]	X[c]	Z		X[a]
Point intercept	Z		Z	Z	X
Production	Required in all States for native rangeland, cropland, and pastureland				
Herbaceous		R[d]	R	R	R
Woody	X[b]	R	X[e]		
Clipping	X	R	X	X	X
Quadrat size	variable	X,O.5 m^2	variable	Z,often 0.25 m^2	Z,O.5 m^2
Doubling sampling	Z		Z	Z	
Shrub density	Required in all States for wildlife habitat and in CO, MT, NM and WY for native rangeland				
Shrubs	R	R	R	R[g]	R
Subshrubs		R	R	R[g]	X
Quadrats & belt transects	X	X	X	Z[g]	X
Plotless samples	Z				
Diversity	All States require collection of data that can be used to calculate species/lifeform diversity for native rangeland and wildlife habitat.				

Key to sysbols and superscripts

Symbols

R, written requirement by State regulatory authority, i.e., law, rule or regulation.

X, preferred or recommended by State regulatory authority, i.e., written guideline or unwritten but clear preference. In the case of written guidelines (MT and WY), the guidelines are usually treated as requirements by the coal companies.

Z, not specified but in fact accepted by the State regulatory authority.

Superscripts

[a]for shrubs only
[b]when also wildlife habitat
[c]for trees and shrubs only
[d]by lifeforms only
[e]for palatable species only
[f]for native grassland only
[g]for woodland or wildlife habitat only

SOURCE: Western Resource Development Corp. and Dr. Jane Bunin, “Revegetation Technology and Issues at Western Surface Coal Mines,” contractor report to OTA, September 1985.

ment used the more detailed scales of 1 inch equals 400 feet or 1 inch equals 500 feet. In each State except North Dakota, vegetation maps must show actual premining vegetation types; North Dakota requires such maps for woodland and wildlife habitat only.

Montana, New Mexico, and North Dakota also require “range site” maps as part of baseline vegetation studies. These are based on SCS range site descriptions of the species composition and production of vegetation that *could* develop for a given soil type and climatic regime, free of disturbances such as fires and heavy grazing pressure. Thus, range sites describe potential or “climax” vegetation rather than existing conditions. On poorly managed or overgrazed lands, actual vegetation communities may bear little resemblance to the potential vegetation of range site descriptions. Table 5-7 shows that only the northern two States commonly use range sites, and only North Dakota relies on them exclusively.[15]

All five States require baseline data on annual production of above-ground biomass on the mine site for at least some land uses. Baseline production data are broken down according to plant

[15]Range site data also tend to be best on agricultural lands, which are more common in North Dakota than in any of the other four States.

Table 5-7.—Native Rangeland and Wildlife Habitat Vegetation Data Present in Permit Applications Reviewed by OTA

Data shown were present in permit applications on file at OSM and do not necessarily reflect correspondence between the coal company and regulatory authority (RA) that followed submission of the application; that is, whether the RA required additions or changes, and whether the proposed performance standard was acceptable to the RA.

	Montana	Wyoming	Colorado	New Mexico	North Dakota	Total
Number of permit						
applications reviewed	7	36	21	10	7	81
Study dates[a]	77-81, one 74	most 78-82	most 79-83	most 80 & later	79-81	
Work by						
consultants	4	29	19	4	2	
company personnel	2	6	1	3	1	
combination	1	—	—	2	2	
SCS data only	—	1	1		—	
unspecified	—	—	—	1	2	
Veg map units						
range site	7	7[e]	2	1	7	
veg types	7	29	18	9	19	
ecological response unit	—	—	1	—	—	
Map scales						
1 "=400	6	Most 400,500	Most 400,500		7	
1 "=500	1	up to 2,000	up to 2,000	200-2,000		
Cover sampling method						
quadrat	7	17	5	3	1[g]	
point transect	—	16	7	2	1	
point frame	1 (& quadt)	2	6	—	5	
line intercept		7[b]	5b 2 & herbs	l[b] 5 & herbs		
none		l f	l f			
Cover reported as						
absolute cover	7	35	20	10	7	
relative cover	—	13	5	2	3	
Frequency data	7	18	9	8	7	
Production						
by clipping	7	35	20	9	6	
by double sampling	—	3b	—	—	2	
SCS data	—	l[f]	l f	—	—	
none	—	—	—	1	19	
Woody plants[c]						
density reported	6	28	17	10	l[h]	
shrub heights (inches)	1	24	5	—	—	
Species diversity calculated						
species richness	—	7	2	—	1	
numerical index	1	10	13	1	—	
both	—	2	—	—	—	
Success standard[d]						
reference area	5	5	15	5	4	
control area	—	24	2	—	—	
unspecified comparison area	1	2	—	—	—	
unadjusted baseline	—	—	1	—	—	
historical record	—	—	—	3	—	
technical standard	—	—	—	—	3'	
ambiguous or unspecified	1	5	3	2	—	

[a]usually 1 year of data except for NM
[b]for shrubs only
[c]as reported in permit application; not shown here are data submitted subsequently and found in correspondence files
[d]acceptability to regulatory authority not shown
[e]mostly coal companies
[f]only SCS data used; premine vegetation no longer present
[g]for woody draws
[h]only one permit application included vegetation that has a measurable number of woody plants
[i]in one case, the standard was for postmine land uses of hayland/pastureland for property that was premine native rangeland

SOURCE: Western Resource Development Corp. and Dr. Jane Bun in, "Revegetation Technology and Issues at Western Surface Coal Mines," contractor report to OTA, September 1985.

species morphology. Montana requires production data for both herbaceous and woody species; Colorado and New Mexico require data on herbaceous species and recommend collection of woody species data; North Dakota and Wyoming require production data for herbaceous species only. In New Mexico and North Dakota, operators need not collect production data for land whose primary use is wildlife habitat, and production data for croplands usually are based on yields reported by the rancher or farmer. All five States require or recommend at least some production data by direct clipping and weighing rather than by the "double sampling" method, which is faster but the results are of variable accuracy (see below).

Cover data describe the area of ground covered by the aerial parts of plants. Because cover indicates the probability that a falling raindrop will hit something besides bare soil, these data are closely tied to erosion control. "Absolute cover" is the actual percentage of ground shielded by each plant species and may be greater than 100 percent where plant canopies overlap. "Relative cover" is the percentage of the total vegetative cover contributed by each species and must total 100 percent by definition. All five States require absolute cover data and Montana and Wyoming both recommend submission of relative cover data. Cover data are required for all native vegetation types (i.e., native rangeland and wildlife habitat), but are not required for cropland in any of the five States, and are required for pastureland only in North Dakota.

Woody plants are particularly important as cover and forage for wildlife habitat; for this reason data on woody shrub density are required for all wildlife habitat lands, and on native rangeland in four of the five States. The lack of shrub density requirements in North Dakota reflects the paucity of upland shrubs in that State. Woody plant data are obviously not pertinent to pastureland or cropland and are not required for these land uses. Woody plant density baseline data have become less important as more operators negotiate standards independent of precise premining levels. As discussed in chapter 8, this practice recognizes that the premining shrub densities may be either artificially high or low.

Vegetation diversity may be calculated by species, lifeform (the particular morphologic category of a species such as tree, shrub, grass, or subdivisions of these categories), or seasonality (the time of year when a plant accomplishes most of its growth), and may be based on either cover or production data. Differences among plant species or lifeforms over a landscape provide another measure of diversity.[16]

Four States in the study area currently require revegetation monitoring, but the data usually do not have to be submitted to the regulatory authority until final evaluation of revegetation success. Colorado, the only State currently without a revegetation monitoring requirement, is now in the process of revising its regulations to require periodic submittal of quantitative monitoring data. This will make Colorado's requirements the most stringent, because the other four States do not specify that the revegetation monitoring data must be quantitative.

Important Sources of Previously Collected Data

Fewer site-specific sources of data exist for vegetation (and wildlife) than for soils, overburden and hydrology. Where vegetation data are available, they often are of limited use to operators. The areal extent, intensity, and quality of existing data usually are not adequate for permit application requirements. In addition, as discussed below, the variation in data collection methods used by vegetation specialists makes data from different sources difficult to integrate.

SCS compiles maps of vegetation classified by range site. These maps are useful to land management agencies such as BLM and the U.S. Forest Service (USFS) in establishing the carrying capacity of land, and can give a permit applicant a preliminary idea of the types of vegetation on the site. Their usefulness for permitting is limited, however, because: 1) they describe composition and production only of the best vegetation available in the area; 2) the specific data used to compile the general description of the range site prob-

[16] See reference 14 for a more detailed discussion of the various ways diversity may be calculated.

ably came not from the mine site but from some vegetatively similar area, so that while the species composition and species dominance of the mine-site may be similar to that of the range site description, cover and production values may be very different; 3) the map scales typically are not detailed enough to meet the requirements for permit applications; and 4) range site data may not be available for areas without agricultural importance, such as woody draws. In addition, as noted earlier, vegetation at mine sites is rarely of the high quality described in SCS range sites because of the ubiquitous disturbance from livestock grazing and other sources in the West.

The SCS data are now being entered into a computerized database in Fort Worth, Texas, called the National Range Database. Besides SCS, the principal users of the data are other Federal range management agencies, and range science faculty and students at State universities.

BLM and USFS both collect vegetation data that are more representative of actual conditions than the range sites described by SCS data. BLM data use production and frequency of occurrence as indices of cover and species composition. However, the vegetation being sampled usually has been grazed, and production data typically represent only some fraction of the total possible production. Moreover, the BLM and USFS data are not always collected by experienced personnel, as SCS data are. Nevertheless, because BLM lands often coincide with potential coal development areas, these data can be useful to operators.

All of these federally collected data, while useful for large-scale range management, generally are neither intensive nor objective enough for permit application packages. Researchers in plant ecology and range science also have collected vegetation data using more sophisticated methods that are both more objective (repeatable) and more statistically reliable. These data are not well-distributed geographically, but are concentrated in areas near major universities or their research facilities, or sites of some special interest. Furthermore, the quantitative techniques used, although generally more intensive and objective than range management methods, are far from uniform and thus of limited value for comparing and combining with other data.

Data Collection by Operators

Because vegetation data sources are of limited usefulness, virtually all **baseline vegetation data** must be collected onsite. Since about 1979, vegetation data have been collected under strict statistical constraints and, to a lesser extent, narrow methodological guidelines established by State or Federal regulatory authorities. The statistical and methodological requirements vary among jurisdictions and have varied over time within jurisdictions since 1979. In the study area, there is more than one accepted methodology for collecting data for almost every required vegetation parameter.

Production is almost always determined by clipping, except on agricultural lands, when it is determined by crop yield. All above-ground plant material is clipped within circular or rectangular plots and sorted by species or lifeform. The clipped materials usually are oven-dried and weighed. These values are then used to estimate production per unit area of each mapping unit for each species or lifeform group. This may be expressed in pounds per acre, grams per square meter, or some other unit.

Double sampling also can be used to measure production. In double sampling, vegetation production is estimated visually in all plots, with clipping conducted in a few of the plots to calibrate the visual estimates. Although the accuracy of this method is highly dependent on the sampler, it is faster than the harvest method. It is accepted by all regulatory authorities in various carefully prescribed forms, but rarely has been used in baseline studies.

Two variables affect production data. First, inclusion of shrubs or annual plants affects the production values. Second, variations arise from the seasonality of plant species because production is usually estimated at a single time—presumably the time of maximum standing crop. In much of the study area, the differing times of peak production of the dominant species will cause measured production to be low by an unknown and variable amount.

Cover can be measured in three ways. It can be estimated visually in quadrats (small plots), which are usually on the order of one square meter or less. Subdivisions within the quadrat aid in making the visual estimates. The estimate of cover is then expressed by percent or by cover classes representing a specified range of percentage values. This method may be fairly consistent if the same observer makes all estimates, but variability between observers is to be expected and may be quite large. Second, cover can be estimated by line intercepts, which are somewhat more objective than quadrats. In this method, the portion of a tape (often **30** meters in length) intersected by the aerial parts of each species is recorded. Cover also may be estimated by a point intercept method in which plants are recorded when "hit" by the downward projection of a point, either defined by cross-hairs in a viewing device or by pins suspended in a rectangular frame. Although objectivity and repeatability are theoretically greater in point-intercept sampling, in practice these advantages commonly are reduced substantially by nonrigid point placement or projection and by the slowness of the method. Table 5-7, above, shows that use of the line intercept method is mostly confined to shrub cover data, and that there is a fairly equal spread of use among the quad rat and point intercept methods.

Woody plant density may be measured either by counting all individuals by species within large quad rats or narrow belts, or by plotless methods such as measuring the distance from a number of points to the nearest shrub or tree. Methods may or may not include subshrubs or semishrubs (which are smaller and/or woody only at their bases), depending on the States' regulations or guidelines. Direct counts of all woody plants, including semi- and subshrubs, within large quadrats or belt transects provide the most reliable data. Unfortunately, over 25 percent of approximately 60 mines surveyed by OTA have used very small quadrats or dimensionless samples.

Revegetation monitoring data generally are collected with the same procedures and for the same parameters as baseline data, and are intended to demonstrate compliance with the SMCRA performance standards (see ch. 7). Most coal companies collect at least some revegetation monitoring data, illustrating wide acceptance of the need for tracking the progress of revegetation, Careful monitoring can help operators to recognize problems and modify methods to improve revegetation results. Monitoring data also can be used to adjust livestock stocking rates and to evaluate the successional progress of postmining plant communities.

The States do not require submittal of revegetation monitoring data prior to the 2 years preceding final bond release, although some operators do so voluntarily, As a result, few revegetation monitoring data are available publicly beyond the individual mines. Thus, unlike hydrology and other disciplines, there is not a rapidly growing pool of revegetation data in the public domain, and there is little communication among operators and regulatory authorities about the relative success of various revegetation techniques. The regulatory authorities are concerned that they will not know whether the revegetation standards can be met until the bond release period nears its end on a number of mines. If operators did file their revegetation monitoring data in a specified format with the State regulatory authority, the advance warning of potential revegetation problems might increase the chance of finding mutually acceptable solutions at an early stage and so prevent larger problems in the long run.

WILDLIFE[17]

Data Requirements

All five States require wildlife studies for species that are known from existing information (e.g., an EIS or other regional studies) to occur in the area of the mine site or that are likely to occur due to available habitat on the site. Table 5-8 provides a comparative summary of State baseline data requirements for each of these species studies. For each type of study, a State may list a range of acceptable data collection techniques (see table 5-9). All States except New

[17]Unless otherwise indicated, **the material in this section is based on reference 3.**

Table 5-8.-State Wildlife Baseline Data Requirements

North Dakota	Montana	Wyoming	Colorado	New Mexico
Guidelines:				
State legislature does not allow use of formal written guidelines. All formal requirements must go through formal rulemaking process. PSC uses technical memoranda instead.	Has formal written guidelines, but these are currently being revised. These provide general info on objective, intensity, duration of baseline studies, but no detail info about methodologies.	Has formal written guidelines which provide general info on baseline data collection requirements, and specific info on required and acceptable methodologies. Stress that guidelines not mandatory, but deviations must be approved by Dept, if Game and Fish. Also stress that not all requirements are necessary for all operations and that operators can use existing data collected on adjacent sites. There are also separate guidelines for raptor nest surveys.	Has draft, informal guidelines available on request. These identify pertinent data sources and contain general info on baseline data collection. Specific data collection techniques are not discussed.	Has no formal written guidelines but intends to develop these in the future.
*Emphasis **of required studies:***				
Limited extent of habitat means that greatest emphasis is on woody draws, wetlands, and native prairie. State stresses need for habitat descriptions and mapping.	Species occurence, seasonal occurence, relative population densities of ecologically important species. Also classification, delineation, and species utilization of habitats.	Distribution, relative abundance and habitat affinity of game species, State sensitive species, raptors, and T&E species stressed. Habitat classification, delineation and mapping (both veg and physical characteristics) also emphasized.	Delineation and mapping of habitat including special habitat features. Also, mapping of species use of habitats by game, species with stenotopic habitat requirements, State sensitive and T&E species.	Characterization of premine habitat conditions and quantitative data for all species groups, particularly those felt to be in greatest jeopardy from disturbance.
Required studies:				
Fairly standard for each different species present. Mines must complete site-specific studies; data from adjacent areas cannot be substituted.	Required on a case-by-case basis, with attention to old guidelines. DSL must approve all study designs.	Studies required on case-by-case basis in consultation with DEQ and Dept. of Game and Fish. A list of acceptable data collection techniques by species group is published.	Studies required on case-by-case basis in consultation with MLRD and DOW. A list of acceptable data collection techniques has been published.	Studies required on case-by-case basis in consultation with MMD and State Game and Fish. A list of acceptable data collection techniques has been published.
Duration, intensity & regionality of data collection:				
One year (four seasons) of data collection required. Studies must cover site plus one-mile buffer zone around site.	One year (four seasons) of data collection required (two winter seasons preferred). DSL requires minimum of one field biologist on-site for 1 year for large operations not previously studied. Studies usually must cover site plus two-mile buffer zone. If unique habitats found, must assess extent of these on adjacent lands.	One year (four seasons) data collection required. Seasonal studies vary depending on species group. Studies must cover site plus two-mile buffer. PRB pronghorn study is an exception, a regional study. Some raptor studies also extend outside area boundaries.	One year (four seasons) data collection required. Seasonal studies vary depending on species group. Studies must cover site plus 0.25 miles beyond permit boundary. Only two instances of required studies beyond permit area: elk telemetry study and sage grouse study in North Park.	One year (four seasons) data collection required. Seasonal studies vary depending on species group. Requirement of studies beyond site-specific depend on potential impacts and species to be impacted.

Table 5-8.—State Wildlife Baseline Data Requirements—Continued

North Dakota	Montana	Wyoming	Colorado	New Mexico
Data format and avaliability:				
Data are submitted in permit applications, on file with PSC and OSM. PSC has compiled some data in their files.	Baseline data submitted in permit applications to DSL and OSM. Annual monitoring reports also submitted to DSL and OSM. Dept. of Fish, Wildlife, and Parks occasionally incorporates some data into its reports. FWS maintains limited compilation of raptor data. Otherwise, no systematic compilation or clearinghouse for data.	Data are submitted in permit applications and annual monitoring reports to DEQ and OSM. Dept. of Game and Fish was compiling game, forbearing, State sensitive and T&E species data into regional wildlife resource maps for State, but these not updated since 1981. Game and Fish encourages use of its standard observation form so wildlife info can be easily entered into Game and Fish computers, but forms not always used.	Data are submitted in permit applications and annual monitoring reports to OSM and MLRD. DOW occasionally uses data to update its Wildlife Habitat Inventory System, a computerized data bank of wildlife habitat and geographic info.	Data available only in permit applications filed with MMD and OSM. MMD hopes to compile a database in future.
Users of data.				
Beyond PSC, there is little review or use by others.	In addition to DSL, and occasionally DFWP and FWS, some consultants may use data from adjacent mines to develop wildlife info for their clients' mines.	Occasionally, operators from adjacent mines will use data, but not often. FWS compiles all raptor data available in FWS files.	Aside from OSM, MLRD and DOW review, data rarely used. Colorado Nature Conservancy has reviewed some data on T&E and State sensitive species. Also, a State, Federal and university project to model shale oil development effects on wildlife using some of these data.	Aside from MMD, Game and Fish and FWS, who review data for permit issuance, data used only occasionally by environmental groups.
Required monitoring:				
Monitoring is not uniformly required. Currently formulated on caseby-case basis.	Monitoring using methods similar to baseline data collection methods is required until reclamation considered complete. Aerial surveys once a month and 100 days per year are required.	None specifically required. When it is done, is usually initiated by operator, in consultation with Game and Fish, to address specific concerns and help demonstrate success.	None specifically required, except on case-by-case basis.	None specifically required, except on case-by-case basis in consultation with MMD and Game and Fish.
Evolution of data requirements since 1977:				
State has moved away from strictly counting species and numbers, and has placed more emphasis on habitat descriptions, mapping, and eventual habitat replacement.	More organized and consistent, more tailored toward individual cases and unique info needs. More emphasis on premining data collection to develop success criteria.	Less species inventories, population estimates. More habitat description and delineation. Fewer data required on nongame and nonlegal species, especially where data available from adjacent mines with similar habitats.	State has always emphasized habitat delineation and mapping. Has de-emphasized collection of nongame and other info not used for impact assessment.	Used to be concerned with only those species with "consumptive" value. Now view all species as important, as reflected in data collection requirements.

SOURCE: Cedar Creek Associates, "Wildlife Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.

Table 5.9.-Accepted Data Collection Techniques[a]

Study category	North Dakota	Montana	Wyoming	Colorado	New Mexico
Big game	Aerial survey-late winter	Aerial surveys—2 per month Browse transects Scat and stomach examination	Aerial and ground surveys-late winter, summer, late fall	Aerial and ground surveys-winter, late spring Pellet group and browse surveys	Aerial surveys (2)–spring and fall
Furbearers	Trapping only in wood lands-fall	Incidental observations	Incidental observations	Incidental observations	Spotlight surveys-all seasons Systematic observation of scat and tracks—all seasons
Small mammals	Trapping only in woodlands-fall	Live and snap trapping—spring and fall [grid trapping preferred in all habitats including reclaimed and undisturbed (control) habitats]	Live and snap t rapping— iate spring or summer (transects, grids, or clusters depending on habitat)	Live and snap trapping—late spring or summer (transects)	Live and snap trapping in all habitats—spring and fall Voucher specimens required
Raptors	On-foot nest searches —spring If extensive woodlands are present, aerial nest surveys prior to leaf-out	Ground and aerial nest surveys—spring	Ground and/or aerial nest surveys—spring	Ground and/or aerial nest surveys—spring	Aerial and/or ground nest surveys—spring
Waterbirds	For all wetlands: —breeding pair counts —May-June —brood counts—July —migration counts—April, October	For all surface water: —routine counts— 1 per month —no migratory or brood surveys	For all surface water: —seasonal counts including breeding pair and brood counts	Incidental observations	For all surface water: —breeding bird surveys-spring/summer —migratory surveys may also be required—fall, winter
Upland game birds	Pheasant crowing call counts—April, June Aerial and ground lek location surveys—spring Breeding bird lek counts—spring	Pheasant crowing call counts—spring Aerial and ground lek location surveys—spring Breeding bird lek counts—2 per spring Where leks will be disturbed, intensive telemetry studies are required to determine habitat needs Crop examination	Aerial and/or ground lek location surveys —spring Breeding bird lek counts—spring Vehicle or on-foot production surveys	Aerial and/or ground lek locations surveys-spring Breeding bird lek counts—spring	Breeding bird surveys—spring/summer

Table 5-9.—Accepted Data Collection Techniques[a]—Continued

Study category	North Dakota	Montana	Wyoming	Colorado	New Mexico
Songbirds and others	Variable width belt transects only in woodlands—spring Road survey-winter	Variable width belt transects in all habitats—spring	Variable width belt or point transects in all habitats and some habitat edge areas—spring	Variable width belt transect or variable circular plot in all habitats—spring	Variable width belt transect —spring/ summer
Reptiles and amphibians	Incidental obser-vations	Incidental obser-vations	Incidental obser-vations Trapping and call sur-veys in appropriate habitats—spring, early summer	Incidental obser-vations	Systematic surveys—spring, fail
Aquatic vertebrates and invertebrates		Electro-shocking, sein-ing, bottom sam-pling, dredging, etc. as appropriate (only for waters potential-ly affected by mining)	Stream quality classifi-cation Electro-shocking, sein-ing, bottom sam-pling, dredging, etc. as appropriate	Stream habitat clas-sification Electro-shocking, sein-ing, bottom sam-pling, dredging, etc. as appropriate	Electro-shocking, sein-ing, bottom sam-pling, dredging, etc. as appropriate—seasonally
Threatened and endan-gered species	No T&E critical habitats affected by mining Notification of obser-vations required	Black-footed ferret; full FWS guideline search of prairie dog towns Bald eagle (Tongue R. only): aerial and ground surveys for roost or concentra-tion areas—winter only	Black-footed ferret: density estimation and mapping prairie dog towns; full FWS guideline search of all towns Bald Eagle: aerial sur-veys for winter con-centration areas	Black-footed ferret: full FWS guideline search of all prairie dog towns Bald eagle: aerial or ground surveys for roost sites or winter concentration areas	Black-footed ferret: full FWS guideline search of all prairie dog towns
All wildlife species	Incidental obser-vat ions	Incidental obser-vat ions	Incidental obser-vations	Incidental obser-vations	Incidental obser-vat ions
Habitat	Habitat mapping at 1:4800 scale Distinct communities within a wetland must also be mapped	Delineation and mapping	Classification, delinea-tion, and mapping	Delineation and map-ping of all habitats and habitat features	Characterization, delineation and mapping of all habitats

[a]This table is not intended to represent a listing of methods or techniques required by the States for all operations. All study-area States derive baseline data requirements on a case-by-case basis. Some of the studies listed may not be required, depending on the ecological characteristics of the permit area and/or the availability of existing information.

SOURCE: Cedar Creek Associates, "Wildlife Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.

Mexico now emphasize habitat delineation and mapping rather than population inventories for reasons discussed below.

FWS and the State fish and game agencies both play important roles in requiring and designing wildlife data collection studies. The State agency is particularly important and usually is the principal regulatory consultant in operators' formulation of both baseline and monitoring data collection programs.

As in other disciplines, all States require site-specific studies; applicants may not substitute regional data and data from adjacent areas. Four of the States require studies to include buffer zones ranging from 0.25 to 2 miles around the proposed mine site. All States require 1 year (four seasons) of data collection and Montana prefers inclusion of two winter seasons. Montana also requires large operations not previously studied to have at least one full-time field biologist on-site for 1 year. None of the States routinely requires regional impact assessments, but only in cases of special concern. In Wyoming, a pronghorn study is being conducted by several mines in the powder River basin. In Colorado, two different mines are conducting elk telemetry and sage grouse studies that extend outside the mine-site boundaries.

Important Sources of Previously Collected Data

Wildlife data collected outside the permitting process tend to be general or regional. They are therefore useful only as background information rather than as a substitute for baseline data. Data on species' life histories and requirements are available from literature published by government agencies and researchers. BLM has compiled wildlife baseline information in published reports for several Known Recoverable Coal Resource Areas (KRCRAS), and regional mapping of wildlife habitats and distributions is included on BLM's Unit Resource Analysis maps. Both the Colorado Department of Wildlife and the Wyoming Department of Fish and Game have computerized databases and mapping systems for the States' wildlife resources. FWS compiles site-specific data on raptors in areas where they may be affected by mining, and both regional and site-specific data on federally listed threatened and endangered species.

Data Collection by Operators

Collecting quantitative data on wildlife populations and impacts to those populations is particularly difficult for two reasons. First, as with vegetation, there is significant natural temporal and spatial variation in populations due to environmental factors unrelated to mining. Second, the mobility of wildlife makes species inventories, population estimates, and other measurements very difficult.

One result of these difficulties has been a shift of emphasis in quantitative wildlife data collection in recent years. Instead of collecting intensive data on population size and number of species present, regulatory authorities and operators are now concentrating their efforts on determining habitat characteristics and quality, the assumption being that if habitats are restored, wildlife will follow. This does not mean that population counts and species inventories have been abandoned. They are valuable for delineating the extent of habitats and are considered important indicators of habitat quality, but, because of the above-mentioned characteristics of wildlife, methodologies for measuring populations and number of species present are not considered sufficiently reliable to be the basis for wildlife reclamation.

Wildlife baseline studies usually collect the following types of data:

- species occurrence, including seasonal information;
- species distribution;
- relative species abundance or population estimates, including population size indices and species diversity values;
- reproductive success;
- food preferences;
- habitat preference;
- delineation of habitats; and
- habitat quality.

Table 5-10 shows the different techniques used to collect this information for different species.

Table 5-11 gives brief descriptions of the ways in which these different techniques are carried out.

Wildlife monitoring *studies* use the same data collection techniques as baseline studies, but tend to be much less intense, if they are conducted at all. They are not used to measure reclamation success directly, but indirectly as a gauge of the use of reclaimed acreage by wildlife (see ch. ***7).***

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Table 5.10.—Wildlife Baseline Data and Survey Techniques

Survey *technique:* **data collected or derived**

Big game:

Aerial surveys:
—Animal distribution, relative abundance, seasonal occurrence, population size estimates, reproductive success (fawn/doe or calf/cow ratios), concentration areas, habitat preference

Vehicle and on-foot surveys:
—Animal distribution, relative abundance, seasonal occurrence, reproductive success, habitat preference

Pellet group surveys:
—Habitat utilization, population size indices and trends

Browse evaluation:
—Habitat utilization, food preferences, habitat condition

Stomach contents or pellet analysis:
—Food preferences

Tagging/radio-tracking telemetry studies.'
—Home range, animal movement, population size estimates, habitat utilization

Medium-sized mammals:

Aerial survey:
—Species occurrence, relative abundance

Scent station visitation survey:
—Species occurrence, population size indices and trends

Live trapping:
—Species occurrence

Night spotlight survey:
—Species occurrence, population density estimates

Strip transects:
—Population density estimates, habitat preference

Small mammals:

Live or snap-trap traplines or grids;
—Species occurrence, relative abundance, population size estimates, habitat preference, species diversity

Prairie dog town surveys:
—Burrow density, colony acreage

Raptors:

Aerial surveys:
—Species occurrence, nest locations, concentration areas

On-foot and vehicle surveys:
—Species occurrence, nest locations

Nest surveys:
—Species occupancy, nesting success and production

Waterfowl and other waterbirds:

Ground counts for wetlands and surface water:
—Species occurrence, animal distribution, relative abundance, seasonal occurrence, habitat preference

Breeding pair counts:
—Relative abundance of breeding birds

Nesting surveys:
—Nesting habitat

Brood surveys:
—Brood rearing habitat, nesting success, production

Wetland mapping and evaluation:
—Wetland habitat classification and locations

Upland gamebirds:

Aerial or ground surveys for Ieks (sage grouse or sharptailed grouse breeding grounds):
—Lek locations

Lek breeding bird counts:
—Lek attendance, indices of population size

Nesting surveys:
—Location and extent of nesting habitat

Brood surveys:
—Brood rearing habitat, production

Tagging/radio tracking studies:
—Animal movement, home range, habitat utilization

Crowing call counts (ring-necked pheasant):
—Indices of population size

Crop analysis:
—Food preferences, species occurrence

Roadside surveys:
—Indices of population size, habitat utilization

Songbirds and others:

Variable strip or circular plot surveys:
—Species occurrence, relative abundance, population size indices or estimates, habitat preference, species diversity

Roadside surveys:
—Species occurrence, relative abundance, population size indices, habitat preference, seasonal occurrence

Reptiles and amphibians:

Spring night call surveys:
—Species occurrence, relative abundance

Miscellaneous capture techniques:
—Species occurrence, relative abundance

Wetland searches and seining:
—Species occurrence, relative abundance

Fish:

Seining:
—Species occurrence, relative abundance, population size indices

Electroshocking:
—Species occurrence, relative abundance, population size indices

Aquatic habitat description:
—Habitat quality, classification

Aquatic invertebrates:

Artificial or natural substrate sampling, bottom sampling (Eckman dredge or surber sampler):
—Species occurrence, relative abundance, species diversity

Threatened and endangered species:

Aerial or ground winter concentration or roost surveys (bald eagle):
—Locations of roosts or winter concentration areas

Winter track or sign surveys (black-footed ferret):
—Species occurrence

Night spotlight surveys (black-footed ferret):
—Species occurrence

State sensitive species or species of "high Federal interest" (see applicable techniques by animal group listed above):
—Generally—species occurrence, habitat utilization, relative abundance

All ***species:***

Incidental or opportunistic observations:
—Species occurrence, distribution, habitat utilization, relative abundance

SOURCE: Cedar Creek Associates, "Wildlife Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.

Table S-II.—Table of Survey Techniques and Associated Methodologies

Survey technique: methodology	Survey technique: methodology
Terrestrial *Aerial survey:* —Slow fixed-wing aircraft or helicopter low level flights usually along standardized transects or conforming to specific habitats or topographic features. Record observations by species, numbers, and habitat. *Vehicle/on-foot surveys:* —Slow travel by vehicle or on foot along standardized survey routes. Record observations by species, number, and habitat. *Pellet group surveys:* —Record number of big game pellet groups intercepted by standardized transect or contained within standardized plots within different habitats. *Browse evaluation:* —Determine by standardized evaluation methods the degree of hedging of shrub and tree species by big game. *Stomach or crop contents or fecal material analysis:* —Laboratory analysis of contents to determine plant and animal material ingested. *Tagging/radio-tracking telemetry studies:* —Trap and distinctly tag or attach radio transmitter to a sample number of animals. Record tagged animals by location and habitat when observed during other surveys. Locate radio transmitter animals on a regular basis through use of two or more receivers and triangulation. Plot locations by habitat and individual located. *Scent station visitation survey:* —Establish standardized number of scent stations along standard (FWS) route. Stations consist of scent attractant in the middle of a circle of soft, smooth soil. Tracks of predator visitor recorded by species, station, and habitat. *Trapping:* —Set live "Sherman" or "Havahart" type traps or snap traps in random patterns, clusters, line transects, or grids in suitable habitats. Captures recorded by species, number, and habitat. Various statistical techniques or models used to estimate population size of small mammals. *Night spotlight survey:* —Slowly drive a predetermined route at night. With use of headlights and/or spotlight, record observations by species, number and habitat. Population indices calculated by dividing species numbers by acreage of corridor sampled by spotlight. *Strip transects:* —Slowly walk standardized transect in specific habitats and record species and numbers. Population indices calculated by dividing species numbers by acreage of corridor visually sampled. *Prairie dog town surveys:* —Estimated density of prairie dog burrows by various analytical techniques. Estimate acreage of town and plot extent and location of town on topographic maps. *Nest survey:* —Search all suitable habitat on foot with aid of binoculars or spotting scope. For inaccessible areas, search for nests by aerial survey,	*Waterbird surveys:* —Make seasonal counts of all species and numbers occurring in all or a representative number of wetland or aquatic habitats. Record observations by survey area. For nest and brood surveys, search suitable habitat adjacent to wetlands or aquatic habitat and record nests and broods by location, species, and number. *Wetland mapping and evaluation:* —Classify all wetlands by standard FWS system. Map extent and location of all wetlands on topographic maps. *Lek breeding bird counts:* —Visit all known leks at least twice in early morning during spring breeding season. Record number of displaying males and females. *Crowing call counts:* —Count and record number of pheasant crow calls in early morning for a set time period at standardized stops along a standardized vehicle route. *Variable strip or circular plot surveys:* —Record species and numbers of birds by distance from observer along standardized transects or at predetermined points in all habitats. Population indices calculated for each species based on area sampled for that species. *Spring night call surveys:* —In appropriate habitats, record amphibian calls by species and number for a standard time period in the evening. *Black-footed ferret surveys.'* —Use current FWS guidelines to search prairie dog towns for ferret track or sign. Use same guidelines for conducting night spotlight surveys. *Incidental observations:* —During all field activities, record all wildlife observations by species, number, location, and habitat. ***Aquatic:*** *Seining and electro-shocking:* —Sample aquatic habitats using seine or electro-shocking equipment. Record fish species captured by number and size. *Aquatic habitat description:* —Measure various standardized physical parameters and classify habitat using established classification systems. **Bottom sampling:** —Using standardized sampling equipment, take sample of bottom substrate. Using sieves and washing, separate out aquatic invertebrates. Classify by species and number. *Artificial or natural substrate sampling:* —Scrape or sample by other means representative samples from surface of natural bottom substrate. Separate out aquatic invertebrates and classify by species and number. For artificial substrate, secure standardized plates beneath water surface. Leave for standard time period and then scrape surface and separate out aquatic invertebrates. Classify by species and number.

SOURCE: Cedar Creek Associates, "Wildlife Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.